AH 2004 : 3rd international conference on adaptive hypermedia and adaptive web-based systems : workshop proceedings part 2

Document status and date:
Published: 01/01/2004

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.
Link to publication

Technische Universiteit Eindhoven
Department of Mathematics and Computer Science

AH 2004: 3rd International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems

Workshops Proceedings
Part II

Editors and Co-Chairs:
Lora Aroyo
Carlo Tasso

04/19

Series editors: prof.dr. P.M.E. De Bra
                      prof.dr.ir. J.J. van Wijk

Reports are available at:
http://library.tue.nl/catalog/TUEPublication.csp?Language=dut&Type=ComputerScienceReports&S
ort=Author&level=1 and
http://library.tue.nl/catalog/TUEPublication.csp?Language=dut&Type=ComputerScienceReports&S
ort=Year&Level=1

Computer Science Reports 04/19
Eindhoven, 23rd August 2004

Table of Content

Preface

WORKSHOP 7:
Applying Adaptive Hypermedia Techniques to Service Oriented Environments:
Pervasive Web Services and Context Aware Computing   **467**

Preface

This volume contains the supplementary proceedings of the workshops organized in conjunction with AH'04, the third International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems, hosted by the Eindhoven University of Technology, August 23-26, Eindhoven, The Netherlands. The workshops proceedings consist of two parts:

Part I: Engineering and Evaluation of Adaptive Hypermedia Systems
- Workshop 1: Engineering the Adaptive Web
- Workshop 2: Individual Differences in Adaptive Hypermedia
- Workshop 3: Empirical Evaluation of Adaptive Systems

Part II: Adaptive Hypermedia Applications
- Workshop 4: Personalization in Future TV
- Workshop 5: Semantic Web for E-Learning
- Workshop 6: Authoring Adaptive and Adaptable Educational Hypermedia
- Workshop 7: Applying Adaptive Hypermedia Techniques to Service Oriented Environments: Pervasive Web Services and Context Aware Computing

While the main conference program presents an overview of the latest mature work in the field, the workshops at AH'04 aim at providing a wide international forum for researchers to present, discuss and explore their new ideas, work in progress and project developments within several focused areas of interest and within the overall scope of adaptive hypermedia systems. The workshops are intended to provide an informal interactive setting for participants to address in small focussed groups current technical and research issues related to the Adaptive Hypermedia and Adaptive Web-based Systems. Some of the core topics addressed in the AH'04 edition of workshops are:

- Emerging design methodologies for adaptive hypermedia (AH)
- Engineering of Adaptive Web-based Information Systems (AWIS)
- Design patterns for educational AH
- Authoring patterns and tools for educational AH
- Evaluation of AH authoring tools
- Adaptation and Semantic Web
- Semantic web-based educational AH architectures
- Web services for educational AH
- Existing metadata standards and ontologies for AH applications (e.g. digital TV, e-Learning, web services, individual differences, user modeling)
- Multi modalities and dimensions of individual differences in AHS
- Empirical criteria and methods AHS evaluation
- Personalized digital TV, T-commerce and T-learning

All workshop papers have been reviewed by committees of leading international researchers. We would like to thank each of the workshop organizers, including the program committees and additional reviewers, for their work in managing the review process and in the preparation and organization of their workshops.

August, 2004
Lora Aroyo and Carlo Tasso

WORKSHOP 4:

TV'04: Personalization in Future TV

Methods, Technologies, and Applications for Personalized TV

Workshop Co-Chairs:

Liliana Ardissono
Mark Maybury

Preface

The large volume of TV content made available by digital television and the possibility of interactive viewing are simultaneously an opportunity and a challenge for TV users. Following the tradition of previous TV workshops, TV04 focuses on the design and development of personalization and dynamic content generation techniques aimed at making digital TV effective and enjoyable for any type of viewer.

The main topics addressed in this workshop are:
- content personalization for personal news and personal channels,
- Electronic Program Guides
- community formation and social influences in TV watching behavior
- automated broadcast video content management
- user models for personalized TV
- security and privacy of TV services
- business opportunities: T-commerce, targeted TV advertising
- ontologies for television media models and user models

One aim is that the workshop will generate interesting discussions and inspire new research directions for participants.

We would like to thank all the members of the Program Committee, who supported us in the selection of papers and who provided insightful comments to help the authors improve their contributions.

August, 2004
Liliana Ardissono and Mark Maybury

Program Committee

Liliana Ardissono, *Università di Torino*
Patrick Baudisch, *Microsoft Research, USA*
Michael Bove, *Media Lab, MIT, USA*
Alfred Kobsa, *University of California, USA*
Judith Masthoff, *University of Brighton, UK*
Mark Maybury, *MITRE Corporation, USA*
Sean McNee, *GroupLens Research Project, University of Minnesota, USA*
Barry Smyth, *ChangingWorlds Ltd., Ireland*
Mark van Setten, *Telematica Institut, The Netherlands*
Howard Wactlar, *Carnegie Mellon University, USA*

Personalization of Interactive Objects in the GMF4iTV Project

Bernardo Cardoso[1], Fausto de Carvalho[1], Gabriel Fernàndez[2], Benoit Huet[3], Joakim Jiten[3], Alejandro Lopez[2], Bernard Merialdo[3], Helmut Neuschmied[4], Miquel Noe[2], David Serras Pereira[5], Georg Thallinger[4]

[1] PT Inovação, S.A., Aveiro, Portugal
{bernardo, cfausto}@ptinovacao.pt

[2] La Salle School of Engineering, Ramon Llull University, Barcelona, Spain
gabrielf@salleURL.edu

[3] Institut Eurécom, Sophia Antipolis, France
{huet, jiten, merialdo}eurecom.fr

[4] Joanneum Research GmbH, Graz, Austria
helmut.neuschmied@joanneum.at

[5] Duvideo, Lisboa, Portugal
dpereira@duvideo.pt

http://www.gmf4itv.org/

Abstract. This paper describes the personalization mechanism that is being implemented in the GMF4iTV Project. GMF4iTV is a European project which aims at developing techniques to create television programs with interactive objects using the DVB-MHP platform. Interactive objects are moving areas of the TV picture (generally superposed to characters, objects in the scene, or specific spots) with associated metadata. When the user selects one of these objects, the associated metadata is displayed. Personalization is used for both object and associated metadata selection. This paper describes the current version of the GMF4iTV prototype.

1 Introduction

Hypertext is now of common use with the World Wide Web. Although the interest for hypervideo has already been demonstrated in several projects, its usage remains limited, in great part because of the lack of appropriate platforms for creation, distribution and presentation. For example, the Hypercafé project [1] is a nice illustration and application of a hypervideo engine. Bove et al [15] have shown how to use video segmentation and tracking to facilitate the authoring of hypervideo. The Viper system [14] allows creating personalized programs through the selection of clips at the user side.
In the GMF4iTV project, our objective is to extend the capability of the Multimedia Home Platform (DVB-MHP) [16] standard to support personalized hypervideo. The

DVB-MHP specification is an open standard API (Application Program Interface), which facilitates services across broadcast, telecommunications and computer platforms and is supported on several available set-top boxes. In the GMF4iTV project, a regular TV broadcast (MPEG-2 encoded) is augmented with additional information (MPEG-7 encoded) which defines active objects in the video, along with additional content to be displayed when those objects are selected. The GMF4iTV project addresses all the aspects involved in the creation, distribution and presentation of personalized hypervideo programs:

- video producer side: tools to select and track video objects, and associate additional information (HTML, MPEG-4 clips, MHP applications) to those objects using an MPEG-7 structure.
- broadcaster side: multiplexing of the MPEG-2 video with the additional MPEG-7content and the MPEG-7 description, synchronization so that the required information is available when needed.
- user side: storing of the additional content, interaction with the user to select among active objects, presentation of the additional information when selected, and personalization based on user profile and preferences.

The GMF4iTV project develops a new authoring, multiplexing, server and multimedia terminal architecture for application development, synchronization, scheduling and end-user terminal systems. The GMF4iTV prototype is an end-to-end platform which provides interactivity at the moving object level. The platform allows content and service providers to create, manage, synchronize and distribute pre-recorded linear video streams (MPEG-2/-4) in conjunction with non-linear additional content (e.g. HTML, MPEG-4, JPG) employing enhanced metadata schemes, included in an environment of live video feeds. The direct interaction with objects on the TV-screen enables the typical more lean-back oriented TV-viewer to access the additional content in an active but highly convenient way. The production part of the platform allows the development of new scenarios for a variety of program types (documentation, sports ...).

The GMF4iTV prototype allows the personalization of the interaction between the user and moving objects. All objects, shots and additional content items can be labeled with specific MPEG-7 metadata, which is broadcasted together with the main program. This information is added by the video producer on the production site. On the receiver side this information is compared with the user profile by a personalization engine which uses program specific rules to activate or de-activate objects, and select the proper additional content items to be displayed.

The project makes use of advanced techniques for video coding (MPEG-2, MPEG-4), metadata encoding (MPEG-7), semantic modeling through ontologies, efficient rule processing using an inference engine.

The rest of the paper is organized as follows. We first present the various aspects of personalization within GMF4iTV, including some scenarios of interactive programs for illustration. Then we describe the authoring tool which is used to attach metadata to objects, shots and additional content items, the multiplexing tool which broadcasts the video program and the additional information together, and finally the user interaction using a PDA device.

2 Personalization in GMF4iTV

2.1 Demonstration scenarios

The following examples have been constructed in cooperation with video producers within the GMF4iTV project to demonstrate the capabilities of the prototype. Their description should give an intuitive idea of the potential of interactivity and personalization in GMF4ITV.

- **Fashion show**

In a fashion show, models walk along a scene to present various fashion items. In the fashion show scenario, the moving objects are the models, and the additional content consists of information about the fashion items. Model objects may have the attribute Male or Female. Additional information might be about shopping possibilities or the designer.

The user profile (which resides in the set-top box) indicates whether the user is male or female. At the beginning of the TV program, the user is asked whether he/she prefers shopping or designer information to be displayed (this choice is kept in the transient user profile). The rules of the personalization engine indicate that male (resp. female) models should be activated if the user is male (resp. female). If the user selects an activated object, the personalization engine looks at the transient profile to display the adequate shopping or designer information.

- **Music program**

The Music program shows musicians playing a sequence of songs. The additional content consists of the lyrics of the songs, information on the artists' discography and several lists of their concerts to come, organized by geographical region.

Since the discography, list of concerts and lyrics are not related to any particular video object they are simply represented as icons on the screen. The appearance of these indicators is decided during production, where the producer decides to relate certain additional content to a scene or to a time reference. The additional content is activated by user selection. In the case of the lists of concerts, the user profile contains some regional information (for example the city or zip code where the user lives) and the personalization rules contain the necessary knowledge to map this information with the geographical regions of the concerts. Therefore, only the appropriate regional list is displayed to the user.

- **Animal documentary**

The Animal documentary shows several animals in their living environment. The moving objects are the animals. Two types of additional content are provided: the adult version is a HTML text which provides further information on the animal behavior; the child version is a quiz with simple questions about the current animal. The user profile contains age information about the user, and the personalization engine uses this information to select which version of additional content to display.

The pictures below show a simulation of those two versions.

230
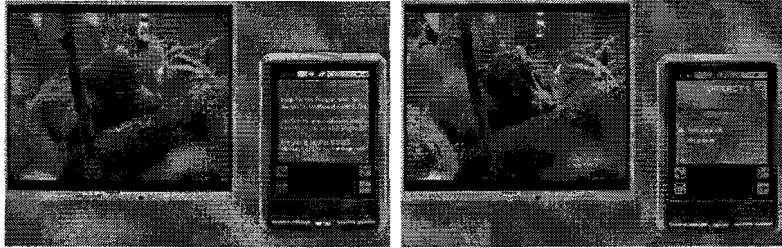
2.2 Global View on the Interactivity Process

The interactivity process in the GMF4iTV system can be divided into three different steps:

- on the production side, objects are defined in the video, additional content is provided, and metadata for objects and content is added,
- for distribution, the extra information for interactivity and personalization is encapsulated in MPEG-7, and multiplexed with the original TV program,
- on the user side, the set-top box retrieves the extra information, displays object locations, prepares the available additional content, and runs the personalization engine. Depending on user interaction, the adequate additional content is displayed.
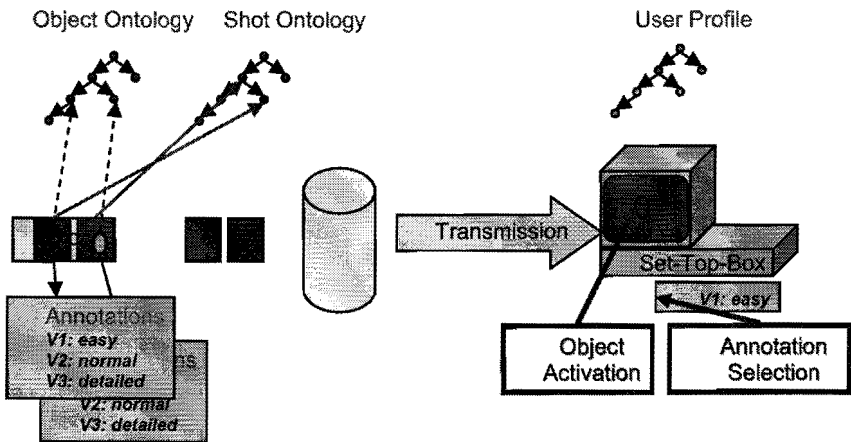
Fig. 1   This picture gives a global overview of the personalization process

231

2.3 Formal Concepts for Personalization

Ontologies

Personalization involves taking decisions based on the nature of various items. In our system, these items are of three different types:

- Objects moving in the video (corresponding to screen areas defined by the video producer),
- Shots in which those objects appear,
- Additional content that will be displayed by user interaction.

The nature of these items is indicated by semantic attributes. The possible values of these attributes are arranged in an ontology [9][17]. Therefore, there are three ontologies for each broadcast program scenario: the object, the shot and the additional content ontology. Each ontology is a tree structure which describes the dependencies between attribute values, from the most general (root) to the most specific (leaves). The advantage of using ontologies is to give the producer a greater flexibility in the level of details during the annotation process. The figure below shows an example of selection of an attribute within an ontology.
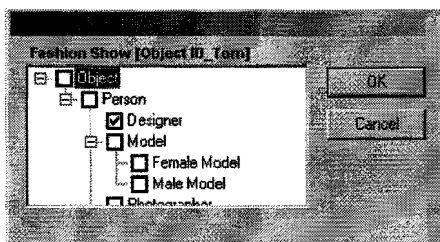
Note that in the applications that we envision for the GMF4iTV prototype, scene and additional content ontologies are generally simplistic, the object ontology being more elaborate.

After discussion, we have decided that those ontologies would be scenario specific (although an ontology can be reused in other scenarios). This avoids the problem of constructing a "universal" ontology which would be known by both the producer and the user sides. As a result, scenario ontologies are encoded in MPEG-7 and transmitted to the user side at the beginning of the program.

User profile

Information about the user is kept in the user profile, which resides in the set-top box on the user side. The user profile is split in two parts a static one (static profile) and a transient one (transient profile). The static profile is not scenario dependent. For the time being, it is manually built by the system administrator, although in real situations, it should be created by the user herself.

In several scenarios, there is the need for some extra information from the user. This may be because this information is not in the user profile (it cannot contain every possible information about what he likes or dislikes), but also because some information is not static (for example it might depend on the mood of the user). Therefore, a

GMF4iTV program may start with a small sequence of questions which allows the user to make custom choices. The answers to those questions are kept in the transient profile which remains valid as long as the scenario is broadcasted, and erased afterwards.

Personalization engine

The personalization engine has two functions:
- Based on the comparison between the attribute of objects and scenes and the user profiles, decides which objects can be activated for this user,
- Based on the above plus the additional content attributes, decides which version of additional content should be displayed.

For maximum flexibility, the personalization rules are written as inference rules, and the personalization engine is a first order inference engine. Attributes and user profile characteristics are facts. Running the inference engine on those facts will start an inference chain which will eventually trigger an activation or selection predicate. The personalization rules are also encoded in MPEG-7 and transmitted at the beginning of the program.

Usages of personalization

The mechanisms described above are quite general and can be used in a great variety of situations. Extensive discussions with video producers have generated a number of potential usages for these mechanisms, of which the following is just an illustrative sample:
- Selection based on user type: male users would like to have information on male clothes, female users on female clothes,
- Selection based on age group: adult and child version of additional content,
- Comparison of characteristics: geographical information,
- Language dependent information
- Etc...

3   MPEG-7 Annotation

The first step in the production of interactive content is the specification of objects for which additional content should be made available in the video. This objects marked by regions. This might be a very time consuming process, therefore it is organized in the following steps:
- Automatic extraction of the structural description of the video: shots and key-frames.
- Manual correction of the automatic extracted information.
- Manual specification of the interactive regions for at least one frame of a shot.
- Automatic tracking of the specified regions to get the region locations in all frames.

233
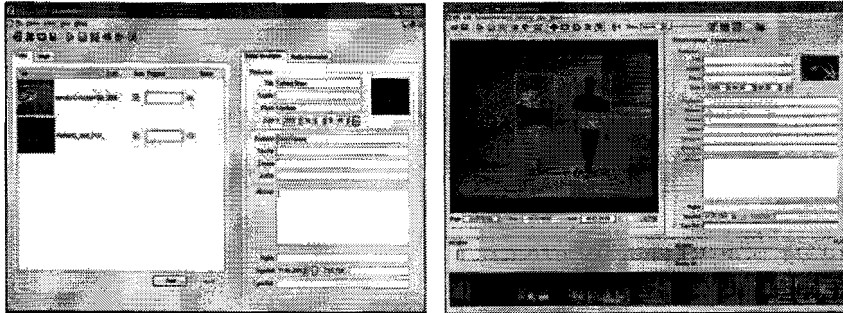
Fig. 2   Import Tool (left image) and GMF4iTV Authoring Tool (right image) used for video annotation

For the above listed tasks two applications have been implemented (see Fig. 2). The Import Tool allows to manually enter general metadata about the video like creation and production information and information about tape location or right holders. Then the automatic analysis process for the extraction of shot boundaries and key-frames is started. The Import Tool supports batch mode so it is possible to handle more than one video at a time. The result is an MPEG-7 description for each video processed. This may be stored in a database and later on used as basis for the generation of the interactive region descriptions by the GMF4iTV Authoring Tool.

The GMF4iTV Authoring Tool provides a user interface for easy navigation in the video. The video structure is shown by displaying the shot boundaries in a timeline. These shot boundaries can be edited for manual correction. The integrated video player has drawing functionalities for specifying the interactive regions. The region tracking functionality of this tool produces metadata about the location of the regions in each frame. These software components have been implemented by using the MPEG-7 library freely available from Joanneum Research [7].

4   Authoring and Multiplexing

In order to associate additional contents to objects or shots within a digital video sequence, Authoring and Multiplexing tools are required. The Synchronization and Authoring tool provides the user interface to associate additional content on one side, and the data encapsulation and synchronization on the other. The process produces a script file (conformant to a Content Description Language, CDL) that is delivered to the Multiplexing tool. This module is responsible for accurately multiplexing all the previously produced streams.

4.1   Synchronization & Authoring Tool

The Synchronization & Authoring Tool is a software component included in the GMF4ITV Authoring Tool which is responsible for the following tasks:

234

- Management of the associations of additional contents to objects, shots or the whole video in a user friendly manner. The process is done taking into account the personalization ontologies, where every additional content item is associated with according entries from the ontologies.
- Encapsulation of a dynamic MPEG-7 metadata service over MPEG-2 according to the corresponding recent amendment [2], by the use of the Fragment Update mechanism (FU) over Object Carousel and Metadata Sections described in [3,4].
- Encapsulation of the associated additional contents such as MHP, MPEG-4, JPEG or HTML over MPEG-2 by using the DSM-CC Object Carousel protocol according to [5].
- Synchronization of MPEG-7 metadata and additional contents to the main MPEG-2 video at frame level by the use of the Normal Play Time concept, NPT [5].
- Global bitrate management.

The Synchronization & Authoring Tool interprets the results of the edition process made by the operator and optimally allocates the transmission period and bitrate for every associated content item. The process also checks the viability of every association according to the already allocated bitrate and time constraints. The complete edition process is done in a friendly and transparent manner adapted to users not familiar with DVB/MHP technology.

Finally, the Synchronization & Authoring Tool generates the CDL file containing the commands for the multiplexer. The CDL file plus the other files containing the additional encapsulated contents, MPEG-7 metadata, NPT and signaling are taken by the multiplexer to generate the output in a DVB Transport Stream (DVB-TS) compliant format.

4.2 Multiplexing

The multiplexer has as main task to multiplex the different contents referenced in the CDL at the marked time points and produce a final Transport Stream to be sent to a DVB network (satellite, cable or terrestrial). The main components of the output DVB-TS are:
- MPEG-2 Video.
- The transcoded MPEG-4 video for use in the PDA.
- DSM-CC Object Carousel and Metadata Sections containing the MPEG-7 metadata.
- Normal Play Time, for synchronization of metadata and different media.
- DSM-CC Object Carousels containing additional contents (including MHP apps).
- Application Information Table (AIT) needed for MHP signaling.

In order to combine the object-based interactive content in a real TV broadcast scenario, the multiplexer is able to seamlessly splice between MPEG-2 encoded live streams and pre-produced GMF4ITV contents.

5   User Interaction

The intrinsic temporal and spatial nature of
video both complicates and invites to new
navigation concepts. Assuming that the tradi-
tional TV viewer is primarily looking for
passive entertainment experiences, user
intervention is set to take place on a supple-
mentary mini-screen, in order to not disturb
the main picture. Keeping the interaction on
a separate unit also allows us to experiment
with new ways of navigation.

5.1   Interaction based on PDA

From the user interface point of view, the
implementation of interaction based on mov-
ing objects is a challenge in itself, particularly in an Interactive TV scenario.
In order to allow the full exploitation of personalized object based interaction,
GMF4iTV project introduced an innovative approach based on common Personal
Digital Assistants (PDA): the PDA is used as an advanced intelligent peripheral
which can be used to interact with the system, by clicking directly on the moving
objects being highlighted over a video stream, a synchronized copy of the main video
stream shown on the TV. Furthermore, the device can be used to retrieve and display
additional content related with the selected object.
The video shown on the PDA is a MPEG-4 stream transcoded from the main MPEG-
2 video stream on the production side, encapsulated in RTP protocol and sent from
the Set-Top Box (STB) to the portable device over the air, using IEEE 802.11b
(WiFi) technology. An additional UDP stream is generated on the STB, based on the
MPEG-7 metadata and personalization options, to convey the information needed for
object highlighting, synchronization and access to additional content.
A specific client application has been developed for the Windows Mobile Pocket PC
used in the project. This client includes modules to extract, synchronize and render
the MPEG-4 packets, as well as to overlay graphical representation of the moving
objects on top of the video stream. Upon object selection, using the conventional
PDA stylus, the associated additional video, audio, graphical and text documents are
retrieved from the STB, over WiFi, and displayed using the PDA web browser.
Besides being a very intuitive and easy way of interacting with a rather complex
system, the introduction of the PDA concept includes other attractive features. In
particular and considering the evolution to a multicast/multi-user scenario, which is
closer to the way people watch TV, it will offer the possibility to have more than one
person on the same room interacting with the system without interference, because
the TV main screen can be kept clean without additional elements beyond the main
TV show. Another possibility will be the download of additional content to the PDA
for later viewing (either push or pull).

Since all the interaction can be performed using a personal device, deep personalization can be achieved and offered as a powerful business opportunity to service and content providers, as well as real added value to final costumers. With the increasing momentum for small powerful personal devices, boosted by the introduction of UMTS and the popularity of WiFi, personalization on Interactive TV will certainly reach new exciting levels in the near future.

6 Conclusion

In this paper, we have described the GMF4iTV prototype which provides interactive objects for TV programs. The prototype contains a complete production chain, from the identification and annotation of objects, link to additional content, semantic annotation, MPEG-7 encoding, multiplexing with the MPEG-2 video stream, decoding on the set-top box and interaction with the user through a PDA. Personalization is possible both for object activation and additional content selection. The personalization process is based on rules which are processed by an inference engine on the set-top box. This powerful process allows a very flexible usage of personalization in a variety of situations provided by different application scenarios.

The project is now in the integration phase. All modules have been designed and implemented by the different partners, according to common specifications. They are currently being integrated together to compose a complete chain. A set of scenarios has been defined and according video sequences have been prepared which are being annotated with the authoring tool. A public demonstration of the project is planned at the IBC 2004 Conference.

References

1. Sawhney, N.; Balcom, D.; Smith, I.; *Authoring and navigating video in space and time,* IEEE Multimedia , Volume: 4 , Issue: 4 , Oct.-Dec. 1997, Pages:30 – 39
2. *Generic coding of moving pictures and audio: Systems.* Amendment 1: Carriage of metadata over ITU-T Rec H.222.0 | ISO/IEC 13818-1 streams.
3. ISO/IEC 15938: Information technology – *Multimedia Content Description Interface.*
4. A. López, D. Gonzàlez, J. Fabregat, A. Puig, J. Mas, M. Noé, E Villalón, F. Enrich and G. Fernàndez : *Synchronized MPEG-7 metadata broadcasting over DVB networks in an MHP application framework,* IBC'2003, Amsterdam, September 2003.
5. ISO/IEC 13818-6: *Generic coding of moving pictures and associated audio information.* Part 6: Extensions for DSM-CC.
6. Nack, F., Lindsay A.: *Everything You Want to Know About MPEG-7: Part I & Part II,* IEEE Multimedia, Vol. 6 No. 3 & 4, (July - September 1999) 65-77, (October - December 1999) 64-73
7. MPEG-7 library: http://iis.joanneum.at/MPEG-7

8. Naphade, M.R.; Huang, T.S., *Extracting semantics from audio-visual content: the final frontier in multimedia retrieval*, IEEE Transactions on Neural Networks, Volume: 13 Issue: 4 , July 2002 Page(s): 793 -810

9. Town, C.; Sinclair, D. *Ontological query language for content based image retrieval*, CBAIVL 2001 - IEEE Workshop on Content-Based Access of Image and Video Libraries, 2001, Page(s): 75 -80

10. Kuo, Chung-Chieh Jay, Guo, Ju, *Semantic video object segmentation for content-based multimedia applications*, Kluwer Academic Publishers, 2001, ISBN : 0792375130

11. Dai, W., Cohen, R. (2003). *Dynamic Personalized TV Recommendation System*. In Proceedings of the 3rd Workshop on Personalization in TV. Pittsburgh, U.S.A.

12. H. Lee, J. Nam, B. Bae, M. Kim, K. Kang and J. Kim: *Personalized Contents Guide and Browsing based on User Preference*. Second International Conference on Adaptive Hypermedia and Adaptive Web Based Systems: Workshop on Personalization in Future TV, Malaga, Spain, 2001, pp.131-150.

13. L. Ardissono, F. Portis, P. Torasso. F. Bellifemine, A. Chiarotto and A. Difino . *Architecture of a system for the generation of personalized Electronic Program Guides*. Workshop on Personalization in Future TV, 2001.

14. Stefan Agamanolis and V. Michael Bove, Jr., *Viper: A Framework for Responsive Television*, IEEE MultiMedia, vol. 10, no. 1, July - September 2003, pp. 88 – 98

15. V. Michael Bove, Jr., Jonathan Dakss, Stefan Agamanolis, Edmond Chalom, *Adding Hyperlinks to Digital Television*, Proc. SMPTE 140th Technical Conference, 1998.

16. ETSI TS 102 812 V1.2.1: *Digital Video Broadcast (DVB), Multimedia Home Platform (MHP)* Specification 1.1.1

17. Antoniou, Grigoris, van Harmelen, Frank : *A semantic Web primer*, MIT Press, 2004, - ISBN : 0262012103

Context Aware Personalized Ad Insertion in an Interactive TV Environment

Amit Thawani, Srividya Gopalan and Sridhar V.

Applied Research Group
Satyam Computer Services Limited
#14, Langford Avenue, Lal Bagh Road, Bangalore, India – 560025
Amit_Thawani@Satyam.com

Abstract. The growth of digital television over satellite, cable as well as terres-
trial networks has driven advertisers to 'better target" users by local personal-
ized advertisements, which generates qualified lead for future sales. Context
awareness in ITV applications can be used as a powerful tool to deliver most
relevant and personalized ad based on user's context. In this paper we have
proposed architecture for context aware real time selection and insertion of ad-
vertisements into the live broadcast stream by taking into consideration the
user's current and past contextual information. Our approach is based on aggre-
gating a past sequence of individual contexts and associating the current user
activity to those past contexts to determine the best ad to be delivered relevant
to the current activity.

1 Introduction

The growth of digital television over satellite, cable as well as terrestrial networks
has driven advertisers to 'better target" users by local personalized advertisements,
which generates qualified lead for future sales. The advent of Personal Video Record-
ers (PVRs) and Video on Demand (VOD) is viewed as a threat by advertisers as they
create ad-skippers. As the viewers started evading advertisements, ad agencies com-
pete on innovative ways to ensure their ads are viewed. There is a strong need to re-
work on TV advertising to create innovative features that can exploit advertisement
opportunities. Personalization in interactive and future televisions aims in targeting
content to individual users by adapting the content based on users' likes and circum-
stances. [9] compares different types of addressable advertising and demonstrate su-
periority of home addressable advertising. [4] presents a life-style based approach for
the delivery of personalized advertisements based on segmentation variation and simi-
larity variation. In a related paper [7], we have proposed a Channel Surfing Analysis
(CSA) algorithm for predicting the "user(s) in front" of TV by a dynamic analysis of
channel viewing characteristics. Such user identification can be used along with a
Home Information System (HIS) to categorically decide about the nature of ads that
are likely to have an impact.

Context-aware and situation-aware services together enhance the perceived quality
of the delivered information. Context awareness provides mechanisms for developing

adaptive applications, which is an important aspect of ITV applications. [3] presents a context-aware information retrieval system that analyzes the user's history to derive an enhanced context. [5] proposes to model the user actions from contextual information, in a way to ease its interaction with context-aware ITV applications. Advertisers create multiple versions of advertisements for a single TV spot in order to cater for different user communities. Given multiple versions of advertisements, and also information about user currently in front of the television, the challenge is to make use of and analyze the user's current and past contextual information to select and insert the most appropriate advertisement from the multiple versions of multiple advertisements at real time.

Though research has been done for personalized ad insertion that considers users preferences and user profile information, the use of complete contextual information for personalization needs to be addressed. In this paper we have proposed an architecture for context aware real time selection and insertion of advertisements into the live broadcast stream by taking in to consideration the user's current and past contextual information. Our approach is based on aggregating past sequence of individual contexts i.e. past viewing patterns and associating the current user activity to those past contexts to determine the most appropriate ad to be delivered relevant to the current activity. The proposed architecture is realized by means of four distinct subsystems, CoD (Context Derivation), CaASI (Context-aware Ad Selection and Insertion), UId (User Identification), and BAR (Bulk Ad Retrieval).

2 Context

Context can be described as information that can be used for characterizing the status of an entity in one specific case. One entity can be a one person, one place or one object relevant for any type of interaction between user and application, including the user and the application itself [1]. Parameters such as: a) where is the user; b) who is the user; c) how the user works; d) when the activity is being done; and e) what the user is doing; are used to build a context aware environment. [1] defines the four entities viz. location, entity, activity and time to address the parameters for building a context aware environment. [6] discusses which type of contextual information could be used in an interactive environment.

Fig. 1 describes the general context information comprising of location, identity, activity and time and more specifically context information for ITV applications. *Location information* of the user at home such as *"user is in living room"* or *"user is in bedroom"* can be used to determine the location context of the user. Identity information in ITV environment for context can be characterized as user identity, device identity, content identity and event identity. User identity is specified by user profile as described in the HIS stored in the Set Top Box (STB) at home. User identity typically includes information such as user's name, age, occupation, gender, marital status, favorite channels, movie interests, music interests, ad interest, etc. Device identity specifies attributes such as resolution, features, connectivity, etc. of multimedia devices at home. Content identity is stored in the STB as Electronic Program Guides (EPG) after being retrieved from the broadcast. The EPG also consists of other pro-

gram related information such as category, channel type, genre, parental guidance, summary, etc. The Event identity is determined either by the broadcast or by other sources such as sensors and the network. Event information can be for national or local events that might have an impact on the user context or user's TV watching behavior.
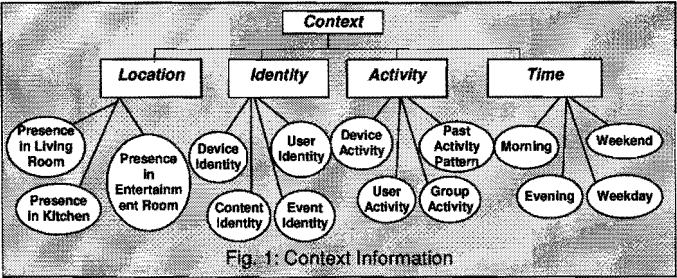
Fig. 1: Context Information

Activity information for context can be characterized for user activity, device activity and user/device history. User activity such as *"user watching TV with family"*, *"user watching TV while working from home"*, *"user watching TV while doing household jobs"*, etc. can be used to derive the user's context information for the activity entity. Device activity information typically includes the device usage information by the user. User and device history information typically includes users interaction with interactive controls of programs and ads in the past, his past purchases, websites and web pages visited in the past and channels and programs viewed in past. Time information for context consists of the current time as well as time information of the users history for channels/programs, purchases and interactivity. Time information gives cues for the context of the user as user's TV watching behavior changes for different time of the day as well as different days of the week.

Our proposed approach considers context information as *Current context* (CCo) and *Analyzed* or *Aggregated Context* (ACo). CCo is defined by the current activity and the entities associated with it. CCo is the information available at hand at an instance of time from direct sources. In our proposed system past context sequences are analyzed and aggregated to derive usage trends and user preferences, in the form of rules which are defined as ACo. For the ITV application of personalized ad insertion, based on CCo and ACo classification discussed above, the CCo information contains identified user watching TV at that instance of time, the user's age, the current program schedule for all the channels derived from the EPG, the program type, the program category, the program genre and parental guidance of the programs derived from EPG, ad slots in the programs and also ad sponsors. Similarly, the ACo information would contain derived user preferences for the programs, program types, program category and program genre, user's demographic information, user's viewing behavior, user's remote usage pattern, user's viewing history, user's purchase history, user's interactivity history and local and national event information.

The XML-based MPEG-7 (also called Multimedia Content Description Interface) Description Definition Language (DDL) [2] along with TV-Anytime Metadata Specification [8] can be used as a representation format for metadata to represent and de-

scribe components of a broadcast, ads and user profiles in the HIS. The representation format of the content enables determination of keywords describing the content. Similarly, keywords can be determined for user attribute information as described in the HIS. Since the context information is based on the content and user attribute information, a set of keywords can be determined to represent the context information. These determined context information keywords are matched against the keywords representing the ad content. The ads whose content description keywords have a match with the context information keywords are identified as the targeted ads to be inserted and presented to the user.

3 System Architecture

Multiple distinct networks are interconnected to deliver broadcast content to home users. The broadcast network broadcasts content to MSOs through radio channel and MSOs deliver content to home users via a cable network. From the point of view of ad insertion, a typical approach is to insert the ads before broadcast. This gives little opportunity to target ads to obtain a better return on investment. While content reaches MSO through radio, the related ads could reach the MSO through Internet or an IP network. In this case, the MSO stores these ads and could insert them at an appropriate place before forwarding the content to the home users. The third approach is to distribute the relevant ads directly to a home network where a set-top box would do the necessary ad insertion into the content before displaying the same. The last two approaches provides an opportunity to select and insert "the most appropriate" ads.

The system level description of our proposed approach is depicted in Fig. 3. As described in Fig. 3., the architecture consists of four distinct subsystems, CoD, CaASI, UId, and BAR Functionality of The CoD subsystem involves determination of both the CCo and the ACo information. The ACo information is used to identify ad tags, which depict analyzed and aggregated context of all users at home, for requesting ads to be retrieved from the MSO. The ACo information, along with inputs from the UId subsystem, is also used to identify appropriate ads from the ad database to populate secondary ad storage (cache).

The UId subsystem implemented on an STB is responsible for processing home users' viewing characteristics. Information such as user's likes and dislikes (such as with respect to movies, sports and music), his/her recent purchases, typical viewing hours on weekdays and weekends, and typical channels viewed are used to analyze the received viewing characteristics to identify one or more users (joint viewing) who might be watching TV [7]. The BAR subsystem is responsible for requesting ads from the MSO based on the context information of the users at home. Considering the number of sponsors and various versions of ads for each product of the sponsor, it is difficult to store all the ads in the STB. This subsystem solves this issue by requesting ads based on analyzed and aggregated context of all the users at home. It receives the context information of all the users at home from the CoD subsystem module and identifies ad tags depicting the context information. It then requests MSO to send ads based on the ad tags thus determined. The CaASI subsystem is responsible for selection and insertion of ads in the broadcast content, based on the context information,

for presentation to the user. This subsystem determines points of ad insertion in the broadcast stream by decoding digital cue tone messages. Targeted ads are identified using CCo and the ACo information and further inserted in the broadcast stream in the STB.

Fig. 3: System Architecture for Ad Selection and Insertion

4 Scenario

Consider a home with four members consisting of a dad (John) and mom (Cindy) and 2 kids (Andy and Samantha). The User profile information stored in the STB depicts: John is an insurance agent and is a sports lover; John's favorite sport is basketball; John generally watches TV from 7 to 10 in the evening; Cindy works for a bank; Andy and Samantha are school going kids. History information stored in the STB depicts: John had been visiting websites searching for a basketball jersey; John had purchased tickets for the finals of the college league basketball; John has been watching ads showing sports jersey and had interactions with the ITV components of type "*contact me*" for these ads; Cindy had been looking for vacuum cleaners on websites; Andy and Samantha had been interacting with ads for "back to school" products. The Events database depicts: Final of college league basketball tournament is on the coming weekend; Wal-Mart has sale for home equipment on the coming weekend. The EPG information depicts: Nike, Wal-Mart and Honda are sponsors for live coverage of college league basketball tournament; Nike has scheduled to show ads for its new range of golf shoes; Wal-Mart has scheduled to show ads for its upcoming sale of home equipment.

Consider a working day and the time 8:00 P.M. John comes back home and switches on the TV and starts watching ESPN channel which is showing live coverage of college league basketball championship. When the TV is switched on, the ACo component analyzes the history data and user profiles for all members of home. From the events database, the ACo component determines that the final of college league

243

basketball tournament is on the coming weekend. Similarly, the ACo component, based on user profiles and history information, determines that Cindy has been planning to buy a vacuum cleaner from Wal-Mart and Andy and Samantha had been planning to buy school bags from Wal-Mart. Based on the information determined, the ACo component determines rules and passes on the information to the BAR subsystem. Typically the rules that can be determined for the scenario under consideration are: Since John purchased tickets of the college league final match, he would like to wear Nike basketball jersey when he goes to watch the final match; Since Cindy had been looking for vacuum cleaners on websites, she would probably be interested in buying one from Wal-Mart sale on home equipment; Andy and Samantha would be interested in buying "back to school products" from Wal-Mart since they had been interacting with such ads.

The BAR subsystem determines keywords such as <sports, jersey, basketball, college league tournament, vacuum cleaner, kids, schooling, school bag, Northface, Home equipment> and requests the MSO for ads matching the context information. The MSO, on receiving the request, sends the following ads to STB at home: Nike ad for recently launched golf shoes; Nike ad for Nike jersey with basketball theme; Nike ad for soccer shoes with football theme; Wal-Mart ad for the weekend sale on home equipment; Wal-Mart ad for "always low prices"; Wal-Mart ad for "back to school" products; Wal-Mart ad for gardening equipment; Honda ad with F1 theme; Honda ad for new coup model.

Further, the ACo component, based on user profile information, determines that only John and Cindy might be watching TV at this instance of time. Based on the rules determined, it then analyzes the received ads and caches Nike and Wal-Mart ads in secondary ad storage. On remote click, the UId subsystem analyses user profiles and remote usage pattern and determines that the most probable user watching TV at that time should be John. Based on inputs from the UId subsystem and also based on user profile and EPG information, CCo component of the CoD subsystem forms rules which determines the CCo. The CaASI subsystem analyses the CCo information and ads in the secondary ad storage and determines that the Nike ad with the theme *"Nike jersey with basketball theme"* is the most appropriate ad as compared to the scheduled ad for recently launched golf shoes. The CaASI subsystem then inserts the ad in the broadcast for presentation.

Ads Requested Based on ACo	Probable Users at Home	Ads Cached Based on ACo and Context Information History	Identified User at Home	Most Appropriate Based on CCo and Inputs from UId
Nike ad for recently launched golf shoes; Nike ad for Nike jersey with basketball theme; Nike ad for soccer shoes with football theme; Wal-Mart ad for the weekend sale on home equipment; Wal-Mart ad for "always low prices"; Wal-Mart ad for "back to school" products; Wal-Mart ad for gardening equipment; Honda ad with F1 theme; Honda ad for new coup model.	John and Cindy	Nike ad for Nike jersey with basketball theme; Wal-Mart ad for the weekend sale on home equipment; Wal-Mart ad for "always low prices"; Wal-Mart ad for "back to school" products	John	Nike ad for Nike jersey with basketball theme
Similarly, if the identified user by the UId subsystem would had been Cindy and not John, the most appropriate ad determined by CCo component would be:				
	John and Cindy		Cindy	Wal-Mart ad for the weekend sale on home equipment; Wal-Mart ad for "always low prices"

For the same day but at different time, say 5:00 P.M. in the evening, when Andy and Samantha are watching their favorite cartoon channel, the cached ads by the ACo component and most appropriate ads determined by CCo component would be:				
	Andy and Samantha	Wal-Mart ad for "always low prices"; Wal-Mart ad for "back to school" products	Andy and Samantha	Wal-Mart ad for "back to school" products

5 Summary

In this paper we have proposed an architecture for context aware real time selection and insertion of advertisements into live broadcast stream by taking in to consideration the user's current and past contextual information. XML-based MPEG-7 DDL along with the TV-Anytime Metadata Specification are used as a representation format for metadata to represent and describe components of the system. The proposed work is part of our ongoing work on developing an STB environment with enhanced functionalities and capabilities. The project also involves development of intelligent iTV applications such as user identification, intent tracking, personalized ad insertion etc. We are currently working on a context sensitive cache conscious indexing technique to perform lookups for ad selection.

References

1. A.K. Dey and G.D. Abowd, Towards a better understanding of context and context-awareness, Handheld and Ubiquitous Computing, (H.W. Gellersen, Ed.), Springer, Berlin, pp. 304-307, 1999.
2. ISO/MPEG N3445 MPEG-7, 2001: Multimedia Description Schemes XM (v.7.0). http://mpeg.telecomitalialab.com/working_documents.htm.
3. H. Kammanahalli, Srividya Gopalan, and Sridhar V., Context aware retrieval in web-based collaboration, Proc. Second IEEE Conference on Pervasive Computing and Communications Workshops. Orlando, FL, 2004.
4. G. Lekakos, and G.M. Giaglis, A lifestyle-based approach for delivering personalized advertisements in digital interactive television, Journal of Computer-Mediated Communications, 9(2), January 2004.
5. J.B.D. Santos, R Goularte, G.B. Faria, and E.D.S. Moreira, Modeling of user interaction in context-aware interactive television application on distributed environments, Proc. TV01 - Workshop on Personalization in Future TV in Conjunction with User Modeling 2001. Sonthofen, Germany, 2001.
6. J.B.D. Santos, R Goularte, G.B. Faria, and E.D.S. Moreira, The modeling of structured context-aware interactive environments, Transactions of the SDPS Journal of Integrated Design and Process Science, v. 5, n. 4, p. 77--93, December de 2001.
7. A. Thawani, Srividya Gopalan and Sridhar V., Viewing characteristics based personalized ad streaming in an interactive TV environment, Proc. 2004 IEEE Consumer Communications and Networking Conference, 2004.
8. TV-Anytime Forum. Specification Series (Metadata). 2003-August. http://www.tv-anytime.org/.
9. V. Dureau, Addressable advertising on digital television, Proc. Second European Conference on Interactive Television, 2004.

AVATAR: Advanced Telematic Search of Audiovisual Contents by Semantic Reasoning

Yolanda Blanco-Fernández, José J. Pazos-Arias, Alberto Gil-Solla,
Manuel Ramos-Cabrer, Jorge García-Duque, Rebeca P. Díaz-Redondo,
Ana Fernández-Vilas, Belén Barragáns-Martínez and Martín López-Nores

Department of Telematic Engineering, University of Vigo, 36200, Spain
`{yolanda,jose,agil,mramos,jgd,rebeca,avilas,belen,mlnores}@det.uvigo.es`

Abstract. In this paper, a new approach to TV personalized recommender systems is presented, based on the use of TV-Anytime formats and Semantic Web technologies so as to reason about TV contents and to generate high quality recommendations.

1 Introduction

Nowadays, a fundamental change is taking place in TV: the migration from analogue to digital TV. This change has two main implications: a considerable increase in the capacity to broadcast more channels in the same bandwidth, and the possibility to send software applications mixed with audiovisual contents, enabling the appearance of new market opportunities in the context of digital TV as it is described in [6].

In this new scenario, TV users will be able to access a large number of contents from different providers. In this situation the recommender systems are highly useful to assist users in discriminating contents that they may find interesting, from among large amounts of irrelevant information. The recommender systems can allow the users to take an active role [8] and ask for concrete TV contents or, on the contrary, these tools can analyze the preferences and the programs the users have watched, in order to recommend, in an implicit way, personalized contents without a previous request. This last possibility aims to reduce the viewers charge in tedious searching processes.

As digital TV deployment evolves, personalized recommender tools are gaining more and more interest among researchers, resulting in the appearance of quite different approaches: expert systems, Bayesian techniques, content-based methods, collaborative filtering, decision trees, neural networks, among others. Some recommendation tools combine several inference strategies so as to augment the precision of the elaborated suggestions. For instance, [9] employs naive Bayesian classifiers and collaborative recommendations, [1] uses neural networks, decision trees and Bayesian methods and [3] proposes the combination of content-based information filtering with collaborative filtering as the basis for multi-agent collaborative information retrieval. What all

these recommenders have in common is that they only analyze program-level metadata and have limited reasoning capabilities, for which we propose an approach based on semantic reasoning, that is, a usual inference methodology in Semantic Web but novel in the domain of TV recommender systems.

We focus on the semantic reasoning about the TV contents, user pro les and historical logs that record the actions carried out by the users. Such a reasoning process undoubtedly requires a high degree of normalization and formalization. In this regard, the TV-Anytime initiative is a recent ETSI standard that normalizes descriptions of generic TV contents, concrete instances and user pro les. This is a suitable framework to make reference, process and locate contents, turning out to be a good starting point for implementation of querying services based on syntactic comparisons. In the other hand, taking into account that this speci cation allows to describe segments within a TV program   by Segmentation metadata [5]   , our personalization tool can provide the most interesting parts of a program to the viewers, instead of offering whole programs.

Other previous works like [4] have tackled the use of metadata too. This way, it proposes to augment the contents offered to the users by means of additional information extracted from different media, such as TV and Web. Our system can also provide extra information, since that the TV-Anytime metadata supply descriptions of the TV contents and information of interest for the viewers (for instance, a brief synopsis of a program or the starring actor's lmography in the case of a movie). However, the main difference between the two approaches is that our system does not only provide informative data about the programs, but it also allows to enhance the TV recommenders, by means of the reasoning about the descriptions of the contents and the user preferences. In this regard, the TV-Anytime standard does not consider any kind of infrastructure for enabling intelligent search and processing. These needs appeared in the Internet a few years ago, where the absence of formal languages and tools dif culted the logical reasoning about the resources properties and the inference of new relations.

In recent years, in the context of the Semantic Web different languages have appeared, allowing to structure, through ontologies, all the relevant information about each application domain, and to formalize the necessary mechanisms to express queries, properties, relations and to infer new knowledge [2].

In this paper, the more relevant characteristics of the work being developed by the authors are presented. The goal is to build a digital TV personalization tool, named AVATAR, that enriches the traditional syntactic content search with new mechanisms to generate recommendations derived from semantic reasoning about the properties of broadcast contents and the personal user pro les. In this regard, the two described tools TV-Anytime and the experience developed in the Semantic Web   are combined to take a step forward in the development of tools that assist the TV users, recommending contents and services interesting for them.

2   The AVATAR tool

The goal of the AVATAR application is to generate recommendations for digital TV users   which we refer to as *target users*   about contents and services appealing to them. To achieve it, it takes as a starting point the metainformation about contents avail-

247

able in TV-Anytime format and about the information stored in user personal pro les. To structure this information, we have developed an ontology by the Prot g -2000 tool following the precepts of the OWL language.

The proposed recommender must tackle very diverse information. For instance, the system uses data referred to the main characteristics of the users and their preferences, and information related to different geography regions. To take into account this, we have imported other ontologies into the TV one. The management of several ontologies in a knowledge-based system has been analyzed in previous works, like [10]. As commented, a user ontology has been developed with several classes and subclasses to consider the preferences and personal data of the viewers. This ontology has been reused in designing the user pro les structure, since that the use of this sort of the Semantic Web technology for user modelling has numerous advantages [7].

The TV ontology organizes the information about contents according to the TV-Anytime metadata and extends it with additional information about the several domains of contents involved (e.g. actor's lmography). Together with the taxonomy of concepts related to TV contents (classes and subclasses), it contains properties and inference rules to favour the acquisition of new knowledge. We include below a portion of our TV ontology with a reduced version of the stored information referred to movies. The complete ontology is available in *http://avatar.det.uvigo.es/ontology*.

```
<owl:Class rdf:ID= Movies >
   <rdfs:subClassOf> <owl:Class rdf:about= #TVContents > </rdfs:subClassOf>
</owl:Class>
<owl:DatatypeProperty rdf:ID= #hasGenre >
   <rdfs:domain rdf:resource= #Movies >
   <rdfs:range rdf:resource= /XMLSchema#string >
</owl:DatatypeProperty>
<owl:Class rdf:ID= ActionMovies >
   <rdfs:subClassOf> <owl:Class rdf:about= #Movies > <owl:Restriction>
   <owl:onProperty> <owl:DatatypeProperty rdf:about= #hasGenre />
   <owl:hasValue rdf:datatype= XMLSchema#string > Action </owl:hasValue>
   </owl:Restriction> </rdfs:subClassOf>
</owl:Class>
<owl:ObjectProperty rdf:ID= #isAppealingTo >
   <rdfs:domain rdf:resource= #ActionMovies >
   <rdfs:range rdf:resource= #JournalistUsers >
</owl:ObjectProperty>
```

The inference rules used in our approach have been elaborated from a database that contains personal data and preferences about TV programs of very different users (e.g. the "isAppealingTo property cited above). Other rules have been introduced ad-hoc because they cannot be inferred from the data contained in the aforementioned database. Some of these rules are involved in the recommendation example shown in Sect. 2.1. The information hierarchically structured in the TV ontology is used to feed the semantic reasoning procedures that process the characteristics of contents broadcast, user preferences and historical records. The aim is to nd hints leading to successful suggestions. The information stored in our ontology is mainly static. However, part of

248

the data of the user pro les is dynamic: it is continuously updated as the user history is recorded and analyzed. The goal is to maintain up-to-date user pro les and to re ect possible changes in the users viewing behaviour.

Recommendations usually consist of an ordered list of programs. As users select one of them or decide to watch any other program not included in the list, AVATAR quanti es the success of the recommendations. This information is used to improve the dynamic pro les and to generate more accurate recommendations in the future. Recent studies in the eld of automatic recommenders show that an application's success depends greatly on requiring a low degree of interactivity with the target users. So, the information requested to the viewers must be minimal so as to they continue using the recommender system. In AVATAR, this information can be reduced to some personal data and likings, obtained from the target users in the rst execution. This way, a basic user pro le is created, that will evolve as the user begins to watch TV.

In Fig. 1, a functional diagram of AVATAR architecture based in agents is shown. To work out a recommendation, AVATAR takes as inputs the information about broadcast contents (*CONTENTS*) and the information about the user pro les (*USER PROFILE*).
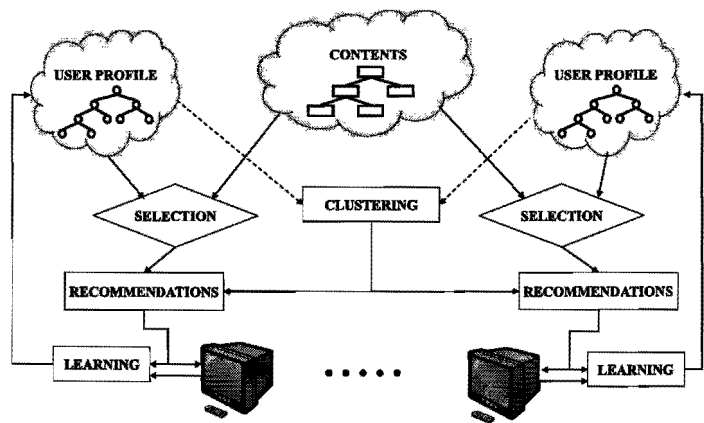
Fig. 1. The architecture of a broadcast recommender system.

To improve the quality of recommendations, AVATAR can group user pro les (*CLUS-TERING*) according to their similarities. This enables to make joint recommendations for all the members in the group starting from reasonings derived from the behaviour of one of them. This is usually named collaborative knowledge. Agents, with the information stored in the ontology, select (*SELECTION*) those programs catalogued as interesting for the user and make recommendations (*RECOMMENDATIONS*). These agents have been designed to act, most of the time, in an autonomous way, without user request. However, it is also possible that their function can be the result of a concrete information requirement, so narrowing the reasoning process. Finally, quanti cation of

recommendation's success enables the agents to learn (*LEARNING*) and modify the dynamic part of user's pro les. The AVATAR architecture favours the existence of various kinds of agents that, using different mechanisms, elaborate their own recommendations, that will be later combined. However, the main novelty of the system is the semantic reasoning about the ontology and the user pro les to generate its recommendations. In the next section, an example of the reasoning process is shown.

2.1 An Example of Semantic Reasoning

In this example we illustrate how the AVATAR recommender system takes the known information personal data and the TV programs contained in the user's view history and reasons about the TV contents descriptions, by means of the axioms and properties contained in the implemented ontology. The goal is to obtain enhanced suggestions, beyond the conventional syntactic searches.

We are concerned with emphasizing the different types of knowledge applied in the inference and reasoning processes: knowledge inferred from the user pro le and from the programs the viewer watched in the past, together with collaborative recommendations, so as to consider the users with pro les similar to the target user's pro le.

Supposed our target user's view history contains the following: "Ghostbusters II (a comedy with Bill Murray in a leading role), "Safaris in Kenya (a documentary) and "CNN News . In addition, his user pro le contains information saying that he is married, has two children, works as a doctor and enjoys going to the cinema.

One of the functionalities AVATAR can offer to users is to include brief interesting subtitles in contents. This way, the system can look for present news that may be of interest for the user and report them immediately. These news could be incidents happening in Africa whose possible interest is suggested by the documentary about Ethiopia the user has watched (making use of the transitive property **Kenya ← locatedIn → Africa**) or strikes at spanish hospitals (**Job ← hasJobName → Doctor** and **Doctor ← WorksIn → Hospitals**, combined with **News ← hasSections → IncidentsNews** and **IncidentsNews ← hasSynopsis → "Hospital strike in Madrid"**). This is an example of knowledge inferred from programs in the view history (documentaries and news) and from information about the user contained in his initial pro le (he is a doctor).

AVATAR can exploit another typical feature in the context of personalized digital television: users can reduce contents fees if they watch programs with inserted advertising. Supposing that the user wants to spend less money in viewing a movie by accepting a given amount of commercials, the system can also select the advertisements according to his preferences. In this way, considering that the user is married, AVATAR could apply the rule **MarriedPeople ← InterestedIn →Cruises**, to recommend advertisements about cruises (this knowledge is inferred directly from the user pro le again). Our system must choose a region. In this case, AVATAR will suggest the user a Nile cruise because it knows a common nexus between Egypt and Kenya (remember the user's view history): both regions are in Africa (information about countries is imported from an external ontology). The properties used in this reasoning process are **Kenya ← locatedIn → Africa, Advertising ← hasProduct → Product, Product ← hasProductName → Cruise, Cruise ← hasDescription → "Cruise on the Nile", Nile ← locatedIn → Egypt and Egypt ← locatedIn → Africa.**

250

Besides, AVATAR allows personalizing services. In the example, the system can use the knowledge about the user being fond of going to the cinema regularly, contained in his user pro le, to offer him the chance to buy tickets for a movie chosen by the recommender. The system can make use of other people's experiences (collaborative knowledge) to produce new inferences. Thus, AVATAR can discover that users who like comedies with Bill Murray (this actor is in his view history) like movies with Jim Carrey in a leading role as well. Therefore, the system offers buying tickets for the premiere of Jim Carrey's last movie to be held the day after tomorrow.

3 Conclusions and Further Work

In this paper, a work in progress has been presented with a new approach based on Semantic Web technologies so as to elaborate enhanced recommendations of TV programs. Our aim is to improve the conventional syntactic search of programs by reasoning about the user preferences and the description of the contents, expressed with TV-Anytime metadata.

Future work will be concerned with designing of a query language for inferring knowledge from the properties and inference rules contained in the TV ontology. Taking into account that there is a direct correspondence between OWL and Description Logics (DLs), we will also investigate the application of the DL reasoners   such as RACER and FACT   about the user preferences and the ontological concepts.

References

1. Ardissono L. et al. *Personalized Digital Television: Targeting Programs to Individual Viewers*, chapter TV Personalization System: Design of a TV Show Recommender Engine and Interface. Kluwer Academic Publishers, 2004.
2. Daconta M. et al. *The Semantic Web: A Guide to the Future of XML, Web Services and Knowledge Management*. John Wiley & Sons, 2003.
3. Delgado J. et al. Intelligent collaborative information retrieval. In *IBERAMIA*, pages 170 – 182, 1998.
4. Dimitrova N. et al. Content augmention aspects of personalized entertainment experience. In *Proceedings of the UM 2003 Workshop on Personalization in Future TV*, pages 42–52, 2003.
5. ETSI TS 102 822. *Broadcast and On-line Services: Search, select and rightful use of content on personal storage systems.*
6. Pagani M. *Multimedia and Interactive Digital TV: Managing the Opportunities Created by Digital Convergence*. Idea Group Publishing, 2003.
7. Razmerita L. et al. Ontology-based user modelling for knowledge management systems. In *Proceedings of the 9th International Conference on User Modeling*, pages 213–217, 2003.
8. Schonfeld, E. Don't Just Sit There. Do Something. *Business 2.0*, 2000.
9. Uchyigit G. et al. A Personalised Multi-Modal Electronic Program Guide. In *Proceedings of the 1st European Conference on Interactive Television*, 2003.
10. Vögele T. et al. Buster - an information broker for the semantic web. 2003.

Selecting News to Suit a Group of Criteria: An Exploration

Judith Masthoff

University of Brighton
Brighton, UK
Judith.Masthoff@brighton.ac.uk

Abstract. In (Masthoff, 2004), we have investigated techniques for combining individual user models to make recommendations to a group. In Masthoff (2003), we have shown how these techniques might also be applicable when adapting to an individual: for solving the cold start problem and for combining ratings on multiple criteria. In this paper, we look at combining multiple criteria in more detail. We present an exploratory experiment into how people combine criteria. A main issue is potential inequality of the criteria's importance. We show how the group modelling strategies can be adapted to deal with this inequality.

1 Introduction

One problem faced by personalized TV is that viewers often watch television in groups. Hence, previously we have studied adaptation to groups of users, in particular strategies for combining individual user models in order to determine group recommendations (Masthoff, 2004). For instance, suppose the TV knows who is watching, and it knows the ratings of each individual for a set of news items, then there are various strategies for deciding which news items to show to the group. In (Masthoff, 2003), we have claimed that the usefulness of these strategies is not restricted to adaptation to groups of people, but that these strategies could also be useful when adapting to an *individual*. We have shown how group modelling could contribute to solving the cold start problem: the problem that the TV does not know enough about the user initially to make good recommendations. If there is a set of known other users, or a set of stereotypes, and the system does not yet know which of these the user resembles, then one way to ensure enjoyment is to present items that the other users (or stereotypes) would enjoy as a *group*. We have shown how this could work on some real data. We have also discussed how the group modelling strategies might be applicable when combining ratings on multiple criteria. Multiple factors can contribute to a recommender's prediction of the user's opinion of an item. For instance, Pazzani (1999) *adds* the rankings produced by content-based filtering, collaborative filtering, and demographic filtering. Nguyen and Haddawy (1998) use a *weighted addition* of attributes describing a movie: director, casting, genre, star rating and running time. Though stressing the importance of aggregating ratings, neither discusses why they have chosen their particular aggregation function. In Masthoff

252

(2003), we have claimed that the same strategies could be used as when combining individual ratings for a group model, however, without evidence to back this up. In this paper, we will explore what really happens when ratings on multiple criteria are to be combined. Our example domain will be personalized news, which is one of the more popular areas for research into Personalized TV (e.g., Maybury et al., 2004; Dimitrova et al., 2004).

2   Summary of Group Modelling Strategies

In this section, we will summarize the strategies subjects seemed to use in the group modelling experiment in Masthoff (2004). For more details and an overview of additional strategies see Masthoff (2004). We had asked subjects to recommend a sequence of items to a group, based on item ratings of the individual group members. In the following, the so-called 'group list' is the sequence in which items would be chosen by a particular group modelling strategy.   Sometimes, two items score the same, like E and F in the average strategy. This is indicated in the group list by placing them between brackets. This means that either E is followed by F, or F is followed by E. Three strategies mimicked the behaviour of many of our subjects:

1. *Average strategy (also called Additive Utilitarianism)*. Ratings are added, and the larger the sum the earlier the alternative appears in the sequence (results are the same as when averaging ratings, hence its name). This strategy (often in a weighted form, where weights are attached to individual ratings) is also used in multi-agent systems (Hogg & Jennings, 1999), Collaborative filtering, and in the INTRIGUE system with recommends attractions to visit to groups of tourists (Ardissono et al, 2002). A disadvantage is that starvation can occur: if a person's opinions differ from those of most people in the group, they might never get anything they like.

	A	B	C	D	E	F	G	H	I	J
John	10	4	3	6	10	9	6	8	10	8
Adam	1	9	8	9	7	9	6	9	3	8
Mary	10	5	2	7	9	8	5	6	7	6
Group	21	18	13	22	26	26	17	23	20	22

Group List:
(E,F)H(D,J)AIBGC

2. *Least Misery Strategy*. The minimum of the individual ratings is taken, and the larger the minimum the earlier the alternative appears in the sequence. The idea behind this strategy is that a group is as happy as its least happy member. The POLYLENS movie recommender system uses this strategy, assuming groups of people going to watch a movie together tend to be small and a small group to be as happy as its least happy member (O' Conner, Cosley, Konstan & Riedl, 2001). A disadvantage is that a minority opinion can dictate the group: if everybody really wants to see something, but one person does not like it, then it will never be seen.

	A	B	C	D	E	F	G	H	I	J
John	10	4	3	6	10	9	6	8	10	8
Adam	1	9	8	9	7	9	6	9	3	8
Mary	10	5	2	7	9	8	5	6	7	6
Group	1	4	2	6	7	8	5	6	3	6

Group List:
FE(H,J,D)GBICA

3. *Average Without Misery Strategy.* Ratings are added, but without items that score below a certain threshold (say 4) for individuals. MUSICFX (McCarty & Anagnost, 1998) uses a slightly more complex version of this strategy, when selecting music for people working out in a fitness center.

	A	B	C	D	E	F	G	H	I	J
John	10	4	3	6	10	9	6	8	10	8
Adam	1	9	8	9	7	9	6	9	3	8
Mary	10	5	2	7	9	8	5	6	7	6
Group	-	18	-	22	26	26	17	23	-	22

Group List
threshold 4:
    (E,F)H(D,J)BG
threshold 3):
    (E,F)H(D,J)IB

In Masthoff (2004), we found that subjects cared about avoiding misery and about fairness. Many subjects' behaviour reflected that of the Least Misery or Average Without Misery strategies. Even subjects whose behaviour completely deviated from these strategies, avoided

3 Experiment: How People Combine Multiple Criteria

We wanted to investigate whether the way subjects combine ratings from multiple criteria reflects that of subjects combining ratings of individual group members. Hence, the experimental design used was identical to that in Masthoff (2004), and the same ratings were used. The only difference was that this time we used criteria rather than group members.

3.1 Method

Subjects were given the individual ratings of three criteria for a set of news items. The criteria used were:
- *Importance.* How important the news is in general. For instance, a major earthquake is more important than a single house collapsing.
  Each item is rated from 1 –really unimportant- to 10-really important.
- *Relevance of Location.* How relevant the location of the news is to you. For instance, for a Dutch person living in Brighton, the relevance of location of news from the Netherlands and Brighton is higher than that of news from Italy.
  Each item is rated from 1 –really irrelevant location- to 10-really relevant location.
- *Recency.* How recent the news is. For instance, something that happened in the last hour is more recent than something that happened yesterday.
  Each item is rated from 1 –really old news- to 10-really recent news.

Bell (1991) provides an overview of criteria used by editors for news selection. He mentions more than 15 criteria. The above are inspired by those. For instance, our Recency criterion is a combination of his Recency and Freshness criteria. Our Relevance of Location criterion is a combination of his Proximity and Relevance criteria. Note that we did not explicitly set out to create criteria of different importance, though the experimental results seem to show such a difference.

In seven questions, subjects were asked which item they would watch, given that they only had time to see respectively 1, 2, 3, 4, 5, 6, or 7 items, and why they made that selection (see Appendix A for exact task wording). The individual ratings used were the same as those that had been used in the Experiments in Masthoff (2004), with Importance having the ratings of John, Relevance of Location having the ratings of Adam, and Recency having those of Mary. See Table 1 for the ratings used.

Table 1. Ratings used in the experiment. A to J are news items.

	A	B	C	D	E	F	G	H	I	J
Importance	10	4	3	6	10	9	6	8	10	8
Relevance of Location	1	9	8	9	7	9	6	9	3	8
Recency	10	5	2	7	9	8	5	6	7	6

The ratings had been chosen primarily to enable differentiating between the strategies we expected subjects to use. In addition, it ensured that Importance and Recency had quite similar ratings, while the Relevance of Location's ratings were frequently the opposite of the ratings of the other two. We also ensured that for one news item, namely item A, Importance and Recency had maximal positive ratings (10), while Relevance of Location had a maximal negative rating (1). The latter would give a good idea of the importance subjects assigned to avoiding misery.

3.2 Subjects

Thirty six subjects participated in the experiment (92% male, 8% female, average age 23.8, standard deviation 4.6). All were final-year undergraduate students in computing attending a lecture of the Adaptive Interactive Systems module. The experiment took place in a lecture room. Students participated in the experiment voluntarily (in addition to the numbers mentioned above, 4 students chose not to participate).

3.3 Results and Discussion

Subjects do not seem to answer the questions independently: they responded which new item should be added to the sequence they had already chosen for the previous question. This made it possible to present the results in the way we have done in Table 2, only showing the new item selected for each question. We have tried to keep the table as simple (and uncrowded) as possible: if a cell does not have an item name in it, then the first name above it applies. For instance, s1 replied F to the first question. Subjects have been ordered to make the table as easy to view as possible.

Table 2. Results. See below for meaning of shading and border lines.

	1	2	3	4	5	6	7	Summary
s5	F	E	A	I	J	D	H	None of the discussed strategies.
s7					H		B	
s33						J	D	
s22								
s1				H	I		?	
s29					J	D	B	
s20				D	H	I	J	
s13			H	J	D	A	I	Average strategy throughout.
s28								
s25				D	B		J	Average strategy or Least Misery strategy for first four items
s3		A	E	I	H	J	D	None of the discussed strategies.
s19		J		A	D	H	I	
s4	E	F	A	I	H	J	D	
s23					J	H		
s24							B	
s26				J	H	I	D	
s16				H	I	J		
s6			H	J	D	B	I	Average strategy for the first five items.
s8							G	Average without Misery throughout.
s10						A	I	Average strategy throughout.
s12					I		D	Average strategy for the first four items.
s2								
s30				D	A	I	J	
s15			J	H	D	A	I	None of the discussed strategies.
s27			I	A	J	H	G	
s11		A	F	I	H	J		
s21				H	D	B	J	
s14	A	E	I	F	H	J	D	
s31			F	I			B	
s32						D	J	
s35					J	H	D	
s36			D	F	I		J	
s17		F	E	I	H	J	D	
s18				H	J	D	I	
s34		I		J	F	H	?	

The table includes information about how well the subjects' replies fit the strategies discussed above:

- Bold borderlines indicate replies that are in correspondence with the Average Strategy. So, for instance, all replies of s13 were the same as those by the Average Strategy. The first two replies by s4 were the same as those by the Average Strategy, but s4's later replies differed.
- Gray cell shading indicates replies that are in correspondence with the Least Misery Strategy. So, for instance, the first two replies by s5 were the same as those by the Least Misery Strategy, but s5's later replies differed.
- Bold dotted borderlines indicate replies that are in correspondence with the Average Without Misery Strategy. So, for instance, all replies of s8 were the same as those by the Average Without Misery Strategy.

Note that strategies can have overlapping starts of their group lists. For instance, both the Average Strategy and the Least Misery Strategy allow a start of FEHDJ. This means that cells can have both grey cell shading and a bold borderline. So, for instance, s13's replies followed the Least Misery Strategy for the first five items, and were in correspondence with the Average Strategy for all seven items. Also, we have only used the Bold dotted borderlines, when the Average Without Misery Strategy starts deviating from the Average Strategy. The results of one subject, s9, are excluded from the discussion. He misinterpreted the ratings, believing 1 to mean good and 10 bad, calling item C "the most important news".

Comparing the results in Table 2 with those in (Masthoff, 2004), the most striking difference is that the results of subjects in (Masthoff, 2004) tended to reflect those of strategies, particularly the Average Strategy and Least Misery Strategy. In contrast, hardly any subjects in this experiment seem to have followed one of the discussed strategies. Particularly, we find hardly any evidence of avoiding misery, which was found to be an important factor for subjects when making group recommendations. This may be due to subjects attaching different weighting to the criteria. Many subjects talk about the Importance and Recency of items when explaining their choice, in contrast to hardly any mention of the Relevance of Location. One subject (s34) even states explicitly that he "is not that interested in local news".

As can be seen in Figure 1, item A and I are clearly introduced earlier in this experiment than in the experiment on adaptation to a group of people reported in (Masthoff, 2004). This indicates that subjects indeed use different weightings, and attach less weight to the "Relevance of Location" criterion than to the other criteria. As many as nine subjects introduce J (ratings 8-8-6) before H (ratings 8-9-6). Again, this seems to show a disregard for criterion 2 "Relevance of Location".

Subjects sometimes seem to interpret ratings, mapping them onto real life news items. For instance, three subjects (S14, S18, and S33) described item A as "September the 11th", a news item of great importance and very recent (at the time of broadcast), but related to (according to them) a less relevant location. Some subjects seem to equate the "Relevance of Location" criterion with whether the news is local or not. In the UK, there are local news broadcasts after the main news, with news items like "elderly lady mugged in Brighton". This might have influenced subjects' opinion of this criterion.
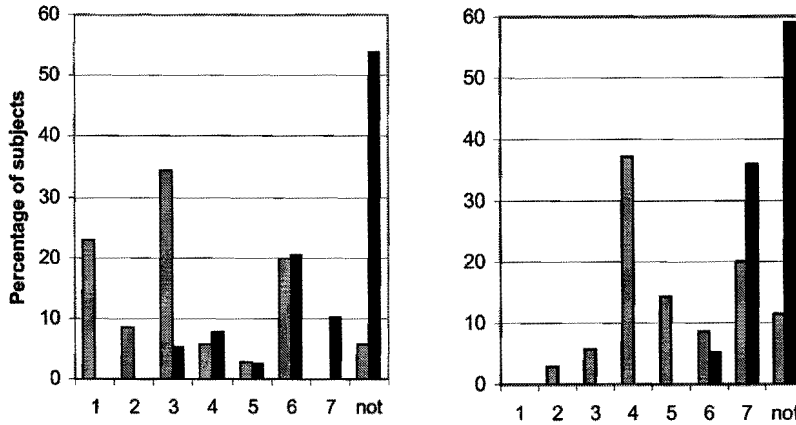
Fig. 1. Introduction of items A (left) and I (right) in this experiment (grey) and in the old experiment (adaptation to a group of people) (black).

4 Adapting the Strategies to Deal with Inequality

In Masthoff (2004), we noted that individuals in a group can be of varied importance, and discussed how weightings could be used in an Average Strategy, or even how only the ratings of the most important individual could be used (we called this the Most Respected Person strategy). In our experiments in (Masthoff, 2004), however, subjects regarded all individuals as equally important, which is not surprising given that they were only provided with their names. (We tried to influence subjects' attribution of importance in one experiment by giving John, Adam and Mary varying ages, but without success). Actually, it seems quite sensible and morally correct to treat everybody equally when a system is adapting to a group of people. Of course, there may be some exceptions, for instance when the group contains adults as well as children, or when it is somebody's birthday. But in general, equality seems a good choice. In contrast, when a system is adapting to a group of criteria, rather than people, there is no particular reason for assuming all criteria are as important. It is even quite likely that not all criteria are equally important for a particular person. The result of the experiment discussed above do indeed show such an inequality between criteria. So, how can we adapt the strategies to deal with this, and to better explain the behaviour of our subjects? There are several ways in which this can be done:

1. *Average Of Important Criteria* and *Least Misery For Important Criteria*
   The ratings of unimportant criteria are ignored completely. For instance, assume criterion Location is regarded unimportant, then its ratings are ignored. The result of the Average Of Important Criteria strategy becomes:

	A	B	C	D	E	F	G	H	I	J
Importance	10	4	3	6	10	9	6	8	10	8
Recency	10	5	2	7	9	8	5	6	7	6
Group	20	9	5	13	19	17	11	14	17	14

Group List:
AE(F,I)(H,J)DGBC

And the result of the Least Misery For Important Criteria strategy becomes:

	A	B	C	D	E	F	G	H	I	J
Importance	10	4	3	6	10	9	6	8	10	8
Recency	10	5	2	7	9	8	5	6	7	6
Group	10	4	2	6	9	8	5	6	7	6

Group List:
AEFI(H,J,D)GBC

2. *Average With Weights.*
The ratings of unimportant criteria are given less weight. The weight of a criterion is multiplied with its ratings to produce new ratings. For instance, suppose criteria Importance and Recency were three times as important as criterion Location. The result of the Average With Weights Strategy becomes:

	A	B	C	D	E	F	G	H	I	J
Importance	30	12	9	18	30	27	18	24	30	24
Location	1	9	8	9	7	9	6	9	3	8
Recency	30	15	6	21	27	24	15	18	21	18
Group	61	36	23	48	64	60	39	51	54	50

Group List
weight 3-1-3:
EAFIHJDGBC
weight 2-1-2:
EFA(H,I)JDGBC

Note that a weight of 0 results in ignoring the ratings completely, as above.

3. *Average Without Misery For Some.*
Misery is avoided for important criteria but not for unimportant ones. Assume criterion Location is again regarded as unimportant. The result of the Average Without Misery For Some strategy with threshold 6 becomes:

	A	B	C	D	E	F	G	H	I	J
Importance	10	4	3	6	10	9	6	8	10	8
Location	1	9	8	9	7	9	6	9	3	8
Recency	10	5	2	7	9	8	5	6	7	6
Group	21			22	26	26		23	20	22

Group List
threshold 6:
(EF)H(J,D)AI
threshold 7:
(EF)AI

Table 3 shows how the subjects' replies fit with the strategies discussed above:
- Bold borderlines indicate replies that are in correspondence with the Average strategy (thin line) or the Average With Weights strategy for weights 2-1-2 or 3-1-3 (fat line).
- Bold dotted borderlines indicate replies that are in correspondence with the Average Without Misery strategy (small dots), or the Average Without Misery For Some strategy (large dots) with criterion Location as unimportant.

259

Table 3. Results mapped onto the strategies with inequality. See above for meaning of shading and borderlines.

	1	2	3	4	5	6	7	Summary
s5	F	E	A	I	J	D	H	Average Without Misery For Some threshold 7 followed by threshold 6
s7					H		B	
s33						J	D	
s22								
s1				H	I		?	Average Without Misery For Some for the first three items. Threshold 7.
s29					J	D	B	
s20				D	H	I	J	
s13			H	J	D	A	I	Average strategy throughout.
s28								
s25				D	B		J	Average strategy or Least Misery strategy for first four items
s3		A	E	I	H	J	D	None of the discussed strategies.
s19		J		A	D	H	I	
s4	E	F	A	I	H	J	D	Average with Weights, 2-1-2. Or, Average Without Misery For Some, t7-t6.
s23					J	H		For first four: Average with Weights 2-1-2. Or Average Without Misery For Some, t7.
s24							B	
s26				J	H	I	D	
s16				H	I	J		Average with Weights, 2-1-2, throughout.
s6			H	J	D	B	I	Average strategy for the first five items.
s8							G	Average Without Misery throughout.
s10						A	I	Average strategy throughout.
s12					I		D	Average strategy for the first four items.
s2								
s30				D	A	I	J	
s15			J	H	D	A	I	None of the discussed strategies.
s27			I	A	J	H	G	
s11		A	F	I	H	J		Average with Weights, 3-1-3, for first six.
s21				H	D	B	J	
s14	A	F	I	I	H	J	D	Least Misery (or Average) for Important Criteria: Importance only.
s31			F	I			B	Least Misery for Important Criteria
s32						D	I	
s35						H	D	
s36			D	F	I		J	None of the discussed strategies.
s17		F	E	I	H	J	D	
s18				H	J	D	I	
s34		F		J	F	H	?	Least Misery (or Average) for Important Criteria: Importance only, for first three items.

260

- Shading indicates replies that are in correspondence with the Least Misery strategy (light grey), or the Least Misery for Important Criteria strategy (dark grey) with criterion Location as unimportant. Subject s14 explicitly indicated that he was using this strategy, stating that he always went for the item with the highest Importance, disregarding the other criteria.

Some replies correspond to multiple strategies. E.g., subject s4's response corresponds both to Average with Weights and Average Without Misery For Some. This has been indicated in the summary column.

Comparing Table 2 with Table 3, we conclude that our adaptation of the strategies to cope with inequality has had some success in explaining subject behaviour. There also seems to be some evidence now that subjects still do care about avoiding misery. Subjects just do not seem to care about the criterion Relevance of Location, and therefore do not care about avoiding misery for that criterion.

5 Conclusions

The problem of combining rating for multiple criteria bears a similarity with that of combing rating for multiple people. We have performed an exploratory experiment to investigate to what extend results from our group modelling work can be used when combining multiple criteria, for instance for personalized news. The results show that a main issue when combining criteria is dealing with a likely inequality of the criteria's importance. We have shown some ways in which the strategies can be modified to cope with this. This is only the first step in the research. The next step would be to show subjects sequences generated by our algorithms and ask them to rate the user's predicted satisfaction.

References

1. Ardissono, L., Goy, A., Petrone, G., Segnan, M., and Torasso, P. (2002). Tailoring the recommendation of tourist information to heterogeneous user groups. In S. Reich, M. Tzagarakis, and P. De Bra (eds.), *Hypermedia: Openness, structural awareness, and adaptivity*, International Workshops OHS-7, SC-3, and AH-3, 2001. Lecture Notes in Computer Science 2266, Berlin: Springer Verlag, pp. 280-295.
2. Bell, A. (1991). *The language of news media*. Oxford, UK: Basil Blackwell.
3. O' Conner, M., Cosley, D., Konstan, J.A., and Riedl, J. (2001). PolyLens: A recommender system for groups of users. In: *Proceedings of ECSCW 2001*, Bonn, Germany, pp. 199-218. As accessed on http://www.cs.umn.edu/Research/GroupLens/ poly-camera-final.pdf.
4. Dimitrova, N., Zimmerman, J., Janevski, A., Agnihotri, L., Haas, N., Li, D., Bolle, R., Velipasalar, S., McGee, T, and Nikolovska, L. (2004). Media augmentation and personalization through multimedia processing and information extraction. In L.Ardissono, A. Kobsa and M. Maybury (eds.), *Personalized digital television: Targeting programs to individual viewers*. Dordrecht, NL: Kluwer, pp203-233.
5. Hogg, L., and Jennings, N.R. (1999). Variable sociability in agent-based decision making. Sixth International Workshop on Agent Theories, Architectures and Languages, Orlando, FL, USA, pp. 276-289.

6.   Masthoff, J. (2004). Group modeling: Selecting a sequence of television items to suit a group of viewers. *User Modeling and User Adapted Interaction, 14*, pp37-85. [Also published in L.Ardissono, A. Kobsa and M.Maybury (eds.), Personalized digital television: Targeting programs to individual viewers. Dordrecht, NL: Kluwer.]
7.   Masthoff, J. (2003). Modeling the multiple people that are me. In: P. Brusilovsky, A.Corbett, and F. de Rosis (eds.) *Proceedings of the 2003 User Modeling Conference*, Johnstown, PA, Berlin: Springer Verlag, pp.258-262.
8.   Maybury, M., Greiff, W., Boykin, S., Ponte, J., McHenry, C, and Ferro, L. (2004). Personalcasting: Tailored broadcast news. *User Modeling and User Adapted Interaction, 14*, pp119-144. [Also published in L.Ardissono, A. Kobsa and M.Maybury (eds.), Personalized digital television: Targeting programs to individual viewers. Dordrecht, NL: Kluwer]
9.   McCarthy, J., and Anagnost, T. (1998). MusicFX: An arbiter of group preferences for computer supported collaborative workouts. *ACM 1998 Conference on CSCW*, Seattle, WA, pp. 363-372.
10. Nguyen, H., and Haddawy, P. (1998). The decision-theoretic video advisor. *Proceedings of AAAI Workshop on Recommender Systems*, Madison, WI. pp. 77-80.
11. Pazzani, M.J. (1999). A framework for collaborative, content-based and demographic filtering. *Artificial Intelligence Review, 13*, pp. 393-408.

Appendix A: Task Wording

You are going to watch the news. For each news item, we know

-   How important the news is in general. For instance, a major earthquake is more important than a single house collapsing.
    Each item is rated from 1 –really unimportant- to 10-really important.
-   How relevant the location of the news is to you. For instance, for a Dutch person living in Brighton, the relevance of location of news from the Netherlands and Brighton is higher than that of news from Italy.
    Each item is rated from 1 –really irrelevant location- to 10-really relevant location.
-   How recent the news is. For instance, something that happened in the last hour is more recent than something that happened yesterday.
    Each item is rated from 1 –really old news- to 10-really recent news.

News Item	Importance	Relevance of Location	Recency
A	10	1	10
B	4	9	5
C	3	8	2
D	6	9	7
E	10	7	9
F	9	9	8
G	6	6	5
H	8	9	6
I	10	3	7
J	8	8	6

1. You have only time to watch one item. Which item would you watch? Why?
2. You have only time to watch two items. Which items would you watch? Why?
3. You have only time to watch three items. Which items would you watch? Why?
4. You have only time to watch four items. Which items would you watch? Why?
5. You have only time to watch five items. Which items would you watch? Why?
6. You have only time to watch six items. Which items would you watch? Why?
7. You have only time to watch seven items. Which items would you watch? Why?

Metadata trust in a Personal Video Recorder

Erik M. Boertjes

TNO Telecom, POBox 5050, 2600 GB Delft, The Netherlands
e.m.boertjes@telecom.tno.nl

Abstract. Trust is the belief or confidence in someone that their recommendations will work for you, i.e. that you will like the TV-programs (or other content) that they recommend. Many systems incorporate some notion of trust. Trust is more than similarity in taste, which makes trust a broader concept than the concept of similarity used in Collaborative Filtering. This paper describes ongoing work on the development of a trust-aware Personal Video Recorder (PVR). It presents a taxonomy of ways in which trust can be quantified and gives first ideas about automatically deriving trust for use in a PVR system.

1 Introduction

The well-known problem of information overload is very much present in the TV domain. The fact that more and more channels become available, broadcasting programs 24/7, makes it hard to find the one program that is interesting for you. Not to mention the fact that anyone can be a content provider nowadays, by offering content via the Internet.

This is where metadata comes in. Metadata is meant to help people find what they are looking for. Ideally, it provides objective and accurate descriptions of the content, based on which a user can decide whether or not the content is suitable.

However, a problem analogous to the one in the content domain arises in the metadata domain as well: "Everyone's a critic", i.e., everyone can be a metadata provider. At that point, metadata is no longer objective, but becomes very much a reflection of an individual opinion about content.

At the Amazon website [1], for instance, people can provide metadata in the form of reviews on books and DVDs. When reading all reviews for one specific book, a user will have a hard time deciding whether or not to buy the book since some reviews are very positive, and others are very negative. Questions that immediately arise then are 'Who wrote this review?' and, 'Can I trust him or her?'.

In the medical domain it is even more important to know whether or not to trust a review: if you follow a positive review on an instruction video with back exercises, you can seriously damage your back if the reviewer is not an expert on the subject.

The Amazon website does help in a way, by providing the average rating about a book, i.e. the mean value of all reviews that users gave on a specific book. This helps, if you are an average customer. Such an average rating will have evened out the extreme ratings that could have matched your interest and still you don't know the

people behind the average rating, so you still don't know whether you can trust the rating.

Amazon follows a better, more personalized, approach in providing personalized recommendations. Using collaborative filtering techniques, it finds people that have the same buying or rating behavior (in the books domain) as you. It recommends books that those people valued high, and you did not have read yet. This approach gives better support for the user in deciding whether or not to buy the book. Collaborative Filtering has some problems though like the 'cold-start' problem: new users cannot be matched with other people, since nothing is known about their buying and rating behavior yet, and the 'sparse density problem': the ratio of the relatively small number of ratings versus the relatively large number of books, may be too small to find similar people with enough reliability. And you still don't 'see' the people behind the recommendation. The only thing you know is that they are similar with regard to rating and buying behavior in the books domain.

In everyday-live, you follow people's advice if you trust them, i.e. when you believe that their advice will work for you. This belief may be based on similarity in taste (of books) but is probably based on a lot more. When you follow your friends' advice to read a book, you may do this because you share the same hobbies, or just because you like them. When you follow your doctor's advice to do the video-exercises, you do this because previous advice worked for you, or because other people that you know well, told you that this doctor is very competent. Knowing that people have the same illness as you have may increase the feeling of trust towards them, even if you don't know their taste in TV-programs.

In this paper we use 'trust' in the meaning of 'the belief in someone that their advice will work for you'. So decisions of whether or not to follow someone's advice or review are based on trust, which is more than just similarity in taste in one specific area. It therefore would be useful to see whether such a notion of trust can be incorporated in an environment where there is an overload of content and objective metadata.

This paper describes the first steps towards a trust-aware Personal Video Recorder (PVR). Section 2 describes related work. We then explain in Section 3 how trust can be derived in an environment where 'everyone's a critic'. Section 4 describes the trust-aware PVR. Section 5 gives conclusions and proposes further work on this subject.

2 Related Work

There are numerous systems that implicitly or explicitly incorporate some notion of trust. At the E-Bay website [3], trust that someone is a reliable seller or buyer is derived from previous experiences of the community with that person; in EBay, trust is not about giving personalized recommendations.

Amazon [1] keeps a list of 'Top Reviewers', that are more trustworthy than other reviewers. Someone becomes a top reviewer if their reviews are valued high other users. Because the ranking is based on the mean value of the ratings of the overall community (mass moderation), it is not a personalized list of Top Reviewers. Trust

has therefore the meaning of 'the belief that someone will write decent, high quality reviews', more than 'the belief that someone will write recommendations that work for you'. The former can be objectively determined, the latter is purely subjective. Amazon does offer the possibility to keep your own list of 'Friends and Favorites'. Based on their profile and reviews, you can choose persons that you trust to give recommendations that work for you.

Slashdot [9] has a very sophisticated way (moderation schema) of calculating the overall trust in someone (the belief that their articles are of high quality). There is no personalization here: the community as a whole decides what is good; you cannot create your own list of favorite writers. Of course, the quality of the content in Slashdot can more easily objectively determined while the quality of recommendations in a PVR system is much more subjective. Like the mass moderation scheme of Amazon, this results in trust in the sense of 'the belief that someone writes high quality reviews', rather than 'recommendations that will work for you'. There's no personal, subjective notion in the kind of trust used in Slashdot.

In the TV-Scout system [2] some users get the chance to become opinion leaders: they are believed to be trustworthy reviewers. Their recommendations (e.g. "Andreas' favorite action movies") can be accessed by anyone. Users can subscribe to their favorite opinion leaders. Not everyone can become an opinion leader though; they need to represent the community's taste. In that sense trust means 'the belief that someone will write recommendations that work for a large part of the community' rather than 'that will work for you'.

In [5] and [6] the importance of giving the user direct influence on the recommendation process is pointed out.

3   Measuring and Using Trust

Trust is the belief that someone's opinion or recommendation will work for you. Trust can be based on similarity between users; for instance similarity in taste of TV-programs (something that CF techniques use), but also similarity in taste of books, in hobbies, favorite holiday-destinations, illnesses, political orientation, etc.

Another factor that influences trust is reputation; i.e. previous experiences of yourself or others with a person in general or with his advice in particular.

Finally, more intangible factors may influence trust. If you know a person in every-day live, things like whether you like a person or not, may influence your feeling of trust towards that person.

This section explains how to come to a quantification of trust in an environment where everyone's a critic. In general, not all of the above-mentioned factors can be automatically derived. The main information that is present in such an environment is reviews, i.e. users' opinions about content, about other users, about other users' opinions etc. They serve both as input for users to form their own opinions and as input for the system to automatically estimate trust relations.

Section 3.1 lists the various types of reviews. Section 3.2 describes how they can be used to get a quantification of trust.

3.1 Types of Reviews

Review of Reviewer

The strongest evidence of trust of user A in user B are reviews that A gives about B. These are direct expressions of how A thinks about B (Figure 1). They should count heavily in the calculation of trust.
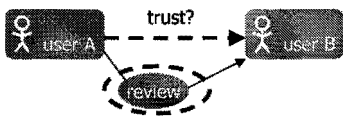
Fig. 1. Direct review of user A on user B

Review of Review

A less direct indication of trust of A in B, is what A thinks about the reviews of B. These reviews of B can be of the various types that we distinguished earlier: review on another user C, review on a review of C, and review on content (Figure 2). These reviews of A about reviews of B should count heavily in the calculation of trust, but not as strongly as the direct expression of A towards B discussed in the previous subsection.
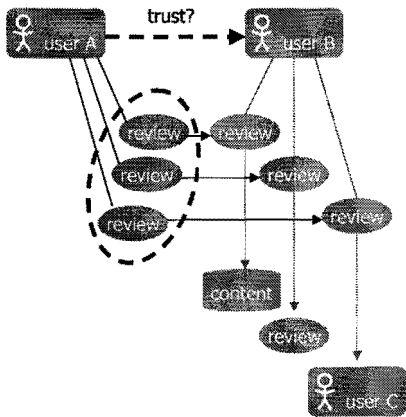
Fig. 2. Reviews of user A on reviews of user B

Review of Content

If user A rates content the same way as user B does, it indicates some amount of trust from A towards B. This is the classical Collaborative Filtering (Figure 3).

267
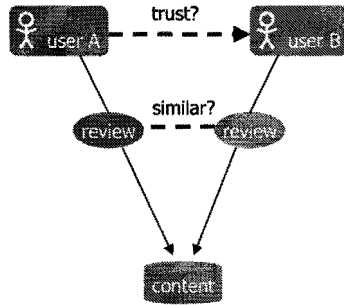
Fig. 3. Similarity in rating of content between two users

Of course, the similarity in review does not have to be limited to reviews of content; also similarity in rating of other users or other reviews contributes to the amount of trust of A in B (Figure 4).
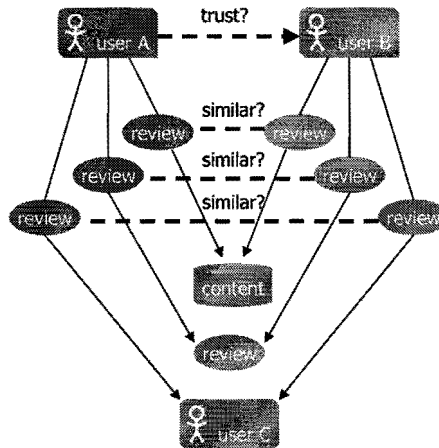
Fig. 4. Similarity in several types of rating between two users

We feel that this kind of similarity is a significantly weaker indication of trust than the ones discussed in the previous two subsections. Those were explicit expressions of user A about user B or about user B's reviews. The similarity discussed in this subsection, is implicitly derived by the system and not based on any explicit indication of A about B.

3.2 Calculating Trust

Based on the findings of the previous two subsections, we propose the following way for calculating a value for trust from user A to user B:

If there is a direct review of user A on user B: use the rating in that review as the trust value. Since a direct review is such a strong indication, trust should be based solely on reviews on reviewers, if they are available.

trust = rating(A,B)

If there is no review of A on B, use the other trust building factors from Section 3.1:

trust = w1 x {average of A's ratings on B's reviews}
+ w2 x {similarity between A's reviews and
B's reviews using Collaborative
Filtering formulas}

Where w1 and w2 are weight factors, with w1 > w2 since reviews on reviews are considered a better indication of trust than similarity in reviews as explained in Section 3.1.

If no reviews of A are available, trust could be derived by trust propagation techniques from Section 3.3.

3.3   Trust Propagation

The previous sections showed how trust between two user A and B can be derived from direct evidence given by user A. Once trust is known for a number of users, it may be propagated to other users, without the need for taking into account any reviews. Figure 5 gives a simple example. If trust relations between A and C and C and B are calculated, then a trust relation between A and B can be derived using the principle 'Friends of our friends are our friends': if A trusts C and C trusts B, then A very likely trusts B.

This is an example of scalar trust metrics. These metrics are common in the Agent Networks research area, where especially for trade agents it is important to know whether or not an agent can be trusted (see e.g. [4]).
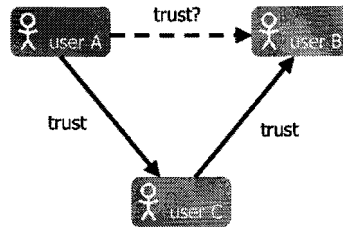

Fig. 5. Trust propagation using scalar trust metric

Trust propagation can also be done using group trust metrics. This is how Google sorts web pages on their level of interest [7]. If a page has many backlinks, it is supposed to be more relevant than pages that have few backlinks. Links from relevant

pages count heavier than links from less relevant pages. And links from pages that have only a few outlinks, count heavier than links from pages that have many links outward. Analogous to this, trust can be determined (see Figure 6).

Contrary to scalar trust metrics, this gives a general value of trustworthiness of a user instead of a trust relation between two specific users. One could argue whether such a general value is of any use since, analogous to the average book rating from Section 1, it is based on average trust values.

Since a trust relation between A and B that is derived by trust propagation is not based on either reviews from A nor B, we feel that this is the weakest way of determining trust.
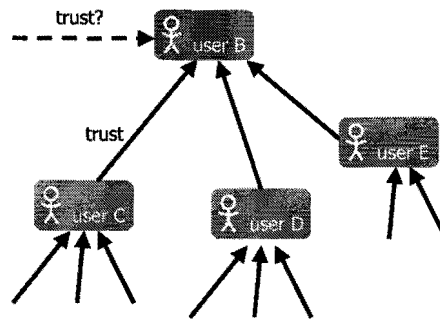
Fig. 6. Trust propagation using group trust metrics

4 A Trust-aware PVR

A Personal Video Recorder (PVR) is a device that stores TV-content digitally on a hard disk. An Electronic Program Guide (EPG) is often integrated, allowing programming the PVR with 'one-click-of-the-mouse' by simply selecting the program to record. In addition, PVRs often offer advanced search functionality and a recommendation service, suggesting interesting TV programs, or recording those automatically. These recommendations are normally based on your previous recording behavior, explicit ratings, and similarity in taste of TV-programs of other PVR users. Well-known examples of PVR systems are Philip's TiVo and SonicBlue's ReplayTV ([8], [10]).

Section 4.1 lists some functional requirements of a trust-based PVR. Section 4.2 gives some ideas about how to give trust-based recommendations.What would such a system look like, when trust is incorporated into it?

4.1 Functional Requirements

Some of the requirements are aimed at providing users with enough information to allow them to express trust towards other users ('Reviews of Reviewers'). Other

requirements are aimed at collecting enough data for the system to estimate trust relations automatically.

- Users should be encouraged to provide as much information about them (like hobbies and the like). Other users should be able to see this information to see how similar they are.
- Users should be able to write reviews on TV-programs, reviews about other users' reviews, and reviews about other users. Maybe even reviews about content providers or certain TV-channels.
- Anyone should be able to see these reviews.
- Users should be able to tell the system explicitly to what extend they trust other users.
- Users should be able to share their experiences with other users' recommendations. One common way is to allow users to comment on other users' reviews and make these reviews-on-reviews available to anyone.
- The PVR should have 'people-finder' functionality; allowing users to quickly find possibly similar users that are candidates to be trusted.
- Users should be stimulated to provide reviews. One way (analog to Amazon) is to publish a list of top reviewers; another is to give users insight in how succesfull their reviews are, i.e. how many users followed their advice to watch or record a recommended TV-program. The PVR could use a credit system: by providing good reviews, the user earns the right to record content.
- The PVR should use trust as the basis for automatic recommendations. These could be recommendations of TV-programs, but also recommendations of possible trustworthy users. The next section gives a first idea of how to do this.

Since this work is still in progress, we don't expect to have given the complete and final list of requirements here.

4.2 Trust-based Recommendations

Now that we calculated trust in Section 3, the question is how to use it in automatically recommending content. We follow the same approach as in Collaborative Filtering: a prediction of how a user will value content is based on similarity between the user with other users, and the rating of those other users for the content. Content that has a high estimated rating is then recommended. In our case, we use the broader concept of trust instead of similarity. The calculation has the same form:

estimated_rating(userA, content) =
    average{trust(userA,userX) x rating(userX,content)}

over all userX of which trust(userA,userX) is known and rating(userX,content) is known.

We then recommend to user A the programs that have high estimated ratings. Besides recommending content, we also plan to recommend possibly good reviewers,

271

i.e. other users that might be trustworthy. This is something not commonly found in existing applications. This type of recommendation could be based on trust propagation with scalar trust metrics as explained in Section 3.3. Although we did not look thoroughly into this yet, a first attempt could be:

estimated_rating(userA, userB) =
    trust(userA, userX1) x ... x trust(userXn,userB)

with userXi the intermediate users in a path from userA to userB in the trust network.

Some research should be into determining the maximum path length to be considered.

5   Conclusions and Further Work

Trust-awareness seems to be a valuable addition to applications in environments with multiple metadata sources. It helps users to get recommendations from people that not only have similar taste of content but also can be trusted. Metadata trust is especially vital in medical environments.

We explained how the notion of trust can be incorporated in a PVR system, and showed the expected gain. We discussed the mechanisms and data structures required.

It is important not to underestimate the user in his ability to explicitly express trust towards another user. Trying to purely automatically derive trust relationships, without taking into account these explicit user statements, will give unsatisfactory predictions.

The implementation of our trust-aware PVR is still in progress. Further work is aimed at a user pilot with a prototype of the system, getting answers to questions like:

- What are effective ways of stimulating users to provide reviews?
- Do the proposed ways of calculating trust and generating recommendations provide useful feedback? Do users act upon recommendations that they receive?
- Is trust really more than similarity in taste? It may be interesting to see whether people rate content the same way as people they trust. If they do, there may not be a difference between trust and similarity in taste in content.

The main goal behind these questions is to prove the value of trust-awareness.

Another interesting question is whether communities will develop within applications like the trust-aware PVR. Such a community may consist of a user group with very tight trust relations between the members of the group.

Other future research is planned on how to deal with context-dependency of trust. The type of content at hand may be of influence on whether you trust a person's review or not. A doctor may very well be an expert on medical videos, but may not be trusted when reviewing the latest James Bond movie.

Even the way trust is calculated may be content dependent. In some context (e.g. movies) similarity in taste may be more important than reputation; in other contexts (medical) reputation is more important than similarity in taste.

In addition to metadata trust, another type of trust is the reliability of content providers. In addition to metadata trust, trust of content providers could be added to the system. Reviews about, for instance, Disney stating that 'they always know how to entertain children'.

Finally, we want to look how reviews of certified organizations (like a governmental movie censorship committee) should be handled in a trust-aware system. Those organizations may be trusted by default.

References

[1] http://www.amazon.com
[2] P. Baudisch and L. Brueckner, TV-Scout: Lowering the Entry Barrier to Personalized TV Program Recommendation, Proceedings of the 2nd International Conference on Adaptive Hypermedia and Adaptive Web Based Systemts, Malaga, Spain, 2002.
[3] http://www.ebay.com
[4] G. Gans, M. Jarke, S. Kethers, G. Lakemeyer, L. Ellrich, C. Funken, M. Meister : Towards (Dis)Trust-Based Simulations of Agent Networks, Procs. of the 4th Workshop on Deception, Fraud, and Trust in Agent Societies, Montreal, Canada, May 2001, pp. 49-60
[5] J. Herlocker, J. Konstan and J. Riedl, Explaining Collaborative Filtering Recommendations, Proceedings of the ACM 2000 Conference on Computer Supported Cooperative Work, 2000.
[6] D. Maltz and K. Ehrlich, Pointing the Way: Active Collaborative Filtering, Proceedings CHI, 1995.
[7] L. Page et al, The PageRank Citation Ranking: Bringing Order to the Web, 1998. http://citeseer.nj.nec.com/- page98pagerank.html.
[8] ReplayTV, http://www.replaytv.com
[9] http://slashdot.org
[10] The TiVo Homepage, http://www.tivo.com

iTV Enhanced System for Generating Multi-Device Personalized Online Learning Environments

Alcina Prata[1], Nuno Guimarães[2], Piet Kommers[3]

[1] Higher School of Management Sciences, Information Systems Department,
2914-503 Setúbal, Portugal
aprata@esce.ips.pt
http://www.esce.ips.pt/docentes/cv_docent/aprata.htm
[2] University of Lisbon, Faculty of Sciences ,Informatics Department,
1749-016 Lisbon, Portugal
nmg@di.fc.ul.pt
http://www.di.fc.ul.pt/~nmg/nmghome.html
[3] University of Twente, Faculty of Behavioral Sciences, Psychonomy and Human Performance Technology Department,
7500 AE Enschede, Netherlands,
P.A.M.Kommers@edte.utwente.nl
http://users.edte.utwente.nl/kommers/graduate.html

Abstract. This document briefly describes an iTV Enhanced System capable of generating Online Learning Environments (OLE), namely, educational websites to be viewed through several types of devices. Explained are the motivations for the development of the above mentioned System, what is new about this System and what we expect to achieve with it. Also presented in this work, in general terms, the system architecture, functionalities and evaluation method. Some conclusions are presented and also future lines of research are point out.

1 Introduction

Television, love by ones and hate by others, it is, for some, the secret best friend, for most, the main information source and for all a magic window with the power to transport us to anywhere in the world whenever we decided. It is "central to the entertainment, information, leisure, and social life of millions of homes all over the world" [1].

As technology never stops to improve, also Television benefited quite a lot with the emergence and/or transformations occurred in several areas, namely, devices, communication platforms and ways/methods of transmission. In fact, the appearance of a new paradigm, the Interactive Television (iTV), allows the viewer to interact with an application that is simultaneously delivered (via a digital network) in addition with the traditional TV signal [2]. Thus, we may say that the iTV technology achieved, by the integration of two privileged environments like TV and Internet, the creation of a new and very rich environment where several types of services are pos-

sible with different types and levels of interactivity. The traditional education system also had the necessity to adapt to this new environments (TV and Internet) [3] which had became powerful learning tools: In the 60's the TV was used in a project called Teleschool which consisted simply in broadcasting classes over the traditional TV network [4]. In the 90's the Internet allowed Long Distance Learning (LDL) to evolve and turn into e-learning [5]. More recently, iTV is also being used in order to provide classroom's at a distance, that is, to allow a certain level of interactivity amongst students and teachers. So, in a typical learning environment where the learners are, usually, in a conscious state of reflexive cognition, that is to say, in a conscious state of 'need to learn more or need to learn something new', these three environments work efficiently. However, people are not always in a state of constant reflexive cognition and yet there are moments in our lives when that happens, even when we are outside of a typical learning environment, such as, the classroom. For instance, simple quotidian things like exploring our mobile phone menus, listening to the radio or seeing a TV program, may, at some point in time, create reflexive cognition states. Everybody has, sometime, felt the need to learn more about a certain something that, for instance, he or she was watching on TV or listening to on the radio. Unfortunately, until now, the only solution was to undertake some private research in order to satisfy that need. In fact, none of the above mentioned devices/environments is prepared to answer to this particular unconscious need of the user to know more about something and, based on that, prepare him a personalized lesson. Thus, and as part of the first author phd studies, we decided to implement an iTV Enhanced System capable of generating personalized multi-device Online Learning Environments (OLE) appropriate to respond to the learning opportunities specifically created by TV. Thus, in general terms, the main goal of this work is to provide, via an informative environment like Internet, an answer to the learning opportunities created by an entertainment environment like TV. The OLEs will be prepared in order to be viewed via several types of devices, namely, iTV, computers, Personal Digital Assistants (PDAs) and mobile telephones. From a conceptual point of view, with this work we expect to understand the advantages, which will be the added value, of connecting these two environments. From a practical point of view, we expect to propose a new and personalized type of service, which is, for Jana Bennet Director of BBC Television [6] and for several other researchers the biggest challenges ahead and the next direction to follow [7, 8, 9, 10, 11, 12]. Since the system is now in an early stage of development it will be generally and briefly described to in this work, namely its architecture, cognitive patterns, type of programs, functionalities, development and evaluation method. Some future lines of research are also referred.

2 System

In order to briefly refer to the system's way of functioning, in general terms we may say that, while watching a TV program, the viewer will be able to tag, via a simple

click, the specific issues/contents in which he or she is interested in learning more about. In order to easily refer to this functionality we decided to call it the "tagging content interface" which can be seen in figure 1. At the end of the TV program, or whenever the viewer decides to interrupt it, a website with a personalized web lesson on all those tagged issues will be generated by the system, in a server, and be made available to the viewer, via the Internet. The viewer will receive an e-mail (default option), a sms, or both, with the web link to the online personalized lesson. When asked by the viewer, the system will also be able to prepare the lesson in order to be viewed via several types of devices, namely, computers, iTV, PDAs and mobile telephones as can be seen in figure 1.

Important to mention that in spite all the system functionalities, the design of the "tagging content interface" will be the scope of our work since it is the first author phd thesis main goal.
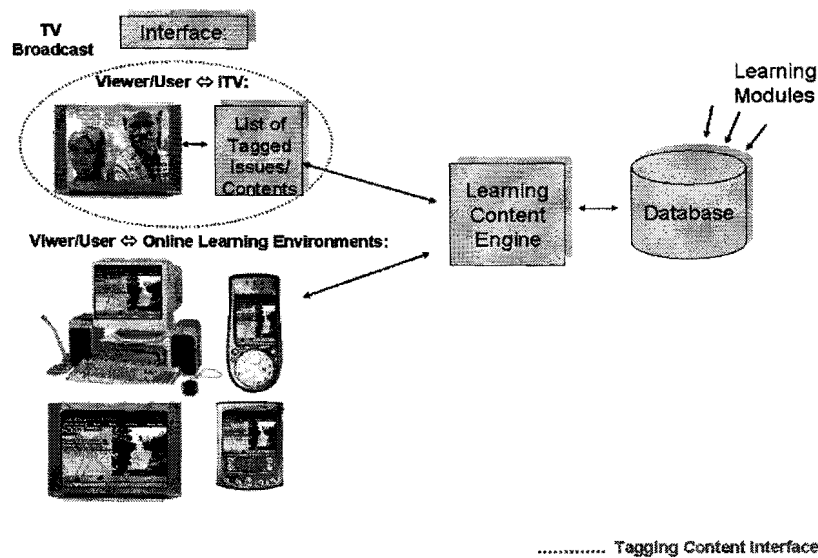
Fig. 1. System Architecture

Cognitive Patterns. The first phase of this work consisted on a detailed study of the cognitive patterns associated with the devices to be used: Computers, PDAs, TV/iTV and mobile telephones. This study was fundamental to help us understand the particularities of the aforementioned devices and environments (Internet and TV), the pedagogical potentials and learning situations associated with each one of them, and to help us find the appropriate interface and adequate transition between them.

276

Type of Programs. There are lots of different categories/subcategories of programs, for instance: movies (drama, terror...), documentaries (historical, biological...), reality TV, Informative (daily journal, technical). As the state of mind, feeling, reflexive cognition state and way of learning, amongst other factors, varies according to what we are watching, we had to focus in just one category/subcategory. The chosen category/subcategory was Information technical Programs.

Functionalities. The proposed system will work integrated with the traditional iTV and will functioning as described next:

User authentication and service choice. After activating the system, the first menu that appears on the TV screen will allow the user to login to the system and choose the service that he intends to use. If the user is using the system for the first time he will be asked to fill an electronic form which will allow the system to define his profile. The form comprises personal data like gender, age, e-mail address, mobile phone number, the way in which the user wants to be informed about the web lesson location (e-mail, sms or both), amongst other data. After the conclusion and submission of the form the system will generate the user correspondent login and password. Also on that first menu the user will be able to choose the kind of service that he wants to use and which may be: 1) iTV; 2) Online Learning and 3) iTV & Online Learning:

- Service 1: iTV - simply allows the user to access the traditional interactive TV service.

- Service 2: Online Learning - will allow the user to activate the specific service already described early and which is the main goal of this work. This service will allow the user to easily tag the issues in which he is interested in learning more about and, a website with a personalized lesson on all those tagged issues will be generated by the system and be made available via the Internet to several types of devices.

- Service 3: iTV & Online Learning (already outside the ambit of this specific work)-will allow the user to use the previous described two services at the same time, that is, in some moments tag the program in order to see a web lesson latter, and, in other moments, follow the link immediately and interrupt the program.

Finalization of Services 2) and 3). At the end of the program transmission, or when the user decides to interrupt it, he will be conducted to the screen where he will see the list of tagged issues. On that screen he will have the possibility to: access the complete list of issues that may be tagged and modify his own list of previous tagged issues by increasing or removing certain tags. Also on that screen the user will have the possibility to change the way in which he will be informed about the location of the web lesson. The possibilities are: via e-mail (default option), sms or both. Yet on the same screen the user will have the possibility to decide which device he wants to use in order to view the web lesson: a computer, the TV, a PDA or a mobile tele-

277

phone. In all cases the lesson will be created and made available via the web. If the user chooses to view his lesson on the TV he will be asked if he wants to see it immediately or latter. In any case and independently of the device that he decided to use, he will be informed about the exact location (address) of the website correspondent to his web lesson. If, for some reason, the user turns off the TV without remember to access the "Services Finalization Screen" the system will prepare, by default, a web lesson to be viewed through the computer, with all the issues that he tagged before turning off the TV. The system will inform the user about the location of the lesson using the method defined in the user profile.

Development. For the development and implementation of the final system, with the above mentioned characteristics, very specific and expensive human and physical resources are needed, considering that real TV stations will have to be involved. Thus, and since we intent to focus our work in the "tagging content interface" design, we opted in developing a prototype. The prototype, capable to completely simulate the functionalities of the real system, namely service 2, (already described earlier), will work on a Computer which screen will simulate the TV screen and which keyboard keys will simulate the control keys from the TV remote control. The computer will be connected to a server, which will have as main functions: store the data base with the web modules delivered with the TV program in order to serve as material to create the personalized web lessons, store the personalized web lessons generated by the system, store the interaction interface module and store the user data (profile). The development of the prototype, in terms of interface design and implementation, may be divided in two fundamental parts that will be independently evaluated. Part 1, and the most important one since it is the main focus of this work, is the initial interface, the "tagging content interface", that is, the interface that will allow the user to tag particular issues/contents on a program and, in practical terms to do the bridge between both environments: Internet and TV. These environments will have to be connected with an interface, as user-friendly, easy to understand and intuitive as possible, and, at the same time, taking into account the specificities of each one of them. That is to say that, the interface will have to be the less intrusive possible in order to don't interfere and/or conflict with the TV viewer entertainment experience. Also important to refer that the transition between the devices/environments will have to be very smooth but, at the same time, taking advantage on what is best about each one of them. This interface is now being implemented. Part 2 refers to the development of the remaining interface screens and web lessons.

To the development of the prototype some software programs and programming languages are, simultaneously, being used, namely:

- to the video editing: the program Adobe Premiere Pro;

- to the interfaces development: the program Macromedia Director MX and the programming language Lingo;

- to the web lessons development HTML, DHTML e XML;

278

- to test the web lessons that are going to be viewed through the TV (the so-called TV sites): the Microsoft program Web TV Viewer;

- to the dynamic integration of the several components: the programming language PHP.

To make the system work we need more than a specific TV program. In fact, the TV program will have to be supplied to the TV operator with additional web modules developed under certain specific criteria and standards. These modules will be installed on the server data base in order to serve as material to the construction of the personalized web lessons.

Evaluation Method. The evaluation will be of two types: Formative Evaluation which will occur during the whole process of development and will be based in the expert's opinion, and the Final Evaluation which will occur after the conclusion of the prototype and will count with the participation of experts and user. The final evaluation will consist in a final test or experiment and in the application of a questionnaire. The final test will probably help us understand if the system is in fact effective, useful, intuitive and easy to use and the questionnaire will probably allow us to know, the experts and user opinions on the system.

3 Conclusions and Future Work

This work is part of a major project, namely, the first author phd studies. Thus, and considering that one of our major concerns was to obtain feedback from other professionals, the system functionalities were already discussed with some professional/experts in the areas of interactive television, educational sciences and human computer interfaces. Until now the enthusiasm was obvious amongst the majority of them. In relation to more specific data and as the prototype is already in an early stage of development it was impossible to present more concrete results. As future works and after concluding our system, we will try to adapt the system interface to other possible categories of programs. Another future work could be the study and development of an appropriate interface for service 3) iTV & Online Learning.

References

1. Masthoff, J., Luckin, R.: Preface of the Workshop Future TV: Adaptive Instruction in your Living Room, (2002). Available at:
   http://www.it.bton.ac.uk/staff/jfm5/FutureTV/Preface.pdf
2. Perera, S.: Interactive Digital Television [Itv]: The Usability State of Play in 2002. Scientific and Technological Reports (2002). Available at: http://www.tiresias.org/itv/itv1.htm
3. Chambel, T.: Video Based Hypermedia Spaces for Learning Contexts. Phd Thesis presented at FCUL, Lisbon, December (2003)

4. Prata, A., Lopes, P.: Impact of a On-line Application for Teaching Video to a Multimedia Course in Higher Education. Proceedings of the ITRE 2003 - IEEE International Conference on Information Technology: Research and Education, USA (2003) 620-624.

5. Rosenberg, M.: E-learning - Strategies for Delivering Knowledge in the Digital Age. McGraw-Hill, New York (2001)

6. Bennet, J.: Red Button Revolution – Power to the People. Proceedings of the MIPTV and MILIA 2004, (2004)

7. Port, S.: Who is the inventor of television. PhysLink.com (2004). Available at: http://www.physlink.com/Education/AskExperts/ae408.cfm

8. Chorianopoulos, K.: The Virtual Channel Model for Personalized Television. Proceedings of the EuroiTV2003, UK, Brighton, (2003).
   Available at: http://www.brighton.ac.uk/interactive/euroitv/euroitv03/Papers/Paper7.pdf

9. Damásio, M, Quico, C., Ferreira, A.: Interactive Television usage and applications: the Portuguese case-study. Computer&Graphics review, March (2004)

10. Eronen, L.: User Centered Research for Interactive Television. Proceedings of the EuroiTV2003, UK, Brighton, (2003).
    Available at: http://www.brighton.ac.uk/interactive/euroitv/euroitv03/Papers/Paper1.pdf

11. Gill, J., Perera, S.: Accessible Universal Design of Interactive Digital Television. Proceedings of the EuroiTV2003, UK, Brighton, (2003).
    Available at: http://www.brighton.ac.uk/interactive/euroitv/euroitv03/Papers/Paper10.pdf

12. Quico, C.: Televisão Digital e Interactiva: o desafio de adequar a oferta às necessidades e preferências dos utilizadores. Proceedings of the Televisão Interactiva: Avanços e Impactos conference, Lisbon, Ordem dos engenheiros, 22 of March 2004, (2004)

A real implementation of personal TV services with deployment in a broadcast demo testbed

Giovanni Ballocca, Luca Broglio, Alessandro Cota, Daniele Peretto, Antonio Ponzetto, Roberto Politi

CSP Innovazione nelle ICT
via Livorno 60, 10144 Torino

giovanni.ballocca@csp.it, luca.broglio@csp.it, alessandro.cota@csp.it, daniele.peretto@csp.it, antonio.ponzetto@csp.it, roberto.politi@csp.it

Abstract. A testbed is presented for experimenting the convergence of IP-based and in particular peer-to-peer services, and Digital Television. The testbed implementation comprises the setup of a real broadcasting production environment, of the related contribution links and the development of a set of applications for content management and fruition.

1 Introduction

The adoption of Digital Terrestrial Television technologies in many of EU countries is fostering major changes in the TV broadcasting arena. High quality digital MPEG-2 encoding of PAL analog format for A/V TV content may require up to 5 to 6 Mb/s bitrates. Digital signal modulation provides an average bandwidth of 20 to 26 Mbit/s on a fixed frequency channel (assuming UHF – ultra high frequency – 8Mhz channel width). Accordingly, broadcasters will have the capacity of transmitting up to 6 digital channels where they used to have only one analog available. [1]
The role of broadcasters is therefore rapidly changing as they the are becoming network operators offering their infrastructure for third party content distribution: TV operators switching to digital may choose not to fill up the entire bandwidth with their own contents but to provide "transport services" over the remaining capacity.
At the same time, on the Internet side, widespread adoption of cheap broadband access technologies is making multimedia content and services more and more appealing and accessible to home users especially thanks to p2p content sharing applications.
Terrestrial TV digitalization, with its highly pervasive infrastructure, allows us to conceive a new sort of integration between Internet and television worlds: beyond the

simple internet access services dating back to satellite era, the convergence of IP and DTV makes the development of new generation services possible.
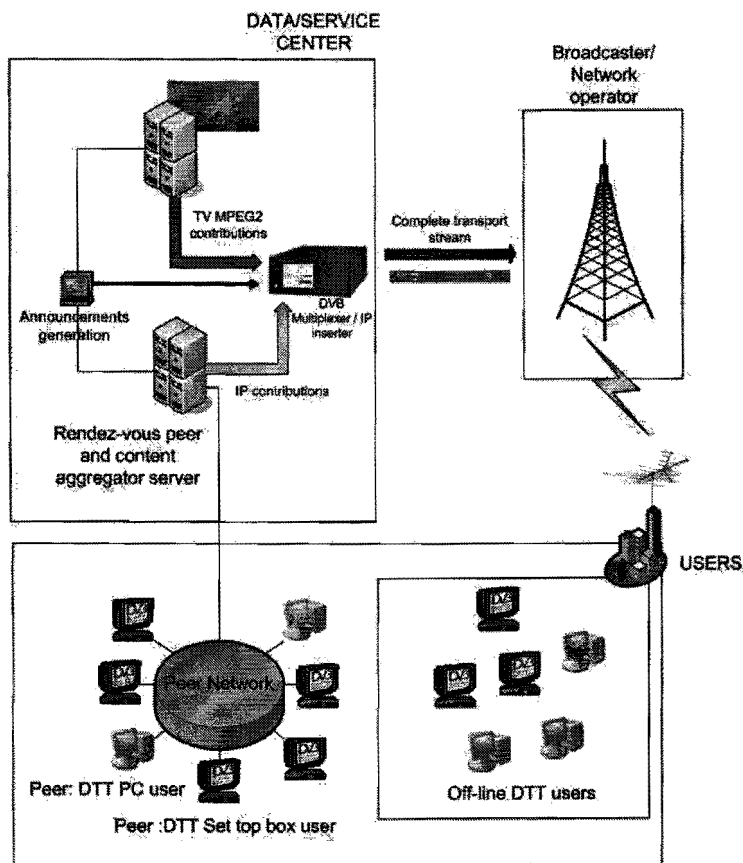
Our work focuses on the development of a new kind of Personal TV services for presenting home users a unified interface for publishing and accessing multimedia contents coming from TV and/or the Internet. The aim is also to provide service/data centers (and broadcasters) with means to assemble in a transport stream such contents coming both from IP and TV worlds and to organize them in service/program lists and schedules. An announcement protocol will be used for service announcement and description. This way the end user with a single device (Set Top Box or DTT-enabled PC) will be able to transparently identify, navigate, access and consume contents coming from broadcast/multicast or unicast networks. The data/service center will be able to select digital contributions from a plurality of sources (the users as well!) and organize them in the TV program schedule according to given policies. To complete the DTV process chain a broadcaster/network operator will provide the frequencies and physical infrastructure for the transmission of the assembled transport streams, collecting them from a plurality of service/data centers and from heterogeneous contribution links such as ATM, satellite or radio based, in various transfer formats (IP, DVB-ASI).

The reference technical background for our work is defined by two different sets of standards/technologies. On one side, digital television leverages on european and worldwide adopted standard DVB [2] defining mechanisms for multiplexing multimedia (MPEG2) and encapsulated data streams in a single transport stream and delivering it to the end user. On the other, peer-to-peer applications in general rely on dedicated middleware and/or applications with, at least, a relevant exception: general purpose middleware JXTA. JXTA protocols specification has been submitted as an Internet draft

Our aim is to provide an infrastructure for the user to access seamlessly multimedia content either coming from the broadcast stream or provided/shared by other users thus enabling her/him to assemble a custom program composed of contributions coming from different sources. The same infrastructure shall provide services for sharing in a p2p architecture digital contents across the user community, leveraging on the broadcast network for distribution and advertisement propagation. Similar approaches have been adopted in various projects such as, for example, Share It! [3], without directly addressing the integration of IP and DVB-based services.

2 The Testbed

The testbed will be located in the Turin area. With reference to the next illustration, a DTV broadcasting network will be provided, in collaboration with a local broadcasting company. The broadcaster will be equipped with a datacenter for collecting contents through contribution links. The contents collected in the datacenter will be merged in the transport stream and broadcast along with suitable MHP applications.

DATA/SERVICE
CENTER

Broadcaster/
Network
operator

TV MPEG2
contributions

Complete transport
stream

DVB
Multiplexer / IP
inserter

Announcements
generation

IP contributions

Rendez-vous peer
and content
aggregator server

USERS

Peer Network

Peer: DTT PC user

Off-line DTT users

Peer :DTT Set top box user

The aforementioned applications are peers capable of announcing and consuming multimedia services and contents. Moreover, they can browse and use suitable sets of metadata included in the transport stream (both in DSM-CC sections – a mechanism for encapsulating generic data in a digital TV broadcast - and in the Service Information – standardised informative sections about the contents of a TV broadcast) to discover contents and create an extended EPG (Electronic Program Guide), guiding the user in content fruition: as an example, metadata will be used to specify that the format of a particular announced content is DVB-MPEG2 (pure DTV content – a TV channel) and needs to be transferred to the decoding chipset in order to be displayed. In another case the content could be an MPEG4 stream transmitted on-air by means of IP over DVB encapsulation: accordingly the TV reception board would work as a normal IP network interface sending the received stream to the appropriate media

playing software. In the following paragraphs we briefly describe the components developed for setting up the testbed.

3 HW Components

Current standards for digital television provide three capabilities: transport of MPEG2 encoded audio and video for direct fruition by the user, IP-based streams encapsulation in DSM-CC private sections through Multi Protocol Encapsulation (DVB-MPE) and a cross platform application distribution mechanism and runtime environment (DVB-MHP).

For efficient management of contribution links a board was designed and developed with the capability of aggregating up to 32 IP fluxes, encapsulating and multiplexing them in a transport stream and feeding it to a generic multiplexer through a local ASI link. The board is based on a FPGAs (Field Programmable Gate Array) chipset and has a throughput of 100 Mb/s.

4 P2P Applications

Most existing P2P systems require the presence of a centralized server storing a list of connected machines (peers). Such systems present many limitations mainly deriving from this centralization. In particular the type of sharable services is reduced, in most implementations, to file sharing and chat. Every single P2P implementation is completely independent and it's often based on proprietary protocols so that it becomes complicated or impossible for an application to access the resources of a different P2P system.

The JXTA [4] project refines the P2P concept enabling a wide range of distributed applications to collaborate together and go beyond the limitations of current P2P applications. A JXTA network doesn't require a centralized server (thus solving the problem of the single point of failure) and above all extends the functionalities of existing P2P systems allowing the sharing and the announcement of any type of service. One of the other peculiarities is the possibility of organizing the peers in communities or groups according to their interests and make possible the exchange of digital contents.

The system that we implemented is based on JXTA technology for publishing and accessing services from peers. When we talk about service we indicate a generic content issue; it is therefore possible to share a particular file (classic file sharing concept), to chat, to perform audio and video streaming (e.g. the creation of a personal radio/TV), to transmit live events and more in general to enable VOD (video on demand). This way a single user becomes "service consumer and producer" of multimedia contents. The shared contents and services are associated to a set of XML encoded metadata describing them, containing information such as author's name, title, version number, encoding, format. Users can also meet to create thematic channels and publish contents with other people sharing common interests. Particular care has to be paid to the possibility of logging users' activities in order to retrieve accurate information about the audience of multimedia content (a much more accurate

system for monitoring audience respect to current systems where only a small sample is selected to provide this information). In our testbed scenario end-user peers will be used to advertise contents and/or services to be published in the broadcasting environment, while the peer at the broadcasting datacenter will be used for polling end user peers to fetch new contents and descriptive metadata. Metadata encapsulation in the DVB stream is described, for example, in [5].

5 Extended EPG

EPG is roughly defined as "a list on a television screen that says which programmes are going to be broadcast on which stations". Depending on their functionality, the EPG may allow viewers to see what programs are available either by date or by subject and time, provide background information, build personal lists of their favourite channels, build personal lists of programs to watch in the days ahead and block out specific channels or programmes above a certain parental guidance rating. More advanced EPGs will allow to buy movies on demand and to store personalized profiles to identify programs of interest. They will also provide more advanced search options.

Substantially EPGs are usually based on two technological approaches. The first, the easiest and standardised, is to retrieve information from DVB-SI (service information) tables that are inserted by the broadcasters in their transmissions according to the program schedule [6]. Using service information APIs an application can access these tables and display their content by means of a well organized EPG.

The other possibility is to leave behind the SI and define a descriptive syntax for all possible broadcast assets (using for example XML) and organize this information in a broadcaster-side database. This database, reaching beyond the descriptive limits of the DVB-SI, is then delivered to set top boxes where a client application elaborates it to obtain complex and flexible EPG functionalities. This approach pays the lack of standardisation in that each broadcaster is likely to define his own EPG system with private data, but this won't be a major problem if the applicative framework becomes standardised. This will probably be achieved with MHP that is reaching a massive diffusion among set top boxes' manufactures, so that EPGs will be soon a platform independent application that will be downloaded from the DVB stream like any other application or resident in the set top box. Both of the abovementioned EPGs building processes will of course be possible with MHP.

Thanks to the built-in functionalities of the MHP platform, creating applications for managing services information and organizing it in form of EPGs is quite simple. Parental control could be achieved using the Service Selection API contained in the Java TV [7] package, that is part of the MHP specification. Using the time references contained in the TDT and TOT (Time and Date Table-Time Offset Table) in association with Java Media Framework API's it is possible to realize a PVR (Personal Video Recorder), provided of course that the device mounts a hard disk.

In a possible scenario, assuming that it is possible (using a Return Channel) to collect customers' preferences and socio-cultural trends, EPG could become a personalized filter to best match the individual viewing preferences. Personalized filtering techniques will be fundamental in a perspective of a growing number of TV channels.

285

Another possible evolution of EPGs could raise from the integration with peer-to-peer technologies, such as JXTA. On the base of the integration of JXTA APIs in the MHP environment, users share their multimedia contents so that their local medias are diffused in form of a service or program list. For instance an user willing to view a documentary about Kenya, might find such a content in the usual TV program schedule, or perhaps he could pick one holiday-film from another user, who is sharing his "documentary" taken during his last holiday in Africa. Both the two kind of resources are listed in a global EPG transmitted on-air or available through return channel. This global EPG is a service presentation engine in a JXTA environment where a precise syntax is defined for describing any kind of media, currently broadcasted on-air or shared by other users. This description of a single service contains the physical link to the service itself: for example a TV service descriptor would carry a DVB locator link type through which a MHP application can tune a broadcast channel while a video file service descriptor shared from a remote user would carry a rtp or ftp link to start a file streaming or transfer session. The media will be eventually presented in a MHP JMF (Java Media Framework – the standard media player available with Java) instance.

6 Future work and open issues

As it will be understood from preceding description, although they are considered major points of interest, critical issues such as Digital Rights Management, data protection, Digital Asset Management, user characterization remain still to be addressed. Moreover, since at the moment there is no commercially available STB capable of supporting the applications developed, our prototyping work has been carried on PC boxes equipped with DVB-T PCI boards and MHP runtime. A great effort will have to be dedicated to tailor the applications developed to limited resources devices such as real-world STBs.

Acknowledgements and References

[1] Herve Benoit, 2002, Digital Television: MPEG-1, MPEG-2 and Principles of the DVB System
[2] The DVB cookbook, A guideline for the use of DVB specifications and standards, TR 101 200, ETSI
[3] Turcan, E.; Strömbäck, L.; Morris, J.: Share it! by bringing P2P into the TV-domain. In: Proceedings of the Third International Conference on Peer-to-Peer Computing (P2P'03), Linköping, Sweden (2003)
[4] http://spec.jxta.org/nonav/v1.0/docbook/JXTAProtocols.txt
[5] Lopez, A.; Gonzalez, D.; Fabregat, J.; Puig, A.; Mas, J.; Noè, M.; Villalon, E.; Enrich, F.; Domingo, V.; Fernandez, G.: Synchronized MPEG-7 metadata broadcasting over DVB networks in an MHP application framework. In: IBC 2003, Amsterdam 2003
[6] DVB-T ETSI 300 468 Service Information(SI)
[7] http://java.sun.com/products/javatv/

A Goal-Based Personalized Electronic TV Guide Demonstrator

Mark van Setten

Telematica Instituut, P.O. Box 589, 7500 AN, Enschede, The Netherlands
Mark.vanSetten@telin.nl

1 Introduction

The purpose of personalized electronic program guides (EPGs) for TV is to help people easily find programs that match their interests; programs they would like to watch. Many research projects so far focused on the prediction and recommendation part of personalized EPGs (see first part of [1], [5] and [6]). But in personalized information systems, besides selecting interesting information, also two other processes play an important role in supporting users to find their needed information easily and quickly: structuring and presentation.

The presentation process is about the user interface. User interface issues for EPGs have been addressed by some studies (see chapters 2, 10 and 11 of [1]). Issues addressed include the way in which to present program information, predicted ratings, explanations about predictions and the way to acquire feedback from users.

Structuring is about the manner in which items that are displayed to the user via the user interface are organized; structuring is about grouping and sorting items. Traditional paper TV guides group their programs by the channels on which they are broadcast; in Europe, most TV guides display the channels as columns and programs are sorted on time within these columns; however, in the US, channels are displayed as rows and programs are sorted on time within these rows. Grouping programs on channel is also used in almost every existing EPG.

In our current research, we examine different ways to structure EPGs, especially structures that can better support users in finding interesting items more easily; using structures that complement the predictions made by a recommendation engine. We are especially interested in examining the benefits of using goal-based structures.

When people watch TV they have certain goals they want to achieve; a certain satisfaction they want to experience. This goal-based nature of people is agreed upon by various decision-making theories. Uses and gratification theory [4] can help to determine the possible goals that users have for watching TV. This theory states that people choose the types of media that they will expose themselves to based on certain gratifications or some sense of personal satisfaction that they expect to receive from a media source. However, one might argue that watching TV is not always goal-directed; e.g. one may decide to just sit on the couch and watch TV by skimming through channels; uses and gratification research has shown that even this behavior addresses a goal: the goal to pass some time.

2 Demonstration

Our personalized EPG combines a prediction engine and a user interface based on our previous research [2] [6] with three ways of structuring:

1. Traditional channel-based structuring.
2. Goal-based structuring based on gratifications people have for watching TV, using the gratifications identified by Lee & Lee [3].
3. Genre-based structuring using the main genre of a TV program, which gives an indication of what gratifications to expect while not referring explicitly to goals. Genre-based structuring is included as making goals explicit is not something users are currently familiar with; genres are more familiar to users.

The personalized EPG also provides various ways to sort TV programs within the used structure: on time, title and (if predictions are used) predicted ratings.

Besides these core aspects – selecting, structuring and presentation – that are the focus of an upcoming experiment, the personalized EPG also provides additional functionality that makes the EPG more interesting to use than a paper TV guide; e.g. the ability to create watch lists, forums in which programs can be discussed, notifying others about upcoming programs, links to websites of a program, a list of programs that are on TV at the moment and several ways to customize the EPG.

In a planned experiment, in which about 400 to 1000 users will use our personalized EPG for about two months, we will investigate which of the three structures (channel-based, goal-based or genre-based) in combination with and without the use of predictions provides the best support for viewers in finding interesting TV programs easily and quickly.

A demonstration of our personalized EPG will include all mentioned aspects: predicted ratings for the selection, a validated user interface for the presentation of the EPG and the three ways to structure TV programs.

References

1. Ardissono, L., Kobsa, A., and Maybury, M. T., *Personalized Digital Television: Targeting Programs To Individual Viewers*. Dordrecht, The Netherlands: Kluwer Academic Publishers, 2004.
2. Barneveld, J. and van Setten, M., Designing Usable Interfaces for TV Recommender Systems. In Ardissono, L., Kobsa, A., and Maybury, M. T. (Eds.) *Personalized Digital Television: Targeting Programs to Individual Viewers*. Dordrecht, The Netherlands: Kluwer Academic Publishers, 2004, pp. 259-285.
3. Lee, B. and Lee, R. S., How and Why People Watch TV: Implications for the future of interactive television. *Journal of Advertising Research*, November/December, 1995, pp. 9-18.
4. Severin, W. J. and Tankard, J. W. Jr., *Communcation Theories*, 5 ed. University of Texas at Austin: Addison Wesley Longman, Inc., 2001.
5. Smyth, B. and Cotter, P., A personalised TV listings service for the digital TV age. *Knowledge-Based Systems*, vol. 13, 2000, pp. 53-59.
6. van Setten, M., Veenstra, M., Nijholt, A., and van Dijk, B., Prediction Strategies in a TV Recommender System: Framework and Experiments. *Proceedings of IADIS WWW/Internet 2003*, Faro, Portugal, 2003, pp. 203-210.

WORKSHOP 5:

SWEL'04: Semantic Web for E-Learning

Applications of Semantic Web Technologies for Adaptive Educational Hypermedia

Workshop Co-Chairs:

Lora Aroyo
Darina Dicheva

Preface

The Semantic Web offers new technologies to the developers of Web-based applications aiming at providing more intelligent access to and management of the Web information and semantically richer modelling of the applications and their users. An important target for Web application developers nowadays is to provide means to unite, as much as possible, their efforts in creating information and knowledge components that are easily accessible and usable by third parties. Within the context of Semantic Web, there are several hot issues, which allow achieving this reusability, shareability and interoperability among Web applications. Conceptualizations (formal taxonomies), ontologies, and the available Web standards, such as XML, RDF, XTM, OWL, DAML-S, and RuleML, allow specification of components in a standard way. The notion of Web services offers a way to make such components mobile and accessible within the wide sea of Web information and applications.

The research on adaptive educational hypermedia and Web-based educational systems (WBES) traditionally combines research interests and efforts from various fields. Currently, the efforts in the field of ontologies and Semantic Web play an important role in the development of new methods and types of adaptive courseware. Starting with the traditional ITS and going towards Web applications, the research on adaptive educational hypermedia strengthens its positions within this context.

Standardization of educational content specification and annotation, course components sequencing paradigms, user modelling and other aspects of educational adaptive hypermedia systems, also play an important role in achieving more flexible and interoperable adaptive hypermedia courseware. There is a significant effort performed by educational standardization institutions (e.g. IEEE Learning Technology Standards Committee, CEN/ISSS, IMS, the US ADLnet, CETIS, ARIADNE) to propose standards for various aspects of educational systems, such as IEEE Learning Object Metadata, IMS Learner Information Package Specification, etc. The research effort in both communities comes together in the attempt to achieve improved interoperability, adaptation and flexibility for single and group users of adaptive educational hypermedia (e.g. instructors, courseware authors and learners).

The goal of this workshop is to outline the state-of-the-art in the application of Semantic Web technologies and standards in adaptive educational hypermedia. We aim at exploring, among others, the relationships between the main components of adaptive hypermedia systems (AHS) presented by the existing referenced models, i.e. resource representation, domain model, sequencing representation, user profiles, and adaptation strategies, and the existing Semantic Web and educational standards. The workshop topics include:

- Using Semantic Web technologies to improve:
    - personalization, adaptation and user modelling
    - information retrieval
    - authoring of educational AHS.
- Web standards and metadata specifications for educational AHS:
    - information exchange protocols between educational AHS
    - consistency in standards evolution
    - mappings between existing Semantic Web and educational standards
    - educational metadata specification languages.
- Semantic Web-based AH architectures.
- Web services for educational AH.
- Real-world systems, case studies and empirical research for Semantic Web-based educational AH.

This workshop follows the successful workshop on Concepts and Ontologies in Web-based Educational Systems, held in conjunctions with ICCE'2002 in Auckland, New Zealand. It is part of the Second International Workshop on Applications of Semantic Web Technologies for E-Learning (SWEL'04), which is organized in three sessions held at three different conferences. The aim is to discuss the current problems in e-Learning from different perspectives, including those of Web-based ITS and adaptive educational hypermedia, and the implications of applying Semantic Web and educational standards and technologies for solving them:

- **SW-EL'04 Session at AH, 23rd August, 2004**
  Session co-chairs: Peter Dolog and Martin Wolpers
- **SW-EL'04 Session at ITS, 30th September, 2004**
  Session co-chairs: Vladan Devedzic and Tanja Mitrovic
- **SW-EL'04 Session at ISWC, 8th November, 2004**
  Session co-chairs: Riichiro Mizoguchi and Yukihiro Itoh

We hope that this workshop will provide some new insights and serve as a catalyst to encourage others to investigate the potential of the emerging Semantic Web technologies for the adaptive educational hypermedia and Web-based educational systems and contribute to the realization of the vision of the Educational Semantic Web.

August, 2004
Lora Aroyo and Darina Dicheva

Workshop Committee

General co-chairs:
Lora Aroyo, *Eindhoven University of Technology*
Darina Dicheva, *Winston-Salem State University*

AH 2004 session co-chairs:
Peter Dolog, *Learning Lab Lower Saxony, University of Hannover*
Martin Wolpers, *Learning Lab Lower Saxony, University of Hannover*

Program Committee:
Heidrun Allert, *Learning Lab Lower Saxony, University of Hannover*
Peter Brusilovsky, *University of Pittsburgh*
Owen Conlan, *Trinity College, Dublin*
Paloma Diaz, *Universidad Carlos III de Madrid*
Vanja Dimitrova, *Univeristy of Leeds*
Erik Duval, *Katholieke Universiteit Leuven*
Norm Friesen, *Athabasca University*
Jim Greer, *University of Saskatchewan*
Tsukasa Hirashima, *Hiroshima Univeristy*
Ulrich Hoppe, *University of Duisburg*
Geert-Jan Houben, *Technische Universiteit Eindhoven*
Mitsuru Ikeda, *JAIST*
Judy Kay, *University of Sydney*
Kinshuk, *Massey Univeristy*
Rob Koper, *Open University of the Netherlands*
Erica Melis, *Universität des Saarlandes, DFKI*
Tanja Mitrovic, *University of Canterbury*
Ambjörn Naeve, *Royal Institute of Technology*
Ossi Nykänen, *Tampere University of Technology*
Gilbert Paquette, *LICEF*
Simos Retalis, *University of Cyprus*
Demetrios Sampson, *Center for Research and Technology-Hellas (CERTH)*
Katherine Sinitsa, *Kiev Univeristy*
Amy Soller, *ITC-IRST*
Marcus Specht, *Fraunhofer Institute*
Steffen Staab, *AIFB, University of Karlsruhe*
Colin Tattersall, *The Open University of The Netherlands*
Brendon Towle, *NETg*
Jutta Treviranus, *University of Toronto*
Julita Vassileva, *University of Saskatchewan*
Felisa Verdejo, *Ciudad Universitaria*
Gerd Wagner, *Eindhoven University*

Ontologies for Scrutable Student Modelling in Adaptive E-Learning

Judy Kay, Andrew Lum

School of Information Technologies,
University of Sydney, NSW 2006
Australia
{judy, alum}@it.usyd.edu.au

Abstract. This paper discusses the problem of inference about core terms in a student model representing a learner's knowledge, using ontological inference. We try to address the challenge of modelling the student's high level knowledge, based upon user modelling evidence that is associated with fine-grained elements of the model, drawn from the learner's activity in an online learning system. We also describe the critical role that ontologies have the potential to play in supporting scrutable user modelling, where the learner can explore the student model and the processes underlying it so that we can support learner reflection on their knowledge as a foundation for them controlling their learning. In particular, we describe how an ontology over the concepts within the student model has a critical role in supporting visualisation of large student models. We describe how the ontological structure can be used to define graphs with useful properties for visualisation. We report on our experiments with constructing and visualising ontologies in the e-learning domain as well as an analysis of their structure and effectiveness.

1 Introduction

For effective adaptation to occur in hypermedia e-learning systems there is a need for user modelling. The student model stores the system beliefs about the learner, and by making inferences, the system can customise and adapt its services to cater for a learner's needs.

It is important to be able to scrutinise student models [1]. Adaptive e-learning systems need to be able to provide explanations as to why elements and relationships in the student model have a particular value or why adaptation happened and also lead to self-reflection [2]. It is also useful for the student to be able to determine what inferences can be made from certain elements in the student model. This is very important in cases where, for example, parts of the student model can be made public [3]. In this case, it should be possible for a learner to define the levels of inference that they are willing for a system to make about them.

There is a problem in how to effectively structure a student model. Student models can potentially contain hundreds or even thousands of elements. One solution is to

use an ontology to structure the student models. The ontology fulfills several roles in our student models. Firstly it defines the terms and relationships. This means that the student model has a common vocabulary with other parts of the system, in particular metadata. Secondly, it provides a structure to the student model data, giving us an immediate mechanism for doing inference. Thirdly, the ontology structure means that we can take advantage of existing graph visualisations which require a graph structure over the data to be visualised. They are critical if we are to build substantial student models about the learner from the small amounts of information that are readily available at the interface, especially early in the learning process.

We have been exploring ways to automatically construct an ontology from existing documents and, in particular, from existing glossary sources. Section 2 describes the construction of these ontologies and the enhancements required for turning them into effective student models. Section 3 reports on our own experiments in creating ontologically structured student models and how we have enhanced them. Section 4 discusses the issues of using ontologies for visualisation and our approaches to addressing problems with these ontologies. The last section provides a discussion of the issues addressed and our conclusions.

2 Scrutable Student Models and Ontologies

In this section, we describe the way that we have tackled the creation of ontologies for use in scrutable student modelling. Essential to our approach is that we want to be able to explain all aspects of the student models and the underlying processes to the learner. We consider this important for ensuring that learners maintain a sense of control of their own learning. In the case of ontological reasoning, this means that we want to be able to explain the ontology and its construction to the learner.

As a foundation to this approach, we have been exploring the automated construction of ontologies from existing glossaries and dictionaries [4]. As we discuss below, there is a clear benefit in using ontologies that are automatically constructed. In the case where scrutability is a priority, there is a significant additional benefit in that dictionaries are written expressly for the purpose of explaining the meanings of concepts to people. Therefore, they serve as a natural means of explaining the underlying ontology of a student model that has been derived from the dictionary.

2.1 Automatic Construction of Ontologies

In general, ontologies are time consuming to construct [5]. On this aspect alone, there is clear appeal in exploiting existing documents which capture the structure of a relevant ontology and automatically build the ontological structure. OntoExtract [6] and Text-To-Onto [7] are examples of such systems. We have been using Mecureo [4] to build ontologies in the broad area of Computer Science based on
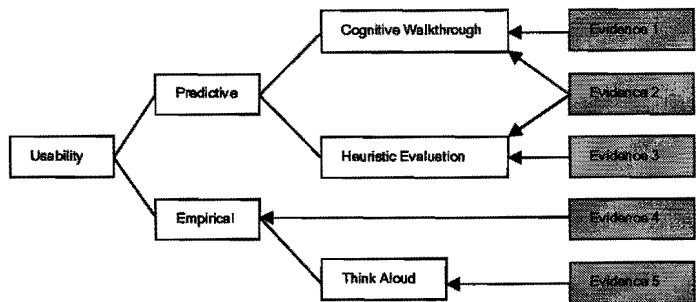
Fig. 1. A student model with fine-grain evidence for learner knowledge of concepts in the HCI domain. Evidence may feed into a single concept (such as sources 1, 3, 4 and 5) or multiple (source 2). Evidence may feed into any level of the ontology, in this case, source 4 feeds into a mid-level concept rather than a leaf concept.

FOLDOC [8], an online dictionary, as well as in the area of HCI [9]. These are light-weight ontologies based on lightweight parsing of dictionaries and glossaries to define the set of concepts and relationships in a domain.

2.2 Enhancement of Ontologies for Student Modelling

Automatically generated ontologies are, more often than not, incomplete. This incompleteness may not only be missing terms, but also may have missing or inappropriate relationships. Enhancement of the ontology is required for it to be useful in modelling the critical learning elements in a course. We call this the *restricted-ontology problem*.

Consider the issue of missing terms. For the case of the HCI Glossary, we discovered higher level terms, such as *novice*, were mentioned in many definitions but never defined itself as a term in the glossary.

There are also the cases where the ontology uses slightly different terminology to what is used in the application domain. This is also a form of the *restricted-ontology problem*.

2.3 Reasoning about Core Terms in the Student Model

One reason for using an ontology is the ability to make inferences about the student's knowledge of the terms in it. The system stores evidence which contribute to the student's knowledge level for each term, though this evidence is often of a fine granularity and may not directly contribute to the higher level terms. For example, a student correctly solving a set problem gives evidence of precise skills for that problem and we now want to reason about higher level skills.

This means there is a need to be able to infer core terms from the finer grained terms. For example, consider the terms in Fig. 1. From the fine-grained evidence supporting student knowledge of the low level concepts, we want to be able to infer the level of student knowledge about higher level concepts. For example, we want to infer the level of student knowledge about *predictive* usability, based upon the fine-grained evidence for *heuristic evaluation* and *cognitive walkthrough*. We also want to be able to infer the student's knowledge about *empirical* evaluation from evidence about methods such as *think aloud*. In addition, we want to be able to infer about the learner's knowledge in the broad area of *usability*, based on their knowledge of both *predictive* and *empirical* usability evaluation. There are many existing numerical methods for probabilistic reasoning that can be applied to the student model to make these inferences such as Dempster-Schafer theory or Bayesian methods.

If an ontology is well built, this should be a straight forward task as the relationships between the terms will have sensible and hopefully scrutable meaning as in the example above. In the case of automatically constructed ontologies, this may not be the case.

Some of the difficulties in making these inferences follow from the elements of the inference process:

- the amount of evidence available about each concept. If we have just one piece of evidence about the learner's knowledge of an aspect like cognitive walkthrough, this would seem to be a weaker indication of learner knowledge than would be the case if there were ten pieces of evidence.
- much of our evidence is positive in that we track when the student appears to have listened to a lecture. This is typical of much work involving the web, where positive data dominates.
- the strength of the ontological inference needs to be taken into account.

3 Experiments in Ontological Inference

We have been experimenting with the challenges of exploiting ontologies for scrutable student modelling. The context of our work has been a course in user interface design and programming. We create detailed student models by collecting evidence of student learning at the course web site. In particular, there are 20 online lectures, each with a series of visual elements, much like overhead slides, and audio lecture content with each such slide. These enable students to listen to lectures flexibly. At the same time, we are able to monitor the duration of time between each slide access. By comparing this with the duration of the audio, we are able to determine whether the full audio could have been played. We also require students to type lecture notes in conjunction with slides. Other student modelling information includes lab marks and other assessed elements.

In order to build student models, we needed to define the elements in it. We did this in terms of an automatically constructed ontology which was based on the Usability Glossary by Usability First [5].
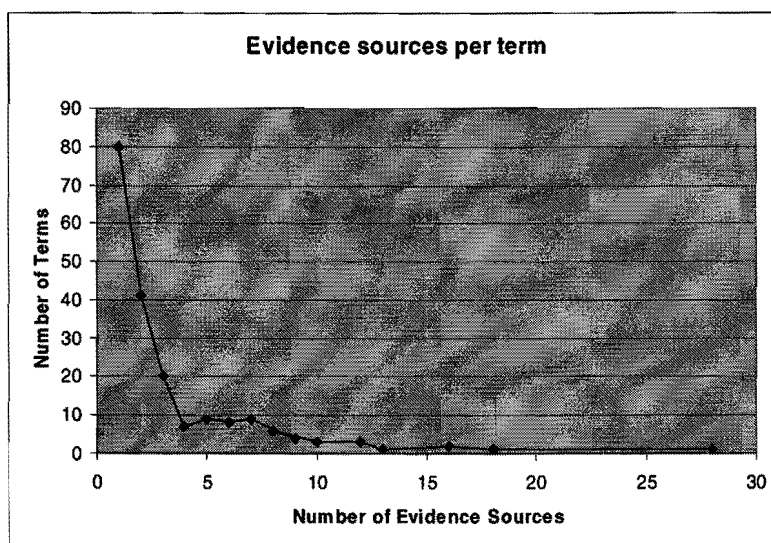
Fig. 2. The amount of evidence sources per term – we can see that the majority of terms have less than 10 evidence sources, though there are a high number with only one evidence source.

The glossary contains 1129 terms and categories. In addition, we defined an additional 105 local definitions which were used to enhance the ontology, giving us a total of 1234 elements. We use a subset of these terms (195 out of the 1234) as metadata terms on each of the learning objects and assessment elements. We then have corresponding elements in the student model.

As described above, the automatically constructed ontology falls short of our student modelling needs. We have developed an extremely simple approach to addresses this problem, while maintaining the benefits of a human-readable dictionary as the basis for the ontology: we define additional terms in a local extension of the dictionary [10].

From the ontology construction and enhancement phases, we have an ontology which contains all the terms of the student model and learning object metadata that the course teacher considered necessary. As the metadata uses the same vocabulary as the ontology, we treat the accessed pages where the terms are used as metadata as evidence sources for the student knowing that term in the student model. For our course, we have added metadata to the learning objects and used a simple heuristic comparing the amount of time a user spent on a slide in a learning object to the audio time for that slide to generate a value of their knowledge for that term.

Fig. 2. shows the distribution of the number of evidence sources per term. There is a high proportion of terms with less than 3 evidence sources (62%), and a small number with many evidence sources. The number of terms with a low amount of evidence poses difficulties in being able to make inferences about the student's

296

knowledge as mentioned in Section 2.3. The values in the user model are not useful in modelling the user's actual knowledge for these terms since the low number of evidence sources means that these terms are not taught in as much depth as a term with a high number of evidence sources.

By having the evidence sources as web page accesses, we only have positive evidence for the terms in the student model. We have weekly homework, laboratory and quiz marks for the students in the course. These will allow us to include additional evidence sources that can have negative values.

In our current work, we do not make any ontological inference on the student models to infer new higher level evidence from the fine grain evidence. We use the Ontology Web Language (OWL) [11] to represent our student models and is used as an input to our visualisation. This could support inference of the student model. We plan to explore this in the future. The ontology used in the student models also has relationship strengths generated by Mecureo during the ontology creation process that can be utilised to contribute to the strength of inference when reasoning about higher level skills. These relationships are typed based on the way the terms are used in the definitions. Types include parent/child, synonym/antonym, and sibling relationships. For example, *auditory feedback* is a synonym of *sound*, and *predictive metric* has parent *usability*.

4 Ontologies for Visualisation of Student Models

As already mentioned, we want to be able to provide learners with a visualisation of their student models. One reason, as noted, is that this can support reflection, an important foundation for improved learning. If the visualisation makes use of an ontology, it can serve a second important role in helping learners to see how their knowledge of one concept in the course can affect or be affected by other concepts.

However, there are additional properties that ontologies should exhibit if they are to be suitable for visualisation. The ontologies should have a modest fan-in and fan-out, that is, the number of relationships leading to and from any term in the ontology. We call this the peerage. Peerage is important because concepts with a number of peers will be isolated from the rest of the ontology in the visualisation. In the experiments we have run with our own visualisation, we found that it was hard to navigate to these concepts and see how they relate to the rest of the ontology. Equally, a large fan-out poses serious problems since it indicates that one concept is related to a large number of others. In a visualisation, this leads to serious clutter and interface problems.

In the case of the ontology for the UIDP course, the basic process described in the last section gives the peerage properties summarized in table 1. This shows that, in the current ontology, user defined terms are for more weakly connected to the rest of the ontology; they have an average of 3 peers, compared with 9 for terms in the foundation glossary (see last column of Table 1).
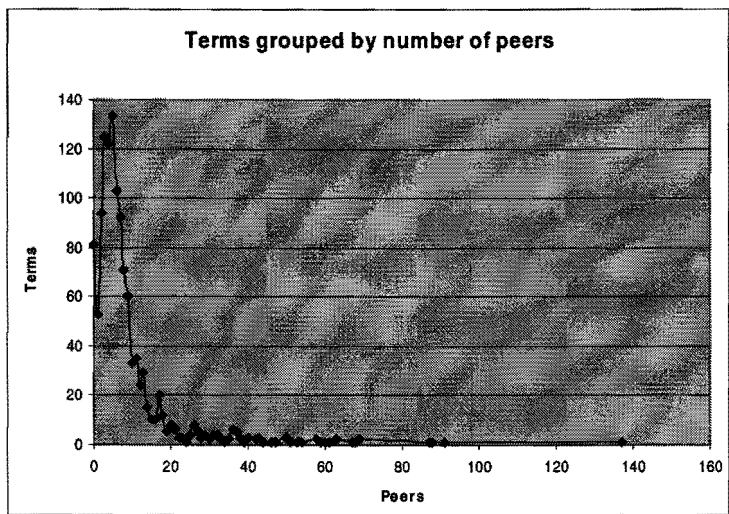
Fig. 3. The distribution of terms in our ontology grouped by the number of peers (fan-out) they have. There are a significant number of terms having a low peerage or an extremely high peerage.
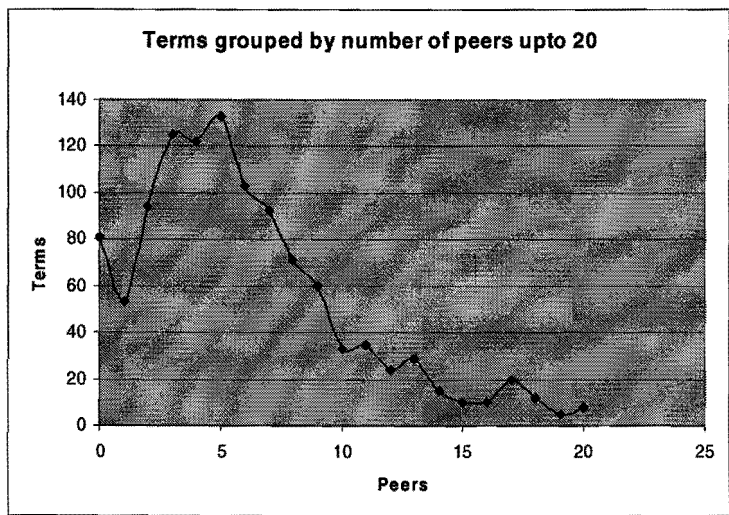

Fig. 4. A close-up of Fig. 3, with cut-off at 20 peers.

Table 1.

	Concepts	Added as course metadata	Peers	Average peers per concept
Defined locally	105	105	345	3.29
Defined in glossary	1129	90	10345	9.16
Total	1234	195	10690	8.66

In Fig. 3, we show some analysis of this distribution. It indicates that although the majority of terms have less than 20 peers, we still have a significant number with no peerage at all, and some outliers having over 100 peers. This extremity in peer distribution results in our visualisation suffering from the problems mentioned above.

We believe visualisation will be most effective if each concept has around 5 to 20 peers. Accordingly, we focus on this region of Fig. 3, as shown in Fig. 4. Clearly, we have significant numbers of terms with very low peerage. In fact, 475 terms (almost 40%) have less than 5 peers. Notably, on average, these are dominated by the user defined terms, as can be seen from Table 1. This is particularly serious since these are the concept terms that are sufficiently important for the course that we added them to the dictionary as. An important way to address this problem is to improve the added terms. We can do this quite easily, because, at present, we have only added new terms without providing a definition for them. In [10] we showed how adding a full definition increased the peerage of the added terms.

Another serious problem relates to concepts that have too many peers. There are 99 terms (8%) that have more than 20 peers in our ontology. The best way to address this problem is to make use of the weights that Mecureo places on relationship links. We have yet to explore this.

6 Discussions and Conclusions

We have identified several issues in reasoning about a learner's knowledge where ontological inference can provide a solution. In particular we want to infer about core terms for a domain when we only have fine grain evidence for lower level concepts. Although there are existing systems such as VisMod [12] that allows exploration of a student model and reasoning about a node and it's neighbours, or Summary Street [13] that provides feedback to users summarising text by comparing their summaries to a semantic space generated by latent semantic analysis, our approach relies on an underlying ontology that not only provides ontological relationships between terms to aid in reasoning, but a readily exploitable structure for visualisation.

In our own experiments, we have created an ontology for our course automatically from an online glossary source. However we have identified several deficiencies in our student model:
- there is a large proportion of terms in the student model with only one or two evidence sources

- the homogeneity of our evidence sources means that we only have positive evidence contributing to the values of the terms
- we need a way to infer evidence about the higher level terms that take into account the relationship weightings.

We have also analysed and discussed obstacles in visualising ontologies and the desirable characteristics. From our own experiments, we have decided that a peerage of 5-10 is desirable to avoid the effects resulting from terms with extremely low or high peerage.

The approach we have described shows promise if we can overcome the issues discussed in this paper. We have discussed two critical roles for ontologies in student modelling. The first is to support inference about core terms. The second is to provide a graph structure for use in visualisation.

7 Acknowledgements

References

1. Kay, J., *A scrutable user modelling shell for user-adapted interaction*, University of Sydney (1999)
2. Bull, S., Brna, P., and Pain, H., *Extending the scope of the student model.* In User Modeling and User-Adapted Interaction. Vol. 5(1) (1995) 44-65
3. Lum, A. *Scrutable User Models in Decentralised Adaptive Systems.* In: P. Brusilovsky, A. Corbett, and F.d. Rosis, Editors. *9th International Conference on User Modelling.* Springer, (2003) 426-428
4. Apted, T. and Kay, J., *MECUREO Ontology and Modelling Tools Special Issue on Concepts and Ontologies.* In WBES of the International Journal of Continuing Engineering Education and Lifelong Learning. (Accepted 2003, to appear)
5. Fensel, D., *Ontologies: A Silver Bullet for Knowledge Management and Electronic Commerce*: Springer (2001)
6. Reimer, U., et al., *Ontology-based Knowledge Management at Work: The Swiss Life Case Studies*, in J. Davis, D. Fensel, and F.v. Harmelen, Editors, *Towards the Semantic Web: Ontology-driven Knowledge Management.* 2003, John Wiley & Sons: West Sussex, England. p. 197-218.
7. Maedche, A. and Staab, S. *Mining Ontologies from Text.* In: *Knowledge Engineering and Knowledge Management. Methods, Models, and Tools: 12th International Conference, EKAW.* Springer-Verlag Heidelberg, (2000) 189-202
8. *FOLDOC: The Free Online Dictionary of Computing*, Available at http://www.foldoc.org/. (2001)
9. *Usability Glossary*, Available at http://www.usabilityfirst.com/glossary/main.cgi. (2002)

10. Apted, T., Lum, A., and Kay, J. *Supporting metadata creation with an ontology built from an extensible dictionary.* In: P.D. Bra and W. Nejdl, Editors. *Adaptive Hypermedia and Adaptive Web-based Systems.* Springer, (2004)
11. *OWL Web Ontology Language Overview,* Available at http://www.w3.org/TR/owl-features/. (2003)
12. Zapata-Rivera, J.D. and Greer, J., *Inspecting and Visualizing Distributed Bayesian Student Models,* in G. Gauthier, C. Frasson, and K. VanLehn, Editors, *Intelligent Tutoring Systems.* 2000. p. 544-553.
13. Kintsch, E., et al., *Developing Summarization Skills through the Use of LSA-Based Feedback.,* In Interactive Learning Environments. Vol. 8(2) (2001) 87-109

An Ontology-based Referencing of Actors, Operations and Resources in eLearning Systems

Gilbert Paquette and Ioan Rosca

Center for Inter-university Research on Telelearning Applications,
CIRTA-LICEF, Télé-université, Université du Québec
gpaquett@licef.teluq.uquebec.ca
irosca@licef.teluq.uquebec.ca

Abstract. We explore some of the multiple relationships between two very active research fields in eLearning and Knowledge Management research: educational modeling languages and ontologies. Our previous research projects in the last 10 years have shown the central importance of the association between the learning activities and the knowledge and skills that they target. Studies on this relationship have led to the concept, we will present here, of a semantically referenced educational function grouping actors, operations and resources or learning objects. The referencing method proposed here is both qualitative (structured by an ontology) and quantitative, using a bi-dimensional skill/performance metric to situate the mastery level of knowledge associated to an actor, an operation or a resource in a multi-actor learning scenario.

1 Introduction

Functions are editable and executable graphic models representing multi-actor processes where activities are executed, using and producing resources. This editing process is similar to methods of task representation, flowchart or workflow modeling, and UML use cases and activities diagramming. When executed at run time, Functions facilitate the coordination of the participants who achieve the represented activities, using and producing resources (so-called "learning objects"). The representation of the cognitive processes involved while executing a Function Map demands the semantic referencing of its components: the operations (virtual or actual activities), the actors (abstracted or concretized by participants), the instruments (virtual or concretized by different kinds of resources).

In this communication a summary of our previous work will be outlined. Then we will present the concept of a Function Model, central to the LORNET project, as a generalisation of IMS-LD, a specification for the educational modeling of multi-actor activities. The third part will focus on ontology referencing of components in an eLearning Function Model and thus enabling eLearning systems to help users find persons, activities and resources that can enhance their knowledge and competencies. Then we will discuss the notion of competency equations to help improve the design, the support and the evaluation of learning activities.

2 Modeling Knowledge and Competency for eLearning

We will first briefly summarize our previous research on Instructional Engineering methodology, Educational Modeling Languages and Web-based eLearning delivery systems.

2.1 Central Instructional Engineering Operations

The fast evolution of learning technologies has multiplied the number of decisions one must make to create an eLearning system. While it is true that a majority of the first Web-based applications have been mostly ways to distribute information, more and more educators have become aware of the need to go beyond these simple uses of information and communication technologies. One of our contribution to this field has been to propose a new approach to Instructional Design (Merrill 1994), founded on cognitive science, labeled as "Instructional Engineering"; it is defined as: *"a methodology that supports the analysis, the design and the delivery planning of a learning system, integrating the concepts, the processes and the principles of instructional design, software engineering and cognitive engineering".* (Paquette 2003)

We have used a knowledge modeling approach to define such an instructional engineering method. This effort, started in 1992, and has led to the actual MISA 4.0 method (Paquette 2001) and to ADISA, a Web-based support system for designers using MISA. (Paquette, Rosca and al. 2001). In one of the main tasks, the instructional designer constructs the structure of the activities, a *network of Learning Events.* A second step in the elaboration of the instructional model is to build a *learning scenario* for each Learning Unit (task 320). A learning scenario is a multi-actor process model where the actors are involved into learning or support activities using and producing resources for themselves or other actors.

Prior or in parallel to that, the instructional designer will built a Knowledge Model that is a graphic structured representation of the concept, procedures, principles and facts in the domain to be learnt. For this, a graphic modeling editor, MOT, is used, as a standalone or as a module of the ADISA Web-based design workbench. A companion task consists in defining entry and target skills and competencies for different types of learners, associated to some of the knowledge units in the domain model. A competency is a statement that a learner can apply a cognitive, socio-affective or psycho-motor skill to unit of knowledge at a certain degree of performance. When the learning units have been defined, a sub-model of the domain model, with its linked competencies, is associated to each learning unit providing a knowledge representation of its content. Later on, when the learning scenarios are defined, other knowledge sub-models can be assigned to the learning resources, in each scenario, providing a knowledge representation of their content.

2.2 Adding Knowledge Representation to IMS-LD

The work on Educational Modeling Languages (Koper 2002, Rawlings et al 2002), and the subsequent integration of a subset in the IMS Learning Design Specification (IMS 2003), is the most important initiative to date, to integrate Instructional Design preoccupations in international standards (Wiley, 2002). It describes a formal way, and an XML binding that can be read by any compliant eLearning delivery system, to represent the structure of a *Unit of Learning* and the concept of a pedagogical *Method* specifying roles and activities that learners and support persons can play using learning objects.

The *Learning Design* is composed of a method, learning objectives and prerequisites, and metadata referencing the unit-of-learning as in the IMS content packaging specification. The Method element and its sub-elements are central as they control the behavior of the unit-of-learning as a whole, coordinating the activities of the actors in the various roles and their use of resources. Like MISA's instructional model, it is a multilevel structure where altenative plays are decomposed in a series of one or more acts, each act being composed of one or more role-parts associating an actor to a single activity or an activity structure that can be decomposed further.

This IMS-LD Function on Figure 1 is composed of two alternative plays, Module A and B, intended for different users. Only the first play is developed here, it contains two acts and 5 learning activities, ruled by individual learners or group of learners, and support activities by a teacher. Each couple Role/Activities correspond to IMS-LD role parts. Resources or learning objects link to activities (by IP links) are used or produced in the corresponding activities.

While IMS-LD is a great progress in eLearning specifications, norms and standards, we believe it has to be expanded, first to a more general Function model that we will present in section 2, and also to associate knowledge and competencies to its components as we do in MISA. Actually, the only way to describe the knowledge in the activities or in the resources is to assign optional educational objectives and prerequisites, to the Unit of learning as a whole and/or to all or some of the learning and support activities. Objectives and prerequisites, although they correspond to entry and target competencies, are essentially unstructured pieces of text composed according to the IMS RDCEO specification (IMS 2002).

Unstructured texts are difficult to compare: consistency checking cannot be supported by a system between different levels of the LD structure, and even, at the same level, between the content of learning activities and resources, and the actors' competency. In fact, the content or learning resources is not described at all, and the actor's competencies are only indirectly defined by their participation in learning units or activities where educational objectives are associated. What we need is both a qualitative structural representation of knowledge in activities and resources, but also a quantitative one that can be provided by adding a metric to knowledge elements.
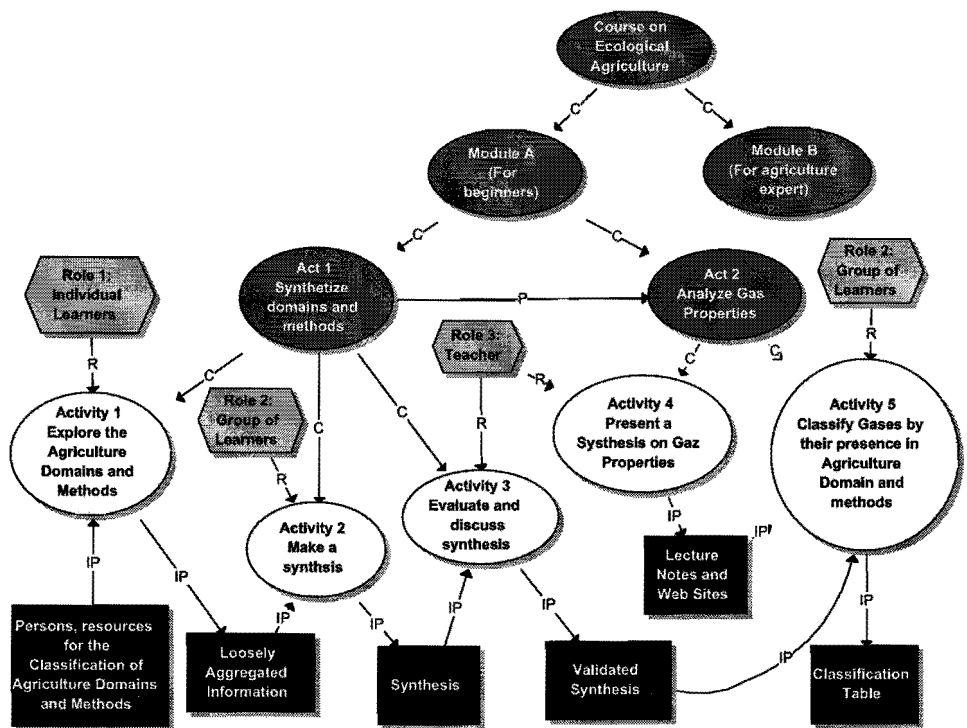
Fig. 1. An IMS-LD Method.

2.3 Adding Knowledge Representation Capabilities to a Delivery System

Without any representation of the knowledge to be processed in a eLearning environment, a delivery system will be unable to help its users according to their present and expected state of knowledge and competency acquisition. To expand the capacity of such systems, the Explor@-2 delivery system (Paquette 2001) has been based from its inception on two structures, the instructional structure (corresponding to the learning design) and the knowledge/competency structure (corresponding to a domain ontology).

Figure 2 shows screens of the knowledge/competency editor provided to Explor@-2 designers. On the left, we see a hierarchy of concepts in the domain of ecological agriculture where the terminal nodes are skills associated to their parent nodes. If we select one of the skills (on the figure, "Analyze-6" is selected), plus some performance criteria (selected in the little window on the left), we can associate to its parent knowledge, here "Agriculture Processes", a target competency and an entry competency.

305
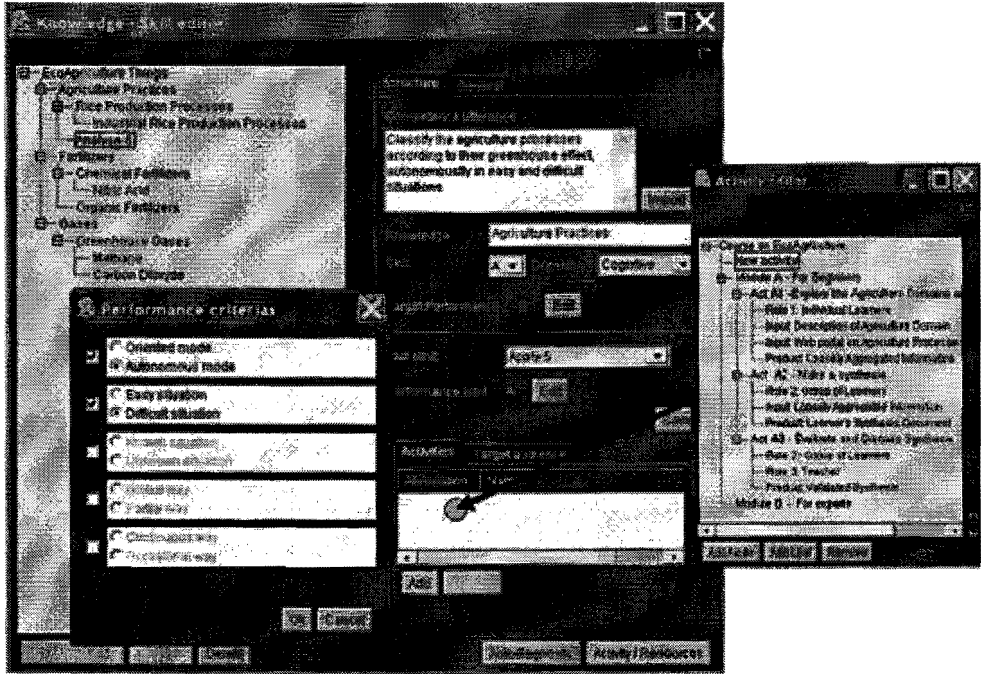
Fig. 2. A Knowledge and Competency Editor.

Competency statements are texts that have a precise interpretation as knowledge/skill+performance couples. For example, the competency statement "classify the agriculture processes according to their greenhouse effect, autonomously in easy and difficult situations", is interpreted as analyze (skill level 6), autonomously in all situations (performance level B) to be applied to agriculture practices (knowledge). The skill and the performance levels form two ordered sets of value that enable comparison between competency statements for a certain knowledge. Performance levels A, B, C and D are derived from a combination of increasingly demanding performance criteria and can be transformed in numbers (A = 2, B = 4, C = 6 and D = 8) so as to obtain a metric enabling to represent the distance between entry and target competency for that knowledge (agriculture practice). This means that learners will stay at the "Analyze-6" level, with an expected increase of performance from A to B, that is from 6.2 to 6.4.

On Figure 4, the lower right corner of the Knowledge/Skill editor is where the designer associates the selected knowledge/skill+performance)/ couples (the entry and target competency statements) to the components of the activity structure that has been built using the Explor@-2 activity editor. In this way, all the activities and the resources can be described by knowledge and competencies.

3 Function Models

There are limitations to the semantic referencing method we have just presented. The most important is that Explor@-2 do not support multi-actor processes and no competencies are assigned to actors except indirectly by competencies assigned to activity structure components. It is now our goal to both generalize the activity structure using a multi-actor workflows called Function Models, and also to reference later on, the actors, operations and resources in these Functions Maps, with Ontology components (for the knowledge part) and a competency metric.

3.1 Function Models as Multi-actor Workflows

A Function Model (or simply Function) within an eLearning system is composed of actors playing a role in activities (or operations) where they use and produce resources for themselves or other actors (Paquette and Rosca 2002). From a computer science view, a Function Model corresponds to a use case (Bosch et al. 2001) of that system. From a conceptual point of view, in a biological or ecological sense, a function is a particular physiology, an interesting subsystem of operations within the learning system organism. Particular cases are instructional scenarios, delivery models and IMS-LD methods.

For example, in a delivery model, learners are work colleagues that can use an electronic performance support system (EPSS) offering integrated training and work activities. They would equipped with the same databases, documents, and tools as those used at work. These organizational resources are provided and supported by the workplace technicians. The learners acquire knowledge and competencies by solving problems similar to those experienced in the workplace. Learners use hyperguides that provide activity assignments to be completed with the training material published on the Internet. The learning material is created and maintained by the training organization designers. The target competencies are validated though various exercises and tests. A trainer-manager supervises the learners' work and training by providing advice and assessing their work and knowledge, skills and competency progress. All these operations can be represented as a multi-actor workflow where the different actors rule operations where they use resources and produce resources for other actors or with other actors.

3.2 Embedding Knowledge and Competency in a Function Model

We obviously need a unique *semantic referential* (for knowledge and competencies) for all the components of a Function that must reach competence equilibrium in a given domain. For example, if a learning activity to be achieved, requires a level of mastery of certain knowledge, then the resources provided to the learner (persons, documents and tools) must enable the learner to progress from a lower entry mastery level to the one required by the activity.

But if we use only a knowledge referential without précising the mastering level, we obtain a coarse granulation of sense and, as a consequence, weak semantic

management services. We need measures of a knowledge mastering, a weighted ability defined on that knowledge. We can use different mastering scales: simple quantitative 1-10, Bloom taxonomy, combinations between skills taxonomies and performance level as in MISA, etc. It would be preferable that the level scale that describes the mastering of any knowledge be reasonably simplified, to be manageable. Still, the levels must correspond to clearly identify cognitive processes such as memorizing, applying, analysis, synthesizing or evaluating knowledge (Paquette 1999). The evolution of a learner on a competence scale materializes a learning process: therefore, it should be managed explicitly and expressively.
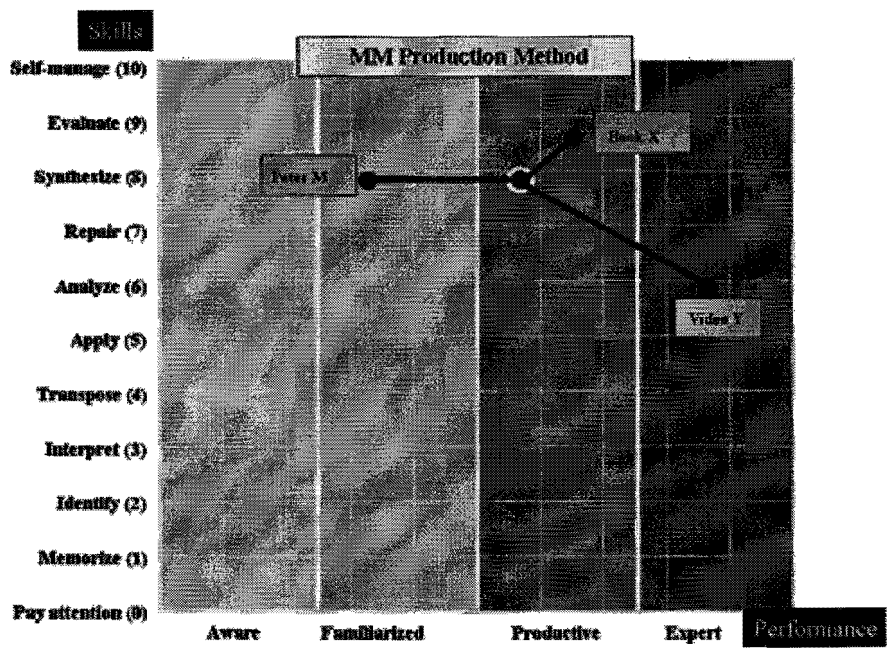
Fig. 3. A Skill/Performance Scale.

Figure 3 presents such a competency scale that is used in the Explor@ knowledge/activity editor presented above. It has also proved a solid tool for instructional engineering projects using the MISA method. Here the mastery of a knowledge term, Multimedia Production Method, is evaluated on bi-dimensional scale. The skills scale, from 0 to 10, is complemented by a performance scale, where values are decimals from 0 to 0.9, corresponding to qualitative terms like "Aware", "Familiarized", "Productive" or "Expert". On the figure, we see that PeterM's knowledge is evaluated at 8.3: he can synthesize MM production methods, at a performance level showing he has familiarized with synthesizing such procedures. On the other hand, Book X is evaluated near 9.7; that might be too much for the actual competency of PeterM, unless we aim a target competency at that level or higher. On the other hand, a lecture on VideoY is evaluated near 6.9 so it is below PeterM's actual competency and might not prove very useful, except maybe as a review.

The knowledge space of a domain can also be structured in many ways: dictionaries, thesaurus, book summary, library catalog, indexes and metadata, knowledge graphs, ontologies, etc. The tree organization of the knowledge referential seems an important aspect because it allows the competence inheritance of a parent node to his children, if these have no other explicit specifications. This can reduce significantly the mechanisms of competence analysis and management. But the tree organization is two restrictive for describing the rich network of relations that ties the concept structures. A relational (predicate) logic must then complete the concept tree and sustain more refined mechanism of conceptual matching.

These requirements suggest that a good candidate for the semantic indexing of the function components will be a combination between domain ontologies (Davies et al 2003, Breuker et al 1999) and a simple and operational competency scale.

4 Ontology Referencing of a Function Model

In the TELOS architecture framework we are developing in the LORNET[1] project, the construction of a domain ontology and its use for referencing actors, operations and resources represented in a Function, is central. It is in continuity with the work presented in section 1. We present here a tool and a process to integrate qualitative and quantitative ontology referencing in a Function Model.

4.1 Construction of a Domain Ontology

Some technologies and methods to develop the Semantic Web are now becoming mature. On February 10, 2004, the World Wide Web Committee has issued a recommendation for the definition of a standard Ontology Web Language: *"OWL is a revision of the DAML+OIL web ontology language incorporating lessons learned from the design and application of DAML+OIL."* (W3C, 2004)

Many ontology engineering methods exists such as the one presented in (Sure and Studer 2003). We present here, as an example, an ontology aiming to identify Agriculture practices that influence the greenhouse effect. A function model (such as the IMS-LD method presented on Figure 1) describes the use of the ontology to find out agriculture alternative practices, in at least five agriculture domains, and to build a transition plan towards the replacement of the old practices by the more ecological ones. The ontology would serve in a browsing mode to access related resources and to launch search agents to find persons, information resources and learning activities useful to solve the problems.

---

[1] LORNET (Learning Objects Repository Networks) is a pan-Canadian research network involved in Semantic Web applications to eLearning and Knowledge Management systems led by one of the authors
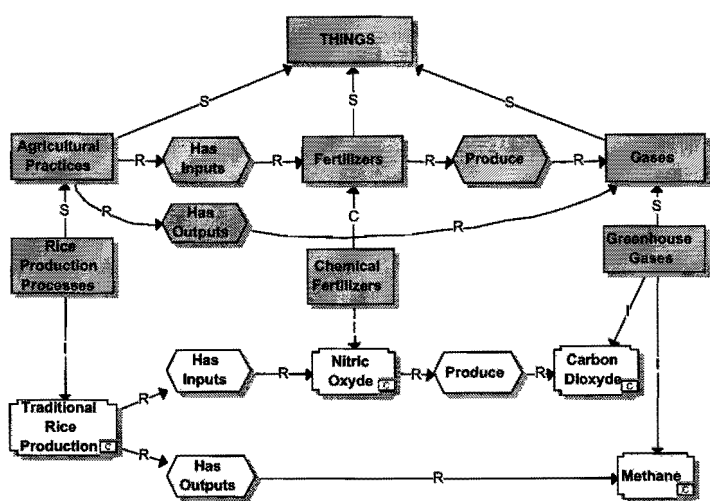
Fig. 4. A Simple Ontology.

Figure 4 presents a simple example to illustrate the use of the MOT+ knowledge editor, used in MISA, as a graphic tool for Ontology Engineering[2]. The upper part of the graph presents the top levels of three hierarchies of concepts (linked by sub-class links "S"): *agricultural practices, fertilizers* and *gases*. Some properties of these concepts are shown on the graph. An Agriculture practice, such as Rice Production Processes, *has inputs* including fertilizers and *outputs* that can be gases. Fertilizers can also *produce* gases, some of which are *greenhouse gases*. Figure 4 also shows a few of the instances that will constitute the knowledge base. Here, we see an agriculture practice, *Traditional Rice Production*, having among its outputs *methane gas*. It also has *Nitric Oxide* amongst its inputs, a chemical fertilizer that produces *Carbon Dioxide*. Both of these gases are example of *greenhouses gases* harmful to the environment.

We can now proceed to reference the components of the Function Model presented on Figure 5. For this, sub-graphs of Figure 4 are associated to actors, acts and activities (operations) and resources used and produced by the activities.

4.2 Competency equations

We will now use the skill/performance scale presented above to show how we can add a metric to represent the mastery of knowledge terms that have been associated to operations, actors and resources of the IMS-LD scenario (or function) presented on Figure 1.

---

[2] We are actually working towards having MOT+ produce automatically a standard OWL description of an application domain instead of its actual XML schema
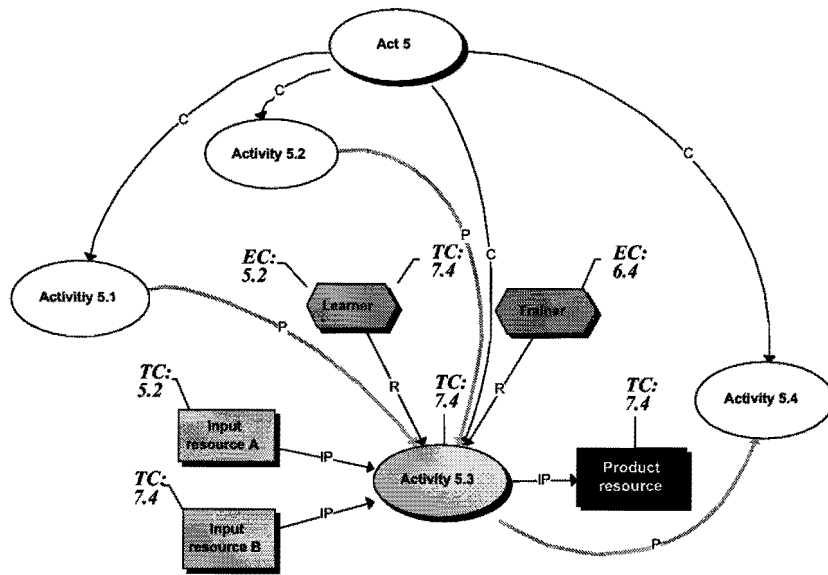
Fig. 5. Associating knowledge mastery values to scenario components.

Figure 5 shows part of a learning design where Act 5 is composed of four activities. Activity 5.1 and 5.2, preceding Activity 5.3, itself preceding Activity 5.4. Let us focus on activity 5.3, an operation performed by a learner and a trainer, both interacting with input resources A and B, helping the learner produce a certain resource.

On this figure, we see that for a certain knowledge term in the ontology, for example "rice production processes", the target competency (TC) of activity 5.3 is evaluated at a 7.4 level (skill: "Repair", performance: B) on the skills/performance scale. Then the produced resource (an exam, an essay, a classification table,....) should show a TC level equal or higher than 7.4.

Since the learner has an entry competency (EC) of 5.2 (skill: "Apply", performance A), he needs help. Here we have a trainer with EC = 6.4 so he alone cannot bring the learner all the way up, but he can certainly help him fill part of the gap. Also, the learner can use two input resources. Resource A is at TC=5.2 so it can only serve to test the entry competencies of the learner, to make sure he has the prerequisites. Fortunately, Resource B has a TC = 7.4, the right target, but lets hope it not a lecture that starts at 7.4, but maybe an aggregate of learning objects that can help him progress with the help of the trainer. By the way the trainer will also learn a little bit in the process, so at the end the activity, we could consider raising his EC for the next run of the activity.

There are many other situations to investigate where competency equations such as these will prove useful, but this example shows that this kind of analysis, by humans,

311

by machines or both, can bring more intelligence in learning environments before learning takes places (at design time), during learning (to help learners use available resources adequately) and after learning (to evaluate and improve designs).

Conclusion

By definition, domain ontologies are continuously evolving in the semantic Web. Furthermore, in communities of practice and project-based learning, the learners themselves can be the ones who will make the ontology evolve. This is why it is important to lower the barrier to ontology construction and referencing, taking in account that ontologies are a moving target. To achieve this, more user friendly graphic tools will have to be designed.

On a more theoretical level, the maintenance of the coherence of the Ontology through versioning by different actors is a huge problem researchers have just started to address. Our approach here is to classify the possible changes from a version to a subsequent one and to provide a tool that will assist the Ontology designer (Rogozan and Paquette, 2004) in the different cases that can occur.

Finally, the knowledge referencing of Functions or multi-actor workflows using an ontology needs to be complemented by a knowledge mastery metric such as the one proposed here. This important aspect will be further investigated to better understand the multiple possible configurations.

The Semantic Web and its associated technologies and methods are recent developments that have barely begun to be used in applications. Extensive solution-oriented applied research in knowledge engineering and distributed computing is needed to adapt, integrate and evolve these technologies, and to produce a framework for building and using learning object (or resource) repositories on the Web, for knowledge management and learning.

References

Breuker, J., Muntjewerff, A., and Bredewej, B. (1999). Ontological modelling for designing educational systems. In *Proceedings of the AI-ED 99 Workshop on Ontologies for Educational Systems*, Le Mans, France. IOS Press.

Davies, J. Fensel, D, Van Harmelen, F. (2003) *Towards the Semantic Web, Ontology-Driven Knowledge Management*, Wiley, 288 pages

IMS (2002). *IMS Reusable Definition of Competency or Educational Objective - XML Binding, Version (2002)*. 1.0 Final Specification, IMS Global Learning Consortium, Inc. Revision: 25 October 2002.

IMS-LD (2003). *IMS Learning Design. Information Model, Best Practice and Implementation Guide, Binding document, Schemas*. Retrieved October 3, 2003, from http://www.imsglobal.org/learningdesign/index.cfm

Klein, M. and Fensel, D. (2001) *Ontology versioning for the semantic web*, International Semantic Web Working Symposium (SWWS), 2001.

Koper R. (2002). *Modeling units of study from a pedagogical perspective – The pedagogical metamodel behind EML* Retrieved march 2002 from http://www.eml.ou.nl/introduction/articles.htm.

Merrill M.D (1994). *Principles of Instructional Design.* Educational Technology Publications, Englewood Cliffs, New Jersey, 465 pages.

Paquette (2003) Paquette, G. Instructional Engineering for Network-Based Learning. Pfeiffer/Wiley Publishing Co, 262 pages.

Paquette G. (2002) TeleLearning Systems Engineering – Towards a new ISD model. Journal of Structural Learning 14, pp. 1-35,

Paquette, G. & Rosca, I. (2002). *Organic Aggregation of Knowledge Objects in Educational Systems,* Canadian Journal of Learning Technologies, Vol 28-3, Fall 2002, (pp. 11-26)

Paquette G. (2001). *Designing Virtual Learning Centers.* In H. Adelsberger, B. Collis, J. Pawlowski (Eds) Handbook on Information Technologies for Education & Training within the Springer-Verlag series "International Handbook on Information Systems", (pp. 249-272).

Paquette, G. (1999) Meta-knowledge Representation for Learning Scenarios Engineering. Proceedings of AI-Ed'99 in AI and Education, open learning environments, S. Lajoie et M. Vivet (Eds), IOS Press, 1999.

Paquette,G., Rosca, I. , De la Teja, I., Léonard, M., & Lundgren-Cayrol, K. (2001). *Web-based Support for the Instructional Engineering of E-learning Systems,* Paper presented at WebNet'01 Conference, Orlando.

Rawlings, A., P. Van Rosmalen, R. Koper, M. Rodriguez-Artacho, P. Lefrere. (2002). Survey of Educational Modelling Languages (EMLs), version 1, September 19th, CES/ISSS

Rogozan, D. and Paquette, G. (2004) *Methodology for the Ontology Evolution within a Dynamic and Distributed Environment,* EKAW – 04 Conference (submitted paper)

Sure, Y. and Studer, R. (2003) *A Methodology for Ontology-based Knowledge Management,* in Davies, Fensel and Van Harmelen, F. (Eds) *Towards the Semantic Web, Ontology-Direven Knowledge Management,* Wiley, pp.33-46

Wiley D.A. (2002). *Connecting learning objects to Instructional design theory: a definition, a methaphor, and a taxonomy.* In Wiley (Ed) The Instructional Use of Learning Objects. Agency for Instructional Technology and Association for Educational Communications of Technology, Bloomington, Indiana, 281 pages.

W3C (2004) Ontology Web Language (OWL) Overview Document (http://www.w3.org/TR/2004/REC-owl-features-20040210/)

313

Using Ontologies for Adaptive Navigation Support in Educational Hypermedia Systems

Pythagoras Karampiperis[1,2] and Demetrios Sampson[1,2]

[1] Department of Technology Education and Digital Systems,
University of Piraeus,
150, Androutsou Street, Piraeus, GR-18534, Greece
[2] Advanced e-Services for the Knowledge Society Research Unit,
Informatics and Telematics Institute,
Centre for Research and Technology Hellas,
42, Arkadias Street, Athens, GR-15234 Greece
{pythk, sampson}@iti.gr

Abstract. Educational hypermedia systems seek to provide adaptive navigation, whereas intelligent web-based learning systems seek to provide adaptive courseware generation. The design of powerful frameworks by merging the approaches used in the above mentioned systems is recognized as one of the most interesting questions in adaptive web-based educational systems. In this paper we address adaptive navigation support in educational hypermedia systems by proposing a framework that combines the approach of automatic courseware generation with the paradigm of educational hypermedia systems based on the use of ontologies and learning object metadata.

1 Introduction

The high rate of evolution of e-learning platforms implies that on the one hand, increasingly complex and dynamic web-based learning infrastructures need to be managed more efficiently, and on the other hand, new types of learning services and mechanisms need to be developed and provided. To meet the current needs, such services should satisfy a diverse range of requirements, as for example, personalization and adaptation [1].

Educational hypermedia systems seek to provide adaptive navigation, whereas intelligent web-based learning systems seek to provide adaptive courseware generation. Adaptive navigation seeks to present the content associated with an on-line course in an optimized order, where the optimization criteria takes into consideration the learner's background and performance on related knowledge domain [2], whereas adaptive courseware generation is defined as the process that selects learning objects from a digital repository and sequences them in a way which is appropriate for the targeted learning community or individuals [3]. The main difference in the above mentioned approaches is that adaptive navigation uses adaptation logic defined over the learner's interactions with the learning system, whereas adaptive courseware generation uses adaptation logic defined over the user profile. The need for gradual

merge between the approach of adaptive web-based learning systems and the approach of adaptive hypermedia systems has been already identified in the literature [4], since those approaches are complementary and have the potential to provide powerful adaptation logic frameworks.

Although many types of intelligent learning systems are available, we can identify five key components which are common in most systems, namely, the student model, the expert model, the pedagogical module, the domain knowledge module, and the communication module.

In most intelligent learning systems that incorporate sequencing techniques, the pedagogical module is responsible for setting the principles of instructional planning based on a set of teaching rules according to the learning preferences of the learners [5]. In spite of the fact that most of these rules are generic (i.e. domain independent), there are no well-defined and commonly accepted rules on how the learning objects should be sequenced to make "instructional sense" [3, 6].

Adaptive Content Selection is based on a set of teaching rules according to the cognitive style or learning preferences of the learners [7, 8]. This process is the first step to adaptive navigation and adaptive presentation. Adaptive Content Selection, Adaptive Navigation and Presentation are recognized as among the most interesting research questions in intelligent web-based education [9, 10, 11].

In this paper, we address the adaptive navigation support problem in educational hypermedia systems proposing a concrete methodology based on the use of ontologies and learning object metadata. The result is a generic framework for extracting the appropriate learning path according to the learner's navigation steps, cognitive characteristics and preferences. The main advantage of the proposed method is that it is fully automatic and can be applied independently of the knowledge domain.

The paper is structured as follows. Initially, we discuss the main steps in the instructional planning of adaptive educational hypermedia and propose the use of ontologies and learning object metadata for knowledge and media structuring. The second part presents a decision framework for extracting the appropriate learning path according to the learner's navigation steps. The selection of learning path takes into consideration learner's cognitive characteristics and preferences. Finally, we present simulation results of the proposed methodology.

2 Instructional Planning

The instructional plan of an adaptive hypermedia system can be considered as two interconnected networks or "spaces" [4]:
- a network of concepts (knowledge space) and
- a network of educational material (hyperspace or media space).

Accordingly, the design of an adaptive hypermedia system involves three key steps:
- structuring the knowledge
- structuring the media space
- connecting the knowledge space and the media space.

315

2.1 Knowledge Structuring

The main component of the knowledge-based approach to developing adaptive educational hypermedia systems is a structured domain model that is composed of a set of small domain knowledge elements (DKE). Each DKE represents an elementary fragment of knowledge for the given domain. DKE concepts can be named differently in different systems—concepts, knowledge items, topics, knowledge elements, but in all cases they denote elementary fragments of domain knowledge.

Depending on the domain, the application area, and the choice of the designer, concepts can represent bigger or smaller pieces of domain knowledge. The simplest form of domain model is a set of independent concepts. The use of ontologies can significantly simplify the task of knowledge structuring by providing a standard-based way for knowledge representation.

Ontologies are specifications of the conceptualization and corresponding vocabulary used to describe a domain [12]. They are well-suited for describing heterogeneous, distributed and semi-structured information sources that can be found on the Web. By defining shared and common domain theories, ontologies help both people and machines to communicate concisely, supporting the exchange of semantics and not only syntax. It is therefore important that any semantic for the Web is based on an explicitly specified ontology. Ontologies typically consist of definitions of concepts relevant for the domain, their relations, and axioms about these concepts and relationships. Several representation languages and systems have been defined. A recent proposal extending RDF and RDF Schema is OWL (Ontology Web Language). OWL unifies the epistemologically rich modeling primitives of frames, the formal semantics and efficient reasoning support of description logics and mapping to the standard Web metadata language proposals. OWL is a W3C Recommendation since February 2004.
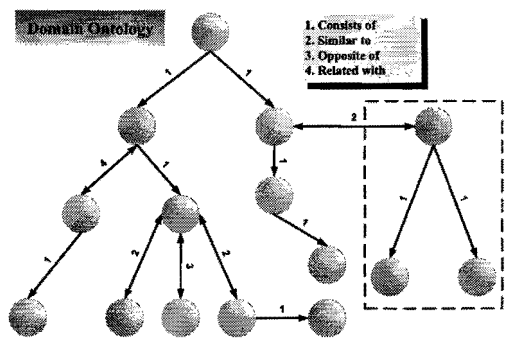

Fig. 1. Concept Relationships used for Domain Knowledge Representation

For the instructional planning process we have identified four classes of concept relationships, namely:
- "Consists of", this class relates a concept with its sub-concepts
- "Similar to", this class relates two concepts with the same semantic meaning

316

- "Opposite of", this class relates a concept with another concept semantically opposite from the original one
- "Related with", this class relates concepts that have a relation different from the above mentioned

Figure 1 presents a concept hierarchy using the four concept relationships identified.

2.2 Media Space Structuring

The process of structuring the media space can be based on the use of learning object metadata. More precisely, in the IEEE LOM metadata model [13], the 'Relation' Category, defines the relationship between a specific learning object and other learning objects, if any. The kind of relation is been described by the sub-element 'Kind' that holds 12 predefined values based on the corresponding element of the Dublin Core Element Set. In our case we use only four of the predefined relation values, namely:

- "is part of" / "has part"
- "references" / "is referenced by"
- "is based on" / "is basis for"
- "requires" / "is required by"
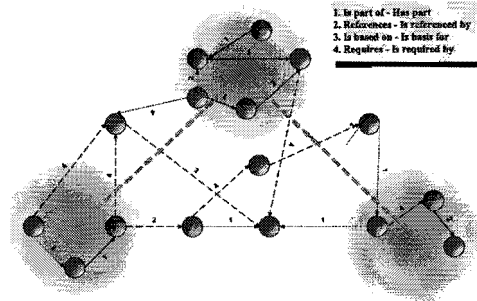
Fig. 2. Knowledge Space and Media Space Connection

2.3 Connecting knowledge with learning resources

The connection of the knowledge space with educational material can be based on the use of the 'Classification' Category, defined by the IEEE LOM Standard as an element category that describes where a specific learning object falls within a particular classification system. The integration of IEEE LOM 'Classification' Category with ontologies provides a simple way of identifying the domains covered by a learning object. Since it is assumed that both the domain model and the learning objects themselves use the same ontology, the connection process is then, relatively straightforward. Figure 2 presents an example of the connection of the two spaces. The result of the merging of the knowledge space and the media space is a directed acyclic graph (DAG) of learning objects inheriting relations from both spaces.

317

3 Discovering Optimum Learning Path

This graph contains all possible navigation paths that a learner can follow in order to reach his/her learning goal. In order to extract from the resulting directed acyclic graph (DAG) of learning objects the "optimum" learning path, we need to add learner preference information to the DAG. This information has the form of weight on each connection of the DAG and represents the inverse of the suitability of a learning object for a specific learner.

The weighting process consists of the following steps:
- *Step1: Selection of Criteria*

The discovery methodology is generic, independent of the learning object and the learner characteristics used. In our experiment, we used learning object characteristics derived from the IEEE LOM standard and learner characteristics derived from the IMS Global Learning Consortium Inc. Learner Information Package (LIP) specification [14]. In Table 1 and 2 we have identified the LOM and LIP characteristics respectively, that can be used as criteria for the selection of the learning path.

Table 1. Learning Object characteristics for Learning Path Selection

Criteria	IEEE LOM	Explanation
General	General/Structure	Underlying organizational structure of a Learning Object
	General/Aggregation Level	The functional granularity (level of aggregation) of a Learning Object.
Educational	Educational/Interactivity Type	Predominant mode of learning supported by a Learning Object
	Educational/ Interactivity Level	The degree to which a learner can influence the aspect or behavior of a Learning Object.
	Educational/Semantic Density	The degree of conciseness of a Learning Object, estimated in terms of its size, span or duration.
	LOM/Educational/Typical Age Range	Age of the typical intended user. This element refers to developmental age and not chronological age.
	LOM/Educational/Difficulty	How hard it is to work with or through a Learning Object for the typical intended target audience.
	LOM/Educational/Intended End User Role	Principal user(s) for which a Learning Object was designed, most dominant first.
	LOM/Educational/Context	The principal environment within which the learning and use of a LO is intended to take place.
	LOM/Educational/Typical Learning Time	Typical time it takes to work with or through a LO for the typical intended target audience.
	LOM/Educational/Learning Resource Type	Specific kind of Learning Object. The most dominant kind shall be first.

Table 2. Learner characteristics for Learning Path Selection

Criteria	IMS LIP	Explanation
Accessibility	Accessibility/Preference/typename	The type of cognitive preference
	Accessibility/Preference/prefcode	The coding assigned to the preference
	Accessibility/Eligibility/typename	The type of eligibility being defined
	Accessibility/Disability/typename	The type of disability being defined
Qualifications Certifications Licences	QCL/Level	The level/grade of the QCL
Activity	Activity/Evaluation/noofattempts	The number of attempts made on the evaluation.
	Activity/Evaluation/result/interpretscope	Information that describes the scoring data
	Activity/Evaluation/result/score	The scoring data itself.

- *Step2: Weight Calculation*

After identifying the set of characteristics/criteria that will be used, we define a weighting function that corresponds to the inverse suitability of a learning resource based on the profile of the target learner or group of learners. After identifying the set of characteristics/criteria that will be used, we define a weighting function with the following formulation:

Let us consider a set of learning objects, called A, which is valued by a set of criteria $g = (g_1, g_2, \ldots, g_n)$. The assessment model of the suitability of each learning object for a specific learner, leads to the aggregation of all criteria into a unique criterion that we call a suitability function: $S(g) = S(g_1, g_2, \ldots, g_n)$. We define the

suitability function as an additive function of the form $S(g) = \sum_{i=1}^{n} s_i(g_i)$ with the

following additional notation:

$s_i(g_i)$: Marginal suitability of the ith selection criterion valued g_i,

$S(g)$: Global suitability of a learning object.

The marginal suitability evaluation for the criterion g_i is calculated using the formula $s_i(x) = a_i + b_i x \exp(-c_i x^2)$, where x is the corresponding value of the g_i learning object selection criterion. This formula produces, according to parameters a, b and c as well as the value space of each criterion, the main criteria forms, we have identified:

Monotonic form: when the marginal suitability of a criterion is a monotonic function;

Non monotonic form: when the marginal suitability of a criterion is a non-monotonic function.

Figure 3 presents the different criteria forms supported by the proposed knowledge extraction methodology. The calculation of the optimal values of parameters a, b and c for each selection criterion is defined as follows:

Let us call P the strict preference relation and I the indifference relation. If S_{O_1} is the global suitability of a learning object O1 and S_{O_2} is the global suitability of a learning object O2, then the following properties generally hold for the suitability function S:
$$S_{O_1} > S_{O_2} \Leftrightarrow (O_1)P(O_2),$$
$$S_{O_1} = S_{O_2} \Leftrightarrow (O_1)I(O_2)$$
and the relation $R = P \cup I$ is a weak order relation.
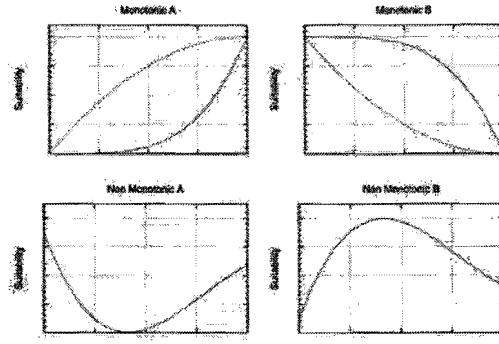
Fig. 3. Supported Selection Criteria Suitability Forms

The expert's requested information then consists of the weak order R defined on A for several learner instances. Using the provided weak order relation R and based on the form definition of each learning object characteristic we can define the suitability differences $\Delta = (\Delta_1, \Delta_2, \ldots, \Delta_{m-1})$, where m is the number of learning objects in the reference set A and $\Delta_k = S_{O_k} - S_{O_{k+1}} \geq 0$ depending on the suitability relation of (k) and (k+1) preferred learning object for a specific learner of the reference set.

We can introduce an error function e for each suitability difference: $\Delta_k = S_{O_k} - S_{O_{k+1}} + e_k \geq 0$. Using constrained optimization techniques, we can then solve the non-linear problem:

$$\text{Minimize } \sum_{j=1}^{m-1} (e_j)^2$$

Subject to the constraints:
$$\left. \begin{array}{ll} \Delta_j > 0 & \text{if } O_j P O_{j+1} \\ \Delta_j = 0 & \text{if } O_j I O_{j+1} \end{array} \right\}$$
for each one of the learners of the reference set. This optimization problem will lead to the calculation of the optimal values of the parameter a, b and c for each learning object selection criteria over the reference set of learners.
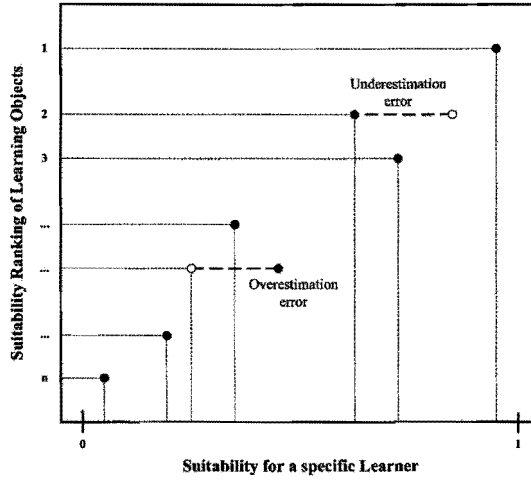
Fig. 4. Ordinal Regression Curve (Ranking versus Global Suitability)

Figure 4 presents the introduced error function, the suitability overestimation error as well as the suitability underestimation error e, on the ordinal regression curve, which is the suitability ranking of the reference set of learning objects versus the approximation of the global suitability of each one of the learning objects in the reference set.

At this phase we need to generalize the resulted marginal suitability model from the reference set of learners to all learners, by calculating the corresponding marginal suitability values for every combination of learner characteristics. This calculation is based on the interpolation of the marginal suitability values between the two closest instances of the reference set of learners. Suppose that we have calculated the marginal suitability $s_i^{L_1}$ and $s_i^{L_2}$ of a criterion c_i matching the characteristics of learners L_1 and L_2 respectively. We can then calculate the corresponding marginal suitability value for another learner L using interpolation if the characteristics of learner L are mapped inside the polyhedron that the characteristics of learners L_1 and L_2 define, using the formula:

$$s_i\left(c_i\right)^L = s_i\left(c_i\right)^{L_1} + \frac{c_i^L - c_i^{L_1}}{c_i^{L_2} - c_i^{L_1}}\left[s_i\left(c_i\right)^{L_2} - s_i\left(c_i^{L_1}\right)\right], \text{ if } s_i\left(c_i^{L_2}\right) > s_i\left(c_i^{L_1}\right)$$

Let $C_i = \left[c_{i^*}, c_i^*\right] i = 1,2,\ldots n$ be the intervals in which the values of each criterion – for both learning object and learners – are found, and then we call the space $C = \times_{i=1}^{n} C_i$ global suitability surface. The calculation of the global suitability over the above mentioned space is the addition of the marginal suitability surfaces for each of the learning object characteristics over the whole combination set of learner characteristics. After the calculation of the global suitability function, we can define the weighting function for the DAG as $W(g) = 1 - S(g) \in [0,1]$. After weighting the DAG using the weighting function, we need to find the optimum (shortest) path by

the use of a shortest path algorithm. The result of applying the shortest path algorithm
is the learning path (sequence of learning objects) that covers the desired concepts
(thus reach the learning goal) by providing all necessary information according to
cognitive characteristics and preferences of the learner.

4 Simulation Results

In our experiment we extracted an ontology from the ACM Computing Curricula
2001 for Computer Science [15]. The ontology consists of 14 areas, 132 units and
950 topics. In order to evaluate the total efficiency of the proposed methodology, we
have designed an evaluation criterion based on Kendall's Tau, which is defined by:

$$Success\ (\%) = 100 * \left(\frac{1}{2} + \frac{N_{concordant} - N_{discordant}}{n(n-1)} \right),$$

where $N_{concordant}$ stands for the concordant pairs of learning objects and $N_{discordant}$
stands for the discordant pairs when comparing the resulting learning objects ordering
with one given by an expert and n the number of learning objects used for testing.
The efficiency of the proposed method was evaluated by comparing the resulting
learning objects sequence with those proposed by an expert for 30 different naviga-
tion stages (10 cases per concept level) over the concept hierarchy. Average simula-
tion results are shown in table 3. It is evident that the proposed method can perform
as well as an expert instructional designer.

Table3: Experimental Results

	Learning Path Root		
	Area	Units	Topics
Min Successes (%)	79	84	95
Average Successes (%)	88	92	99
Max Successes (%)	91	97	100

5 Conclusions

In this paper we address adaptive navigation support in educational hypermedia sys-
tems proposing a flexible, efficient and effective framework that combines the ap-
proach of automatic courseware generation with the paradigm of educational hyper-
media systems based on the use of ontologies and learning object metadata. The main
advantage of this method is that it is fully automatic and can be applied independently
of the knowledge domain.

6 Acknowledgements

Integrated Virtual Environment for Supporting on-line Learning Communities" contract 2823/4-3-03.

References

1. Dolog, P., Henze, N., Nejdl, W., Sintek, M.: Personalization in Distributed eLearning Environments. In Proc. of the 13th International World Wide Web Conference, New York, USA (2004)
2. Brusilovsky, P.: Adaptive and intelligent technologies for web-based education. Künstliche Intelligenz, Vol. 4 (1999) 19-25
3. Knolmayer, G.F.: Decision Support Models for composing and navigating through e-learning objects, In Proc. of the IEEE International Conference on System Sciences, Next Generation Learning Platforms minitrack (2003)
4. Brusilovsky, P.: Developing adaptive educational hypermedia systems: From design models to authoring tools. In: Murray, T., Blessing, S., Ainsworth, S. (eds.): Authoring Tools for Advanced Technology Learning Environment. Dordrecht: Kluwer Academic Publishers (2003)
5. Brusilovsky, P., Vassileva, J.: Course sequencing techniques for large-scale Web-based education. International Journal of Continuing Engineering Education and Life-long Learning, Vol.13 (2003)
6. Mohan, P., Greer, J., McGalla, G.: Instructional Planning with Learning Objects. Workshop on Knowledge Representation and Automated Reasoning for E-Learning Systems. In Proc. of the 18th International Joint Conference on Artificial Intelligence, Acapulco, Mexico (2003)
7. Brusilovsky, P., Eklund, J., and Schwarz, E.: Adaptive Navigation Support in Educational Hypermedia on the World Wide Web. In: Howard, S., Hammond J., Lindgaard, G. (eds.): Human-Computer Interaction. New York: Chapman & Hall (1997)
8. Stash, N., De Bra, P.: Incorporating cognitive styles in AHA!. First International Workshop on Adaptable and Adaptive Hypermedia. In Proc. of the IASTED Conference on Web Based Education, Innsbruck, Austria (2004)
9. McCalla, G.: The fragmentation of culture, learning, teaching and technology: implications for the artificial intelligence in education research agenda in 2010. International Journal of Artificial Intelligence in Education, Vol. 11 (2000)
10. Dolog, P., Nejdl, W.: Challenges and Benefits of the Semantic Web for User Modelling. Workshop on Adaptive Hypermedia and Adaptive Web-Based Systems, In Proc. of the 12th International World Wide Web Conference, Budapest, Hungary (2003)
11. Devedžić, V.B.: Key Issues in Next-Generation Web-Based Education. IEEE Transactions on Systems, Man and Cybernetics Part C, vol. 33(3) (2003) 339-349
12. Gruber, T.: A Translation Approach to Portable Ontology Specifications. Knowledge Acquisition, Vol. 5 (1993) 199-220
13. IEEE Draft Standard for Learning Object Metadata, IEEE P1484.12.1/d6.4 (2002)
14. IMS Global Learning Consortium Inc., Learner Information Package (LIP) Final Specification v1.0 (2001)
15. Ronchetti, M., Saini, P.S.: Ontology-based metadata for E-Learning in the Computer Science domain. In Proc. of the IADIS e-Society 2003 Conference, Lisbon, Portugal (2003)

Content based personalization for asynchronous communication tools: the ifForum system

C. Tasso, P.G. Rossi, C. Virgili, A. Morandini

Artificial Intelligence Laboratory - InfoFactory Group
University of Udine
Udine, Italy

Abstract. The users of a large and active learning community can greatly benefit from adaptive personalization tools capable of timely selecting and recommending new incoming information which meets their specific interests. We claim that in a collaborative learning environment, personalization techniques based on cognitive filtering can be enhanced by means of social analysis tools, aimed at analyzing interrelationships and communication among users as well as their evolution over time. In this paper we present ifForum, a discussion forum included in MyTWM, an innovative e-learning platform for blended learning. ifForum features advanced tools for monitoring social interactions among users combined with adaptive content-based (semantic) filtering used for analyzing the conceptual content of messages posted in the discussion forum. This technique should allow new more effective recommendation patterns, reducing in this way information overload. The project is currently ongoing and the paper describes the first achievements and the results of the first experiments.

1 Introduction

E-learning environments can greatly profit from the features offered by the new personalization techniques for accessing to information [Tasso & Omero 2002]. There are several reasons for this claim, the most important one being that the amount of information available to the learner is very huge, coming from several specific sources, providing both structured and unstructured information. Consider for example thematic data banks and repositories, as well as all the (synchronous and asynchronous) communication and cooperation tools, like discussion forum and chat. When a learning community is large and very active the amount of information and the incoming flow of new information constitute an 'information overload' problem for the single learner, which becomes unable to read all the available information and to select the information most relevant from him/her. Personalization techniques can help the user by timely recommending specific individual information which meets his/her specific interest, searching and filtering the different information sources. Another specific aspect of the e-learning context is the role of the tutors, which are engaged in several activities which also can greatly benefit from personalized information tools, especially for monitoring learners and assessing both qualitative

and quantitative aspects of their participation [Rivoltella & Ardizzone 2003] [Rossi & Toppano 2003].

This approach relies on user modeling techniques [Brusilosky et al. 2003]: personalization can be obtained by means of personalized adaptive information filtering tools, capable of representing interest profiles of the users and of matching them against the new, incoming documents. Besides information filtering, recommendation for communication tools such a discussion forum can be based on 'social' considerations: the user of an e-learning system is indeed a member of a learning community and a recommender system should profit also from the dynamics taking place within the discussion forum, knowing the level of participation, the ways of interaction, groups' interrelationships and their evolution, and so on. Collaborative filtering represents another useful technique for exploiting the behaviour of the community; social cluster of users can be created so a user model can influence (and be influenced) dynamically the other user models of the community. The benefits of such an approach are clear: the user can avoid reading a lot of useless information, and is able to locate easily (new) relevant information, saving in such a way a lot of time and cognitive effort. From a general perspective, the new personalization tools can contribute even more at a higher level, i.e. at the level of knowledge building: if we have better means for exploring a learning community (or a community of practice) [Wenger 1998] [Wenger et al. 2002], understanding how their members communicate, how they cooperatively build new knowledge, and how they organize themselves, we can ex-post re-model and improve the overall educational design [Gero 2002a] [Gero 2002b].

The aim of this paper is to present an ongoing research project devoted to experiment personalization techniques within e-learning and knowledge management systems. The research has been developed within the more general framework of the infoFactory project [Mizzaro & Tasso 2002], devoted to apply innovative adaptive tools for personalized information access on the web.

2 Related Work

Other proposals concerning the exploitation of user modeling within e-learning systems, specifically devoted to personalized information access, can be found in the literature.

In [Hernandez et al. 2003] it is presented a multiagent user modeling system in an adaptive learning collaborative environment. The system exploits several learning agents, each one including a different machine learning algorithm. The various agents classify the user behaviour, in order to recommend later to the user potentially interesting links. In [Tang & McCalla 2003] the proposal concerns an evolving Web-based learning system, with the ability of finding relevant content on the Web. This goal is achieved by means of classifying the students'

learning level (beginner, intermediate, expert) and interests and by of prompting them with appropriate lists of recommended books. A different approach is given in [Esposito et al. 2004]; the focus is on developing an adaptive personalized e-learning system capable of suggesting reading materials to students. Each user model is based on users' learning performance and communication preferences, so the educational model can be improved by adapting it to the characteristics of the single learner. Other relevant work on personalized information intermediaries can be found in [Barret & Maglio 1999].
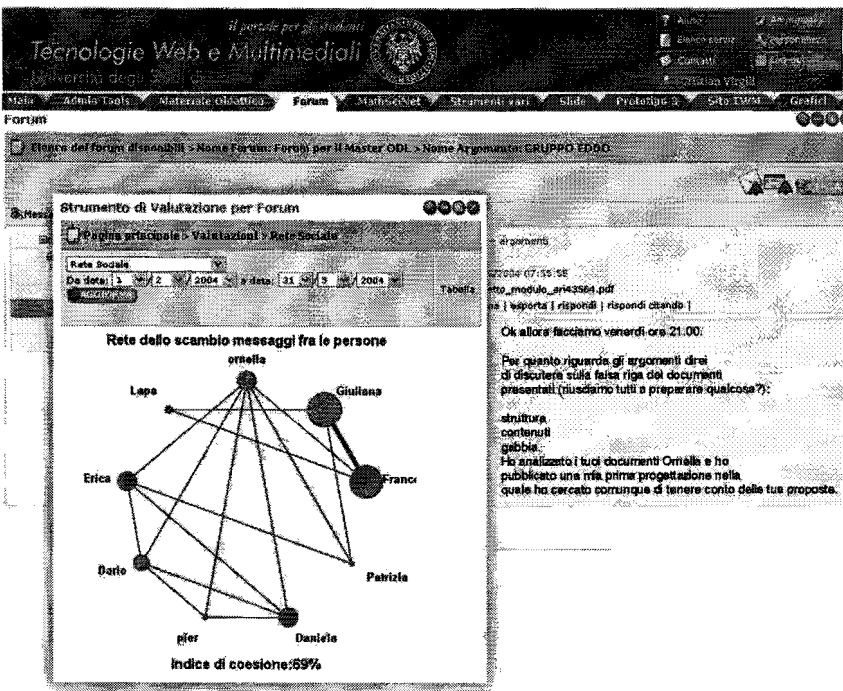
3 An innovative e-learning tool: *ifForum*

Fig. 1. Screenshots from the ifForum enviroment.

The ifForum system, shown in figure 1, is an asynchronous communication system, which is made up by a set of discussion forums; each forum contains some discussion topics, organized into several threads. Each thread is structured

in a messages tree, where the first post is the root of the tree and the consequent replies are the nodes of such tree. The ifForum is a module of the myTWM portal [myTWM], an e-learning platform utilized for blended learning at the University of Udine. MyTWM is an initiative developed by means of the U-Portal enviroment, an user-customizable framework for an integrated delivery of content gathered from an assortment of information sources [uPortal].

Besides standard features, ifForum provides some advanced features intended for both generic users and tutors. The features for the users include: on-demand alerting on new messages sent to a selected discussion thread (which can be received by email or sms), fully XML SCORM-compliant and exportable forum structure and messages, a WYSIWYG html editor and a user rating system to rate the quality of other users' messages. On the tutor side, the most interesting features are: an hierarchical group manager, the possibility to edit the users/group permission to read and manage a forum (topic and thread) and a set of tools capable of monitoring social interaction among users (actions comparison, network's interactions visualization, eigenvector centrality, clique analysis, principal component analysis and some other tools) and the attributes of topics/threads (ramification index of threads, evolution over time, number of participants, etc.). In the next section we will briefly illustrate how content-based analysis and social information can be intergrated in order to provide better personalized recommendations.

4 Personalization tools in *ifForum*

Figure 2 illustrates the overall architecture of ifForum: it can be noticed that beside the standard posting database, ifForum includes also the capability for the participant to download/upload documents from/to shared repositories.
The approach to personalization is hybrid and it is obtained by means of two main mechanisms: adaptive information filtering and analysis of social interaction. As illustrated in figure 2, the first one is based on cognitive filtering techniques. Individual profiles are adaptively built for each individual user on the basis of the conceptual analysis of the information he reads or writes, such as messages of the discussion forum as well as documents posted or downloaded by him in shared repositories. Whenever new information is available (both in the discussion forum or in the document repository), it is analyzed in order to identify its conceptual content and it is matched against the user profile. If the matching score is above a given threshold, the user is alerted. The Conceptual Semantic Analyzer and the Conceptual Matcher follow the IFT information filtering approach [Minio & Tasso 1996] previously developed at the University of Udine and exploited in all the filtering, classification and crawling tools of the infoFactory [infoFactory].

Personalization based on social interaction is approached by taking into consideration information which is collected during normal operation of the forum:
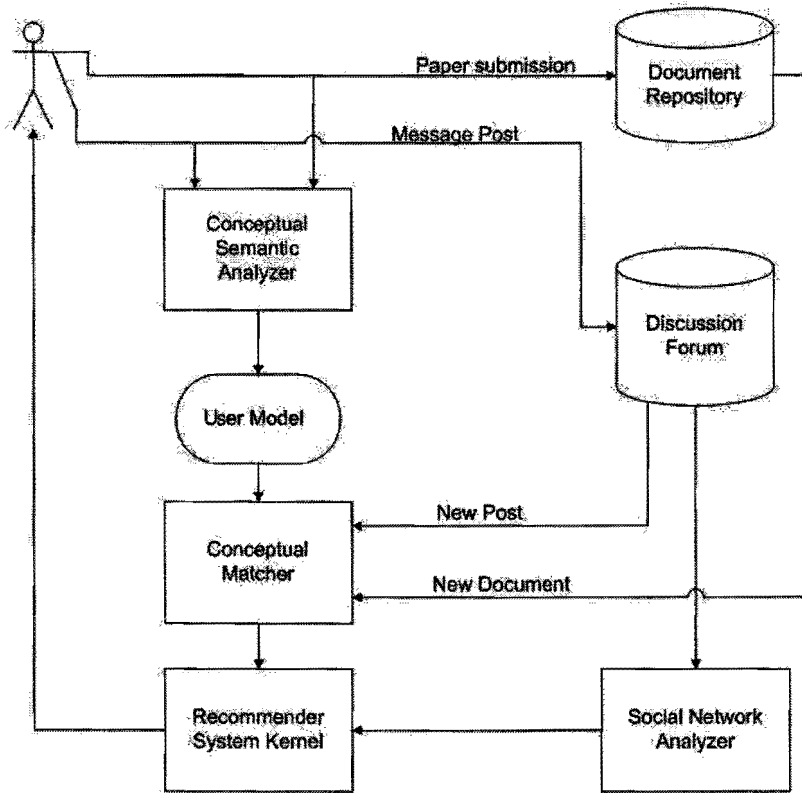
Fig. 2. The hybrid approach to personalization in ifForum.

usernames, timestamps, and actions performed (visualizing, posting, replying). The tree structure of the postings allows to infer the interaction that took place among users. So it is possible to reveal the hidden social structure of the community (leaders, information bridges, clusters of users, etc.) that can be used for empowering (personalized) recommendation.

The Recommender System Kernel produces two kind of actions:

- *Normal Personalized Suggestions.* New relevant information is prompted to a specific user.
- *Extended Recommendation.* Whenever a user is recommended some potentially relevant information and the same user is also a leader (and/or a member) of a specific cluster of users, the same recommendation can be sent to all the members of the cluster.

A further possibility is to discover different clusters of users, which share an interest for similar contents. Further strategies for hybrid recommendation are currently being evaluated within an experimental activity concerning the real use of ifForum.

Another major goal of the proposed hybrid approach, that goes beyond the specific personalized adaptive services offered to individual users, concerns the educational design level. More knowledge of personal user interests and of the social relationships actually taking place in the community, allows a better, more coherent and autopoietic tuning of the educational design. The (adaptive) coherence of the three levels (contents, relational, educational) is indeed a major potential outcome of the proposed approach, to be verified in the ongoing and planned experimental activities [Rossi 2004].

5   Evaluation and Conclusions

The development of ifForum is underway. During March 2004, the baseline including all standard features and all the social analysis tools has been completed and systematically tested. A first validation experiment was carried out with a group of 25 real users working for three months on the system, reaching a total of more than 13 thousands single operations. The evaluation has been based on qualitative scores provided by the users, as well as comments posted in a specific threads of the forum. The data gathered, still under processing, proved useful for incrementally improving the design of the system. The social analysis tools received a first very positive assessment, being considered very useful for providing (to the teacher/tutor) an effective and a immediate global view of the learning community.

Currently, we are developing the personalization module, by reusing cognitive filtering components developed within the infoFACTORY and, at completion of the first prototype, a systematic evaluation is planned, both in e-learning and knowledge-management contexts.

References

[Barret & Maglio 1999] Barrett R., and Maglio P. P., Intermediaries: An approach to manipulating information streams. *IBM Systems Journal* 38, 1999, 629-641.

[Brusilosky et al. 2003] Brusilosky, P. Corbett A. and de Rosis F. (Eds.), *User Modeling 2003, Proceedings of UM 2003 - 9th International Conference on User Modeling*, Johnstown, PA, USA, June 2003, SpringerVerlag, Berlin, LNAI 2702, 2003.

[Brusilosky & Tasso 2004] Brusilosky P. and Tasso C., Preface to Special Issues on User Modeling of Web Information Retrieval. *User-Modeling and User-Adapted Information* 14(2-3), June 2004, 147-157.

[Esposito et al. 2004] Esposito F., Licchelli O., and Semeraro G., Discovering Student Models in e-learning Systems. in *Journal of Universal Computer Science* 10(1), 2004, 47-57.

[Gero 2002a] Gero, J.S. Computational models of creative designing based on situated cognition. In T. Hewett and T. Kavanagh (Eds.),*Creativity and Cognition 2002*, ACM Press, New York, NY, 2002, 3-10.

[Gero 2002b] Gero, JS (Ed.) *Artificial Intelligence in Design'02*, Kluwer, Dordrecht, 2002.

[Hernandez et al. 2003] Hernandez, F., Gaudioso, E., and Boticaro J.C., A multiagent approach to obtain open and flexible user models in adaptive learning communities. In P. Brusilosky, A. Corbett, and F. de Rosis (Eds.), *User Modeling 2003, Proceedings of UM 2003 - 9th International Conference on User Modeling*, Johnstown, PA, USA, June 2003, Springer Verlag, Berlin, LNAI 2702, 2003, 203-207.

[infoFactory] http://www.infofactory.it, The infoFactory group.

[Minio & Tasso 1996] Minio, M., and Tasso, C., User Modeling for Information Filtering on Internet Services: Exploiting an Extended Version of the UMT Shell. *UM96 Workshop on User Modeling for Information Filtering on the World Wide WEB*, Kailua-Kona, Hawaii, USA, January 1996.

[Mizzaro & Tasso 2002] Mizzaro, S., and Tasso, C., Ephemeral and Persistent Personalization in Adaptive Information Access to Scholarly Publications on the Web. *Proceedings of AH2002 - Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems*, Malaga, Spain, May 2002, SpringerVerlag, Berlin, LNCS 2347, 2002, 306-316.

[myTWM] http://twm.dimi.uniud.it, The infoFactory group.

[Rivoltella & Ardizzone 2003] Rivoltella, P.C., and Ardizzone, P., *Didattiche per l'E-learning*, Carocci, Roma, 2003.

[Rossi 2004] Rossi, P.G., Progettazione e gestione di ambienti on line. In *B. Tellia (Ed.) E-learning*, Forum, Udine, 2004.

[Rossi & Toppano 2003] Rossi, P.G. Toppano, E., Open Distance Learning and the knowledge-building in computer conference debate. *Girep 2003*, Udine 3 Settembre 2003.

[Tang & McCalla 2003] Tang, T.Y., and McCalla, G. Applications of data mining to electronic commerce. *AIED Artificial Intelligence in Education*, 2003.

[Tasso & Omero 2002] Tasso, C. and Omero, P. *La personalizzazione dei contenuti Web, e-commerce, i-access, e-government*, Franco Angeli, Milano, 2002.

[uPortal] http://www.jasig.org/, uPortal v. 2.1.5, The JA-SIG Collaborative, 2003.

[Wenger 1998] Wenger, E., *Communities of Practice: Learning, Meaning, and Identity*, Cambridge University Press, New York, 1998.

[Wenger et al. 2002] Wenger, E., Mc Dermott, W., and Snyder, M., *Cultivating Communities of Practice*, Harvard Businnes School, Harvard, 2002.

Authoring Topic Maps-based Digital Course Libraries

Darina Dicheva, Christo Dichev, Yanli Sun, Somath Nao

Winston-Salem State University, Computer Science Department,
Martin Luther King Jr. Drive, Winston Salem, NC 27110, USA
{dichevad, dichevc}@wssu.edu

Abstract. Digital course libraries are educational Web applications that contain instructional materials to assist students' learning in a specific discipline (course). To address the critical issues of findability and reusability of learning resources, we propose a general framework for standards-based, ontology-aware course libraries and use it to develop an environment for building, maintaining, and using such libraries. The proposed environment, TM4L (Topic Maps for Learning), is based on the new ISO standard XML Topic Maps that provides a paradigm for organizing and retrieving online information and for interchanging semantic information on the Web. In this paper we present the TM4L authoring tool for creating ontology-aware Topic Maps-based repositories of learning materials (TM4L Editor).

1 Introduction

Digital course libraries are educational Web applications that contain instructional materials to assist students' learning in a specific discipline (course) and support students' course-related work aimed at reinforcing their knowledge. They play a vital role in out-of-class learning, especially in project-based and problem-based learning, as well as in lifelong learning. Digital course libraries are expected, from one side, to provide learners with powerful and intuitive search tools that allow them to efficiently access learning resources, and from another, to support instructors with powerful authoring tools for efficient creation and update of instructional materials. The latter is closely related to the issue of *reusability* and *shareability* of learning content, which in turn is concerned with both the existence of shared agreement on the content and the standards-based representation of the materials.

We address the problems of findability, reusability and shareability of learning materials in digital course libraries by suggesting the use of Semantic Web technologies in creating them. More specifically, we propose a framework for digital course libraries that incorporates a meta-layer – *semantic layer*, based on conceptualization of the course subject domain. The fundamental idea is to build those libraries as both *concept-based* and *ontology-aware* repositories of learning objects [1]. Further on, we propose that the implementation of such libraries is based on the ISO XTM standard - XML Topic Maps [2]. Topic Maps (TM) [3] are an emerging Semantic Web technology, that can be used as a means to organize and retrieve information in e-learning repositories in a more efficient and meaningful way.

The expressive power of Topic Maps, commonly perceived as a method for indexing information resources, places the standard very close to artificial intelligence and knowledge modeling. Topic Maps resemble semantic networks and conceptual graphs, but offer more - a unique, standards-based way of encoding and exchanging knowledge on the Web. Topic Maps provide an external meta-structure (a knowledge navigation layer) in form of a dynamic, semantically based hypertext. As a result, TM-based courseware can offer the following benefits [4]:

- *For learners:* efficient context-based retrieval of learning resources; better awareness in subject-domain browsing; information visualization; customized views, adaptive guidance, and context-based feedback.
- *For instructors:* effective management and maintenance of knowledge and information; personalized courseware presentations; distributed courseware development; reuse and exchange of learning materials, collaborative authoring.

Currently available commercial TM software is mainly aimed at supporting rapid development of TM-based applications (e.g. Ontopia Knowledge Suite [5], Mondeca Intelligent Topic Manager [6], etc.). There are some available TM authoring tools but they are too general and good for experts in knowledge representation, not for end users. We are not aware of existing specialized education-oriented TM tools that can be used to facilitate the creation, maintenance, search, and visualization of Topic Maps-based learning resources. This was our motivation for designing the general framework for ontology-aware digital course libraries and using it to develop a specialized environment for creating, maintaining, and using TM-based learning repositories – TM4L (Topic Maps for Learning). In this paper we discuss briefly the framework and present the authoring tool of TM4L (TM4L Editor).

2 A General Framework for TM-based Course Libraries

The proposed framework is aimed at supporting the development of *ontology-aware* repositories of learning materials. It is focused on enabling authors to capture, share and access knowledge. Subject ontologies aim at capturing domain knowledge in a generic way, and provide a commonly agreed upon representation vocabulary of a subject domain, which may be shared and reused across people and applications. Ontology editing is an essential aspect for all ontology-aware systems. An important issue within ontology editing is the underlying ontology model or "structure" that is to be edited. In our framework for developing repositories of learning resources it is a network of concepts. This involves creating views of a specific domain in terms of domain concepts and relationships among them that suggest the semantics of the resources relevant to that domain. Such a conceptual structure would enhance information retrieval within the repository since the set of concepts, relationships, and inference rules defined by the domain ontology constrain the possible interpretations.

Thus the proposed general framework of ontology-aware discipline-specific repositories is based on building a conceptual structure that represents the subject domain ontology and using it for structuring and classification of learning content. The classification involves linking learning objects (content) to the relevant ontology terms (concepts), i.e. using the ontological structure to *index* the repository content.

This will allow applications and users to understand the relationships between the resources and insure efficient topical access to them. By providing shared agreement on the subjects meaning, ontologies can serve as a means of establishing a conceptually concise basis for communicating knowledge for many purposes, for example, in ontology-based merging of digital repositories. The framework utilizes the advantages of concept-based and standards-based content organization to benefit both learners and authors. For learners it supports efficient contextual retrieval of information relevant to their needs and for authors - the reusability, shareability, and exchangeability of created instructional materials.

We have proposed a layered information structure of the learning material repository consisting of three layers, each of which captures a different aspect of the library information space - conceptual, resource-related, and contextual:

- *Semantic layer*: contains a conceptual model of the knowledge domain in terms of *key concepts* and *relationships* among them.
- *Resource layer*: contains a collection of diverse information resources associated with the specific knowledge domain.
- *Context layer*: contains specifications of different views (contexts) on the library resources depending on a particular goal, type of users, etc., by dynamically associating components from the other two layers.

The developed framework for ontology-aware digital course libraries is described in detail in [1]. This general framework requires using Semantic Web technologies that support efficient organization, retrieval, and interchange of information on the Web. We chose to use the ISO 13250 XTM standard - XML Topic Maps (www.y12.doe.gov/sgml/sc34/document/0323.htm) to implement the developed framework. In the next section we discuss our implementation - the Topic Maps-based environment TM4L - and specifically its authoring tool, the TM4L Editor.

3 The TM4L Editor

Ontology-aware e-learning applications must provide support for both ontology development and ontology usage. In the last decade a number of tools for ontology construction have emerged (see [7]); however, they are not particularly appropriate for use in a TM-based environment. Although some currently available ontology editors such as Protégé-2000 [8] have plug-ins, which allow exporting ontologies to Topic Maps, they do not support essential TM features that can be of significant importance for reusability and sharability of e-learning content and interoperability of e-learning applications, in particular:

- *published subjects* (can provide a platform for interoperability),
- *merge* of topic maps (can support individual or collaborative authoring),
- *scope* (can be used to implement adaptivity through defining contexts).

Thus our goal was to develop an authoring environment guided by two considerations: conformance to the TM standard coupled with facilitating the task of e-learning content authoring. Taking into account these considerations, we have designed an environment, TM4L, which enables the creation, maintenance, and use of ontology-aware courseware based on the ISO standard – Topic Maps. Ontologies and Topic

Maps are complementary tools that aim at giving a more global vision than terminologies, thesauri and concepts systems. While ontologies provide semantic interoperability, the Topic Maps specification ensures syntactic interoperability.

The TM4L environment consists of a TM Editor and a TM Viewer. We have currently completed the TM4L Editor, which is an ontology editor allowing the user to build ontology-driven learning repositories using Topic Maps. It provides ontology and metadata engineering capabilities coupled with basic document management facilities. The TM4L Editor benefits from the Topic Maps' fundamental feature to support easy and effective merge of existing information resources while maintaining their meaningful structure. This allows for flexibility and expediency in re-using and extending existing repositories.

The learning content created by the Editor is fully compliant with the XML Topic Maps (XTM) standard and thus interchangeable and interoperable with any standard TM tools. The Editor can read/open external XTM files directly, i.e. without any *import* pre-processing.

The TM4L Editor is Topic Maps-based, thus the main objects that it manipulates are topics (representing domain ontology concepts), relationships between them (corresponding to the TM associations), resources, and contexts (implementing the TM scoping feature). It includes four different sections (views): *Topic Map, Topics, Relationships,* and *Views.* A screenshot of the TM4L Editor interface (the Topics section) is shown on Figure 1.
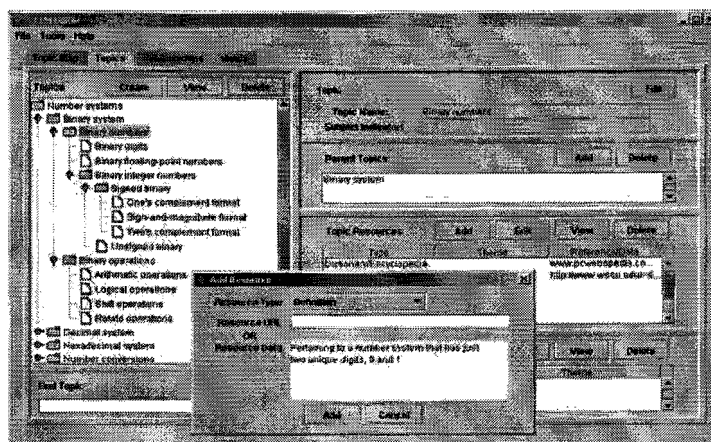
Fig. 1. A screenshot from the TM4L Editor interface.

Topic Map. In the Topic Map section the author defines metadata (Dublin Core [9] and LOM [10] compliant) for the newly created topic map. This includes: TM Title, Creator, Subject / Main Topic (keywords), Description, Publisher, Contributor, Creation Date, Last Modification Date, Location, Source TM (in case of merging TM), Relation, Coverage, IPR / Copyright. Additionally, a Topic Map Subject Indicator is specified. Some LOM tags are automatically included in the TM metadata with

334

pre-specified values, e.g. LOM 4.1 Resource Format ("text/html"), LOM: 5.1 Interactivity Type ("expositive document"), LOM: 5.3 Interactivity Level ("high").

Topics. In the Topics section the author defines, edits, and deletes topics. Each topic definition includes the following information: *subject indicator, names, types*, and related *resources*. For each new topic an ID is automatically generated.

Topic categories. Our major concern in designing the Topic Maps Editor was related to the fact that in the TM standard every subject is a topic, which is a powerful idea but will not make much sense to the uninitiated authors. Different kinds of topics are expected to be used in an educational topic map: 'concept' topics needed to build the ontological representation of the subject domain, 'utility' topics needed as metadata fillers in the topic map, for example, to specify the different types of educational resources, and 'system' topics needed to represent associations, roles in associations, and other entities required by the TM model.

In TM4L we support two distinct categories of topics: *domain ontology topics* and *utility topics*. The former are defined by and visible to the user; the latter are automatically defined by the editor when a specific authoring activity takes place (such as defining a new relationship between topics) and are invisible to the author. We use the following utility topics categories: association types, association role types, associations, occurrence types, occurrences, and themes (for scoping). The category of a topic depends on where it was created by the user, for example, if it was created as a result of user input in the 'Create Relationship Type' dialog, it is an association type.

Topic names. TM4L allows multiple topic names: one *primary* and possibly some *alternative* names. Each name can have alternate names (TM name variants) to be used for special purposes. In this application we have constrained the number of alternate names to four, corresponding to four different purposes of usage of the name: *sort, search, display,* and *draw.*

Topic Types. In compliance with the TM standard, multiple topic types are allowed. The user is given two ways to declare a topic type (or *parent topic*): either automatically by selecting an existing topic prior to the creation of the new topic, or manually in the 'Parent Topic Panel'.

Resources. Resources can be internal and external. Internal resources are short pieces of information about a concept, such as definition, short description, some characterizations, etc., stored locally in the course library. External resources can be any addressable learning objects on the Web referenced by their URI. For authors' convenience, resource types are pre-defined however the author is allowed to define their own types. We have predefined the LOM 5.2. Learning Resource Types: exercise, simulation, questionnaire, diagram, figure, graph, index, slide, table, narrative text, exam, experiment, problem statement, self assessment, and lecture. In addition, we have predefined types of learning resources relevant to characterizing subject domain concepts: definition, example, graphical representation, and simulation.

Relationships. As we already mentioned, relationships in our model are represented by TM associations. Each relationship has a type (e.g. is-component-of) and one or more *members* (concrete topics) along with the *roles* they play in the relationship. There is a pool of pre-defined relationship types (such as class-subclass) that the authors can use. In the 'Relationships' section of the Editor the author can define relationship types and roles; create relationships by specifying their types, roles, and

role players; and edit and delete relationships. When defining relationships the author selects all involved entities – relationship type, members, and roles, from presented lists, so that input errors are minimized. The scope (context) within which the assertion made by a relationship is valid can be defined in the 'View' section. If none such is present, the scope is unconstrained and the relation is always valid.

Contexts (Views). Context can be described as the circumstances in which an event occurs; a setting. It can be defined as a collection of *perspectives* (or viewpoints). In our model, authors use TM scopes and relations to define *contexts*. A scope is a set of *themes of validity* or simply *themes* that describe perspectives. Themes can be defined and applied to objects, thus scopes don't have their own definitions. In relation to scopes we follow the TM standard and allow scoping of topic names, resources, and associations. Authors define their own theme types and scope objects using them. The standard and application provided scopes are used in the ETM Viewer for information filtering.

In summary, the TM4L Editor's functionality includes the following capabilities:
- Creating and maintaining concepts.
- Creating and maintaining relationships between concepts: adding and deleting relationship types, member roles (there is no constraint on the number of members in a relationship), and relationship instances.
- Creating resources: defining resource types, adding, deleting, modifying, and merging resources.
- Creating contexts (organizing learning objects): defining different views on a Topic Map including selected topics, relationships, and/or resources.
- Storing Topic Maps persistently either in standard XTM files or in an Ozone database.
- Merging Topic Maps.
- Checking a Topic Map for broken links to external Web resources.
- Importing/exporting Topic Maps.
- External searches on the Web (through Google).

The TM4L Editor is implemented as a client-server application developed in Java and using the TM4J Topic Map Engine [11], which is an open source providing a comprehensive API that allows creating and modifying Topic Map structures stored either in-memory or persistently in a database. The Editor has open modular architecture that allows easy extension of its functionality.

Conclusion

In this paper we present work in progress that is aimed at contributing to the development of efficiently searchable, reusable, and interchangeable discipline-specific repositories of learning objects on the Web. We propose an authoring environment for supporting the development of standards-based ontology-aware online learning materials. The next step in our agenda is the design and development of a browser for Topic Maps-based learning materials. It will support learners to efficiently navigate educational Topic Maps and search for useful resources. The latter is crucial in pro-

ject-based and self-directed learning where the learners are actively engaged in re-trieval of trusted relevant information.

Acknowledgement

References

1. Dicheva, D., & Dichev, C. A Framework for Concept-Based Digital Course Libraries. Journal of Interactive Learning Research (in press, 2004)
2. Biezunski, M., Bryan, M., & Newcomb, S., ISO/IEC 13250:2000 Topic Maps: Informa-tion Technology, www.y12.doe.gov/sgml/sc34/document/0129.pdf
3. Park, J. & Hunting, S. XML Topic Maps: Creating and Using Topic Maps for the Web, Addison-Wesley (2002)
4. Dichev C., Dicheva D., & Aroyo L. Using Topic Maps for Web-based Education, Ad-vanced Technology for Learning 1 (2004) 1-9
5. Ontopia Knowledge Suite, http://www.ontopia.net/solutions/products.html
6. Mondeca Intelligent Topic Manager, http://www.mondeca.com/english/technologie.htm
7. Denny, M. Ontology Building: A Survey of Editing Tools, O'Reilly XML.COM (2002) http://www.xml.com/pub/a/2002/11/06/ontologies.html
8. McGuinness, D. Ontologies Come of Age. In Fensel, D. Hendler, D. Lieberman, H. & Wahl-ster, W. (Eds) Spinning the Semantic Web: Bringing the World Wide Web to Its Full Po-tential. MIT Press (2002)
9. Dublin Core Metadata Initiative 2003. http://www.dublincore.org
10. IEEE Standard 1484.12.1-2002, Learning Object Metadata (LOM), http://ltsc.ieee.org/wg12
11. TM4J: Topic Maps for Java, http://tm4j.org/dg-d0e35.html

Interactive Ontology-Based User Modeling for Personalized Learning Content Management

Ronald Denaux[1], Vania Dimitrova[2], Lora Aroyo[1]

1 Computer Science Department, Eindhoven Univ. of Technology, The Netherlands
2 School of Computing, University of Leeds, UK
r.o.denaux@student.tue.nl, l.m.aroyo@tue.nl, vania@comp.leeds.ac.uk

Abstract. This position paper discusses the need for using interactive ontology-based user modeling to empower on the fly adaptation in learning information systems. We outline several open issues related to adaptive learning content delivery and present an approach to deal with these issues based on the integration of two existing systems - AIMS (task-based information retrieval environment) and STyLE-OLM (interactive open learner modeling tool). The work contributes to achieving semantic-based reasoning for educational systems and shows a promising direction for the implementation of personalized educational semantic web.

1 Introduction

In the past decade we have witnessed a growing interest in applying personalization and adaptation in numerous application domains. Advanced information systems are styled in a way that enables users to quickly access information relevant for their needs [1]. Deployed in educational settings, these systems will enable offering the most appropriate resources tailored to the learners' needs.

There are two key questions in this context. Firstly, attention should be paid to the use of *technology for engineering of large amounts of domain information and resources* to appropriately tailor them to the individual preferences and knowledge state of different users. The current effort in Semantic Web research examines means for employing ontologies to achieve semantically rich, well-structured, standardized and verified content [2]. The engineering of adaptation and personalization will have to take into account the ontologies used to represent learning content. It is important to understand that adding some semantics to resources has a push effect. This enables the system, and its creators, to have control over what resources are given to the learner and, hence, to shape his/her learning. Thus, appropriate methods are required to tailor the "push" to the needs of each individual user.

Secondly, in order to retrieve the most appropriate learning objects *user semantics should be captured and used*. Typically, adaptive systems maintain a *user model* of the individual user as an overlay of the domain model in order to record the current state of the user with respect to his/her knowledge of domain concepts [3]. There are several aspects to consider: (1) initialization and gradual

maintenance of the user model; (2) quick and most relevant access point to the user; (3) accuracy of the system's assumptions about the user's knowledge, goals, task, etc.; (4) empowerment of the system's diagnosis with learner input; and (5) dealing with information not encoded in the system ontology.

In this position paper we argue that the above issues can be tackled by appropriately combining recent approaches from student modeling and adaptive information retrieval. We discuss advantages of integrating interactive ontology-based student modeling and adaptive learner content management to enable offering information resources tailored to the needs of individual learners. Two systems, developed by us in previous studies, are used to show how their integration enables rapid learner modeling that captures the dynamics of the learner's knowledge and ensures effective personalized learning content management.

Next in the paper we will present the need for integrating ontology-based learner modeling into adaptive learning content management systems and will point at issues that have to be tackled (Section 2). We then show in Section 3 how adaptive learning content management (illustrated in AIMS) [4] and interactive ontology-based student modeling (illustrated in STyLE-OLM) [5] may be used to address the open issues. We argue that the integration of these independently developed systems, as presented in Section 4, will enable capturing the user's view of domain ontology and course structure which will empower the personalized learner support provided by AIMS. Finally, our work will be put in a larger context and future plans will be sketched out.

2 The Context

In this section we will outline the context of our research with the help of three user scenarios. We consider a situation where a learner has to explore materials from a large repository in order to accomplish a learning goal. Each learning object is linked to a list of concepts that, according to the beliefs of the creator of the object, will be mastered when the learner studies the object content. For the sake of clarity, we will use here concepts from the topic *Learning about Linux* which includes main concepts needed to understand how the Linux operating system functions (domain concepts are shown in `typewriter`).

2.1 Scenario 1: The Cold Start Problem

Bill is a Computing student and has an assignment that requires using the `Linux operating system`. Bill happens to have previous experiences with the `Microsoft Windows` and `MS-DOS operating systems` and already knows about `operating systems`, `file systems`, and `command-line interfaces`. Bill has been advised to use a web-based system that provides learning materials on Linux. His goal is to log to the system and quickly learn how to copy his files from a floppy disk and how to compress them, as required in his assignment.

Some adaptive systems would allow Bill to directly search for concepts of interest or to choose a topic to study from a list of contents [6]. In this case,

the system cannot accurately diagnose Bill's goals and prior knowledge based on his choice. The system may provide learning objects confusing him as they may contain unfamiliar concepts. Furthermore, Bill's goal of working with learning objects may not necessarily correspond to the goal defined by their creators.

In other adaptive tutoring systems Bill may have to do a predefined test allowing the system to extract a model of his domain knowledge [6]. This may have a negative effect on Bill's learning motivation because of both the unpopularity of the tests and the learning distraction that testing may cause.

Now imagine a content management system which first *interacts* with Bill in the form of a short dialog to determine his previous knowledge and how it relates to his learning goal. To be domain independent, the interaction should be guided by a generic dialog planning mechanism linked to reasoning about the course domain and structure. As a result the system will extract an *initial learner model* which will determine an adequate starting point for Bill and will further recommend appropriate learning objects.

2.2 Scenario 2: Semantics is Defined Solely by a Course Creator

Linus, as opposed to Bill, has quite some experience with Linux, but he also wants to use resources to learn more about Linux. Suppose now that both Bill and Linus want to learn more about user accounts and file security.

Some adaptive systems would offer different courses, e.g. for beginners, intermediate, and advanced learners. Stereotyping in learning systems is prone to problems. It is difficult to define a general meaning for each of the above categories, let alone to correctly classify a learner into one. However, the main drawback is that it is almost impossible for the course creator to consider the specific goals of each learner and to determine the concepts he will refer to when trying to understand a topic within each category.

What one ideally wants is the system to use a user model in *combination* with the domain, course and resource knowledge to attend the needs of each learner as best as possible. Choosing resources will *depend on the learner's semantics* of what the goal is and what concepts are relevant rather than on the semantics pre-encoded by experts unaware of the specific needs of each individual learner.

2.3 Scenario 3: Inaccuracy and Dynamics of the Learner Model

Assume that both Bill and Linus have spent considerable time with an adaptive course management system. Based on some user modeling mechanisms, e.g. tests or tracking the user's interactions with learning objects, the system builds a model that represents the user's understanding of the domain [6].

The diagnostic mechanism may produce inaccurate learner models. For instance, the correct answers in tests may be guessed and may not necessarily be based on domain understanding. In addition, the system's judgment about the learner's understanding based on pre-encoded ontology and on reading a document, may often be inaccurate. For example, let us suppose that Bill and Linus

both have read a document about user accounts that includes other domain concepts, such as file system, root, file permissions, etc. Bill may be able to create a link between user account and file permissions but may be unsure of all relations between these concepts, while Linus, who already has some knowledge of both concepts, will be able to understand deeply what their relations are. Reading the document, Bill may also discover the link between file system and root, although that link is not explicitly discussed in the document on user accounts. Linus, being confident of his knowledge on user accounts, may skim through the document and, thus, miss some elaborated domain concepts' relations but the system may not have any means to account this.

Furthermore, the learner modeling mechanism may not be able to capture the dynamics of the user's knowledge. For example, Bill and Linus may use other resources to learn about Linux. They may test what they have learned in practice, and may compare their experience with that of fellow students. Their learner models will evolve: more beliefs will be acquired and existing ones will be refined. It will be impossible to capture the dynamics of the learner's knowledge with conventional diagnostic mechanisms.

A desired situation would be to have some combination of *open learner modeling* [7] and *guided diagnostic interaction* [5]. For example, after a knowledgeable learner (like Linus) finishes with a learning object, a clarification dialog can be initiated to enable the learner to identify learned concepts and discovered domain relations. For less knowledgeable learners (like Bill) the clarification dialog may be triggered by showing them their learner models, as discussed in [5].

2.4 Open Issues

The scenarios presented above highlight the following open issues:

- **Dealing with cold start.** Adaptive systems face problems to deal with first time users for whom a user model is not accumulated yet. Rapid user modeling techniques are needed.
- **Use of previous knowledge and experience.** The same document can have different learning effects on different people depending on their prior knowledge. Methods for diagnosing the user's prior knowledge are needed.
- **User models based solely on analysis of learner-system interaction are inaccurate.** In real life, teachers use implicit ways to assess the students' results and performance. Learning systems need explicit mechanisms to clarify the obtained learner models.
- **Semantics of the course author and the learner may differ.** This leads to inaccurate learner diagnosis or inappropriate recommendation of relevant material. Furthermore, such difference justifies why one cannot rely only on the learners' opinion of their domain knowledge (as in open learner models [7]) and that some clarification dialog is needed.
- **The course author's goals and the learner's goals may differ.** Most educational systems assume these two goals are equal and do not adapt to special goals the learners might have. Mechanisms for clarifying the users' goals are critical for providing effective recommendations and guidance.

- **The learner's goals, preferences, and knowledge evolve**. The changes in the learner model are not only gradually between the start and end of the course, but also temporarily during a certain session. Appropriate mechanisms for capturing this dynamics should be employed.

We argue that a fruitful approach to address the above issues is the combination of interactive user modeling and adaptive educational content management.

3   Possible Technologies

This section will briefly outline two existing systems focusing on how they tackle some of the open issues, and will justify the need for their integration.

3.1   AIMS: Adaptive Learning Content Management

AIMS is an *information handling support system* focused on an efficient information provision for *task-oriented problem solving*. It offers adaptive contextual support (through its Search and Browse Tool) that enables users to identify information necessary for performing a particular learning task [4]. As a consequence of the task-orientation, AIMS focuses on the classification of the knowledge in the application (application semantics). Thus, concept-based representations of the content play a pivotal role in modeling the domain content (*domain model*) and the user (*user model*), but also in modeling the application problem-solving strategies (*task model*) and the adaptive mechanisms employed in the system (*sequencing model*). The strict separation between domain-dependent and application related issues and the resources themselves, allows for flexible solutions and reusability. It offers a good content/information basis for adaptive recommendations (as illustrated in the three scenarios), where the domain and the sequencing strategies can be changed easily in order to achieve adaptation.

Adaptive task-based systems like AIMS appear to be especially effective in learning and training oriented application areas, where the sequencing of content, and the concept-based visualization of search results and domain concepts, proves to be a good instrument to guide the user through the material. A key role for achieving this adaptation is played by the user model (its construction and use by both the system and the learner).

AIMS is an example of an adaptive system that suffers from open issues outlined in Section 2.4, e.g. cold start problem, lack of alignment between author's semantics and learner's semantics and lack of understanding of the user's goals (and adapting to them). There is a need for empowering AIMS with user modeling approaches to allow for rapid user modeling, accuracy in the user assessment and alignment of the user's goals and semantics with the ones of the course author. Some of the aforementioned problems are addressed in STyLE-OLM.

3.2   STyLE-OLM: Interactive Ontology-Based Student Modeling

STyLE-OLM is a learner modeling system where a learner model is constructed with the active participation of the learner being allowed to inspect and discuss

the content of the model the computer builds of him/her [5]. The system is based on a computational framework for interactive open learner modeling that includes a *domain ontology, discourse model,* and belief mechanism for *maintaining a jointly constructed user model.* The framework is fairly general and fully domain independent, two instantiations of STyLE-OLM in a Computing and Finance domain have been demonstrated. STyLE-OLM deals with an *extended overlay learner model* that captures not only correct and incomplete learner beliefs (i.e. overlay upon the domain ontology) but also erroneous beliefs (that are not confirmed by the domain ontology). Patterns of the learner's reasoning that might cause erroneous beliefs are also modeled.

The interaction in STyLE-OLM is in a graphical manner and has two modes: DISCUSS, where the learners discuss aspects of their domain knowledge and influence the content of their models, and BROWSE, where the learners inspect the current state of their models. Throughout the discussions, the system makes plausible inferences about what is further believed by the learner on the basis of what is explicitly asserted, and from this a *dialog strategy* is determined. Important in the context of this paper is that STyLE-OLM can be adapted by changing its dialog strategies to tackle knowledge alignment issues, e.g. by following studies about differences that may occur between conceptual models of people [8]. Knowledge probing strategies could also be added to articulate the learner's conceptualization at the beginning of a session.

STyLE-OLM and AIMS are complementary, their integration, discussed below, allows us to address issues outlined in Section 2.4.

4 Integration of AIMS and STyLE-OLM

There are several opportunities for integrating features of both systems (see Figure 1). As pointed in Section 3.1, the architecture of AIMS has to be extended with an appropriate user modeling component. STyLE-OLM is the kernel of this component, as it provides a dialog-based interaction with the user and is a rapid way for extracting information about the user.

4.1 The Role of Ontology in the Integrated Architecture

Both STyLE and AIMS have used ontologies developed for their specific needs. The use of ontologies, especially if they are based on standards, provide several advantages: *extensibility and flexibility* (we can plug in other ontologies or relate our domain ontology to a top ontology), *interopability* (we can share ontologies with other applications) and *reusability of previous work* (we can use existing tools and methods for eliciting, aligning, parsing and visualizing ontologies). A stimulating discussion on these issues in a broader scope is given in [9]. AIMS has already been moved towards supporting standard ontology languages like OWL. STyLE-OLM is being adapted for dealing with a domain ontology encoded in OWL, as well as for maintaining a user model represented in OWL. Using a *common ontology encoded in OWL* is critical and will ensure interoperability of
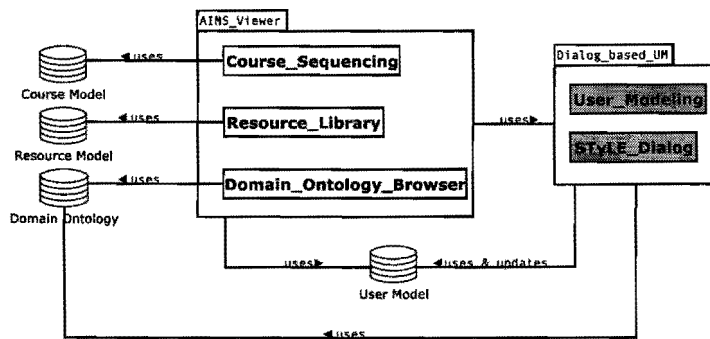
Fig. 1. Integrated architecture of AIMS, STyLE-OLM and user modeling component.

components of both systems and wide application of the integrated system. The other key aspect of the integration is the *common user model*, discussed below.

4.2 Information Related to the User Model in AIMS

Each of the information models (domain, resource library and tasks) of AIMS has some relation to the user model. The domain model provides a point of reference to be used for building an extended overlay learner model. The resource library model is related to the user model by keeping track of which resources have been used by the learner and measuring the learning effects of the resources on the learners. The tasks model in AIMS can be a source of meta-level information about the user and the domain, as it provides the following information:

- **Purpose of the current task.** Each task in AIMS has a purpose which corresponds to the goal the teacher has in mind for the student when performing the task. In practice, the goals of the student might differ from the intended purpose of the course author. Examples of purposes are: Learning new concepts, Brushing current knowledge about some concepts, Reviewing some topics which are already known, etc.
- **Focus of the task.** Each task in AIMS is related to a set of concepts X which the learner should learn about. It can be used to maintain the learner's focus on the current task.
- **Ideal or standard learning path.** The tasks model contains information about pre-conditions and learning effects of tasks. This information can be used to infer which concepts are basic knowledge for the course (concepts required by most of the tasks) and which are intermediate or advanced knowledge. This information could be used to try to solve the cold start problem by using STyLE-OLM to determine the learner's knowledge about concepts required for tasks.

344

4.3 Analysis of the User Model in AIMS with STyLE-OLM

The previous paragraphs discussed how the current information in AIMS about domain, course and resources can be related to user modeling information. We will now discuss how the user model itself can be used in AIMS and how STyLE-OLM can be used to extract parts of the user model and as an interface between the system and the user.

- **Validating task and resource effects.** Right now, AIMS assumes that completing a task or viewing an educational resource will result in the same learning effect for every user. STyLE-OLM can be used as a review of the task or resource to find out what the learner's knowledge is after completing the task or viewing the resource. Depending on the desired quality of the UM, this STyLE-OLM interaction could be done after every task or after a series of tasks or only when a user requests such a review.
- **Tackling the cold start problem and aiding with the task sequencing.** STyLE-OLM could use the tasks model to determine which concepts to probe for if no information is known about a user. In general, STyLE-OLM could be used to determine whether a user has enough knowledge for recommending a task.
- **Adaptive browsing.** AIMS can narrow down the number of concepts shown. The current task already roughly defines which concepts should be learned by the user during the task. By combining the user knowledge, preferences and goals and the specification of the current task, it is possible to determine which concepts and links are more relevant when browsing.
- **Visual representation of open learner model.** The idea behind this is to show the user what their model is. This has two advantages: (1) the user can disagree with their model and initiate a dialog with STyLE-OLM to discuss about the concepts (as a result, the learner model will be refined); (2) the user can see which concepts are little known to him/her and can decide to learn about them.
- **STyLE-OLM as an aid for understanding the domain.** When browsing the domain, users can use STyLE-OLM to focus on a certain set of concepts and discuss their understanding about those concepts. The students can have the initiative every time when starting a discussion and STyLE-OLM will answer students' questions or help the students find out what are the wrong assumptions/conclusions they make.
- **Using the UM for selecting and sorting resources.** When users want to learn more about a certain topic, they can query the resource library to find suitable educational resources. When there are several resources as a query result, these resources have to be filtered and sorted. This can be done based on the user's current knowledge, goals and preferences to determine the kind of resource most suitable for the user. Examples of preferences are preferences for a kind of material format (multimedia or only text) and preference for practical oriented resources (tutorials and examples instead of theoretical resources).

– **Articulating the learner's goals.** To be able to adapt to the user's goals we need to identify those goals. For this we may use information from the current task, a STyLE-OLM dialog or a form filled in by the user. In order to provide this kind of adaptation we need enough and appropriate annotation of the resource library. Also, because the user's goals, preferences and knowledge change in time we need a way of modeling users through time in order to maintain continuity and momentum in the learning activities. We consider the use of *episodic* and *long term* user models. During dialog episodes, a short-term, episodic user model is accummulated. It is used as a source for updating the long term user model at the end of each episode by employing STyLE-OLM algorithms based on non-monotonic reasoning.

5 Conclusions

In this paper we have analyzed the problems of current adaptive educational information systems, and have stressed the need for deploying advanced user modeling techniques to achieve more adequate personalization and adaptation to the individual user needs. We have proposed an integrated approach based on ontologies to represent both domain and user knowledge, and to maintain a user-system dialog that initializes and manages the user model. The work contributes to achieving ontology-based reasoning for personalizing the educational semantic web. There are several ongoing projects in this increasingly important research field. For example, in a recently started project McCalla, Greer, Vassileva and colleagues are employing methods from their work on distributed student modeling to attach user models to learning objects in order to obtain information for personalizing the use of educational resources [10]. Judy Kay and colleagues are adapting scrutable user modeling approaches to capture a student's understanding of ontology [11]. Simon, Dolog and colleagues discuss the use of semantic web technologies in a broader context for learner modeling, learning resource modeling and its matching for providing adaptation [9]. Our work offers an alternative approach that builds upon previous methods for interactive open student modeling and adaptive learning content management. We believe that this is a promising direction that will contribute to the implementation of personalized educational semantic web.

As a next step we aim at designing a computational framework for the use of semantic web technologies (focusing on domain ontology but also considering other types of ontologies) to enhance the effectiveness of adaptive learning systems (considering adaptation both to learners and course authors). We intend to illustrate the framework with the integration of AIMS and STyLE and perform series of user studies in order to assess the effectiveness of the approach. This work is part of the SWALE (Semantic Web and Adaptive Learning Environments) project, started in April 2004, and funded by the British Council and NWO. SWALE is targeted to: (1) identify dimensions of knowledge sharing, employed currently in semantic web technologies, that can be applied to learning systems to enable different viewpoints (contexts) on learning material; (2)

346

determine conditions which facilitate the construction of a shared ontology in learning systems to support the joint construction of educational materials and adaptation to individual teacher/learner needs; (3) develop methods to formalize the construction of shared knowledge in a pedagogical context to provide effective author guidance and learner feedback in environments for individualized learning and course delivery.

References

1. Brusilovsky, P., Tasso, C.: Special issue on user modelling for web information retrieval. User Modeling and User Adapted Interaction **14** (2004)
2. Ding, Y., Fensel, D., Klein, M.C.A., Omelayenko, B.: The semantic web: yet another hip? Data Knowledge Engineering **41** (2002) 205–227
3. Brusilovsky, P.: Methods and techniques of adaptive hypermedia. User Modeling and User-Adapted Interaction **6** (1996) 87–129
4. Aroyo, L., Dicheva, D.: Aims: Learning and teaching support for www-based education. Int. Journal for Continuing Engineering Education and Life-long Learning (IJCEELL) **11** (2001) 152–164
5. Dimitrova, V.: Style-olm: Interactive open learner modelling. Int. Journal of Artificial Intelligence in Education **13** (2003) 35–78
6. Brusilovsky, P., Paylo, C.: Adaptive and intelligent web-based educational systems. Int.Journal of Artificial Intelligence in Education **13** (2003) 159–172
7. Morales, R., Pain, H., Bull, S., Kay, J., eds.: Workshop on Open, Interactive,and Other Overt Approaches to Learner Modelling, at AIED99 (1999)
8. A. Hameed, D. Sleeman, A.P.: Detecting mistmaches among experts' intologies acquired through knowledge elicitation. Knowledge-Based Systems **15** (2002) 266–273
9. Simon, B., Dolog, P., Miklós, Z., Olmedilla, D., Sintek, M.: Conceptualising smart spaces for learning. Journal of Interactive Media in Education (2004(9))
10. McCalla, G.: The ecological approach to the design of e-learning environments: Purpose-based capture of use of information about users. Journal of Interactive Media in Education (2004(7))
11. Cimolino, L., Kay, J.: Verified concept mapping for eliciting conceptual understanding. In Aroyo, L., Dicheva, D., eds.: Proceedings of ICCE Workshop on Concepts and Ontologies in Web-Based Educational Systems. (2002) 11–16

Applying Semantic Web Technologies to Achieve Personalization and Reuse of Content in Educational Adaptive Hypermedia Systems

Lydia Silva Muñoz[1], José Palazzo Moreira de Oliveira[2]

[1]University of the Republic of Uruguay – Computer Science Department
Julio Herrera y Reissig 565 - Piso 5 - C.P.12.300 – Montevideo - Uruguay
lsilva@fing.edu.uy

[2]Federal University of Rio Grande do Sul - Instituto de Informática (II/UFRGS)
C.P 15.064 – 91.501-970 – Porto Alegre – RS – Brazil
palazzo@inf.ufrgs.br

Abstract. Ontologies and metadata standards for the Web can be used to achieve personalization and reuse of content in Educational Adaptive Hypermedia Systems. Web Ontologies can represent the knowledge of the system concerning the educational content, the domain to be taught, and the learner's profile enabling intelligent behavior in building personalized learning objects. Interoperability to reuse of content can be achieved by having the ontologies terminology based on pre-existing standard vocabularies. This paper describes how Semantic Web technologies were applied to the Adaptive Hypermedia System AdaptWeb.

1 Introduction

Educational Adaptive Hypermedia Systems keep knowledge about the student's profile and the domain to be taught i.e. the *Student Model* and *Knowledge Space* of the system [1]. What our proposal adds to the Knowledge Space is a structure describing the educational content capable of providing composition rules represented in a principled way to construct complex learning objects tailored to the student's profile, setting the stage to implement a powerful adaptation mechanism. This structure is a Web Ontology whose individuals are automatically generated each time new educative content is added to the system [2]. We achieve interoperability across the Web by the definition of an application profile of a standard metadata model envisaged to describe e-learning content. This paper describes the AdaptWeb application profile of the Learning Object Metadata (LOM) [3] standard and the representation of the Student Model and Knowledge Space of the AdaptWeb system as Web ontologies. The AdaptWeb is an in-progress research project supported by the CNPq, Brazilian National Research Council. This work is structured as follows. Section 2 describes the Semantic Web technologies used, section 3 describes the Information Space of the System and the defined Application Profile, section 4 shows the student model, section 5 gives the adaptation scenario and section 6 is a short conclusion.

2. Semantic Web Technologies

We used Web Ontologies and in particular *application ontologies* [4] to both represent the knowledge about the student profile and store explicit metadata modeling knowledge about the educational content in the system, called Student Ontology and Content Knowledge Ontology respectively. We also used a *domain ontology* [4] to represent the taxonomy of the domain being learned, called Domain Ontology. The language DAML+OIL was used to enable interoperability at the syntactic level on the Web, while the ontologies vocabularies derived from standards enable interoperability at the semantic level.

3 AdaptWeb Knowledge Space

The Domain Ontology and *The Content Knowledge Ontology*, some of whose individuals are depicted in Figure 1, forms the AdaptWeb Knowledge Space. The Content Knowledge Ontology is an ontology encoded in DAML+OIL [5] that describes the actual pieces of instructional content giving the rules to correctly assemble them (e.g. prerequisite rules defined as transitive properties). This makes the automatic computation of complex learning objects adequate for each student's profile possible by using ontology services, such as reasoning. Qualified links relate Content Knowledge Ontology elements to Domain Ontology ones indicating how each piece of the educative content approaches subjects on the Domain Ontology, e.g. *apply or define*.

Educational Content   **Knowledge Space**
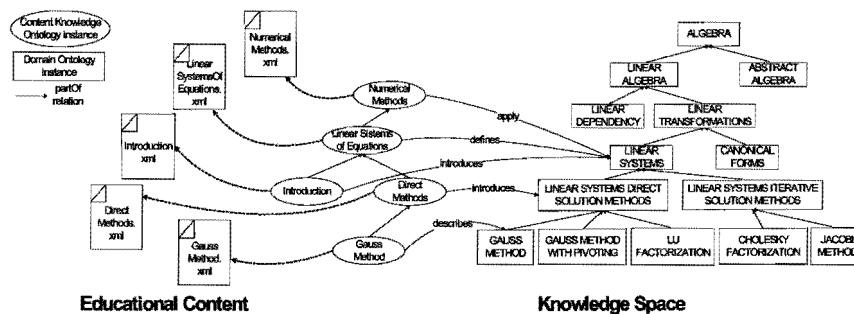
Fig.1. Instances of the AdaptWeb Information Space

3.1 Domain and Content Knowledge Ontologies

The Domain and Content Knowledge Ontologies schemas are represented in Figure 2. The abbreviation *awo* stands for Content Knowledge Ontology that defines the namespace located at http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.daml and *dom* stands for Domain Knowledge Ontology that defines the namespace located at http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.daml. Instances of class *awo:Topic* represent the explanation of some idea supported by examples, exercises and complementary material represented in classes *awo:Example*, *awo:Exercise*, *awo:Complementary* and

awo:e-Support. A topic may have sub-topics giving more specific explanations related by the *awo:isPartOf* relation. The order in which the topics are presented according to learning purposes is given by the *awo:learningPath* relation. The class awo:Course contains customizations of disciplines for students with common background knowledge and learning goals. Class *awo:Contributor* contains creators of educative content and recommenders of Web resources created and maintained out of the system context but described in class *awo:e-Support*.

Fig.2. Classes and Relations of Domain and Content Knowledge Ontology

3.3 Application profile Definition

The Learning Objects Metadata Standard - LOM [3] is a metadata standard to be used in descriptions concerning objects for learning purposes. An application profile [6] takes elements from standard schemas and eventually refines them to create a set of metadata descriptors tailored to a particular application while retaining interoperability with the original base schemas. Several application profiles of LOM such as ARIADNE [7], Heal [8] and CanCore [9] were developed, and some crosswalks providing mappings between them exist. There are a number of implementations of LOM in XML motivated by the current maturity of that language. Nevertheless, the use of RDF [10,11,12,13] to represent LOM metadata provides a standard way to reutilize Web standard vocabularies. We created a new application profile of the standard LOM based in the RDF binding presented in [14], whose elements are defined on the Content Knowledge and Domain ontologies. The elements used with no refinement were 1.3 Language, 1.4 Description, 1.5 Keyword, 2.3 Contribute, 3.3 Metadata Schema, 4.3 Location, 4.4 Requirement and 5.1 Interactivity Type. Table 2 shows the refinement of other LOM elements, for example, the relation *dcterms:requires* was refined to *awo: hasPrerequisite* standing for a learning object that is needed to correctly understand the learning object intended to be taken. This

relation was also declared as transitive, and has an inverse relation *awo:*isPrerequisiteOf, both of which are useful to inference tasks. Any web agent that can not understand our ontology specifications about the *awo:hasPrerequisite* relation can still understand the more general property dcterms:requires, and interpret the *awo:hasPrerequisite* relation with the semantics of this known property, which is the basis to achieve interoperability at the semantic level. The abbreviation dc stands for http://purl.org/dc/elements/1.1/ and dcterms for http://purl.org/dc/ terms/.

Table 2. LOM properties refinement in the AdaptWeb application profile

Ontology Property	Specialized Property	Ontology Property Description	Domain	Range
awo: hasPrerequisite	dcterms: requires	A topic necessary to take the given topic. *It is transitive.*	awo:Topic	awo:Topic
awo:isPartOf	dcterms: isPartOf	The whole of which the topic is part of. *It is transitive.*	awo:Topic	
awo: isAvailableTo	dcterms: isPartOf	To which courses the material is available.	awo:Learning Object	awo:Course
awo:customizes	dcterms:is VersionOf	A Discipline customization. *It is functional.*	awo:Course	awo: Discipline
awo:supportsTo	dc:source	Educative content supporting a Topic learning.	awo:Support	awo:Topic.
awo: isRecommended By	lom-life: educational Validator	The person responsible for recommendations to use an external learning object.	awo:Learning Object	awo: Contributor.
awo:learningPath	dc:relation	Order to present topics for learning purposes.	awo:Topic	awo:Topic
awo:creator	dc:creator	The creator of the learning object.	awo:Learning Object	awo: Contributor
awo:defines	dc:subject	The L. Object defines the subject.	awo:Learning Object	dom:Taxon
awo:apply	dc:subject	The L. Object apply to the subject.	awo:Learning Object	dom:Taxon
awo:describes	dc:subject	The L. Object describes the subject.	awo:Learning Object	dom:Taxon
awo:introduces	dc:subject	The L. Object introduces the subject.	awo:Learning Object	dom:Taxon

4 Student Model

The student ontology, encoded in DAML+OIL [5], available at http://www.inf.ufrgs.br/~tapejara/Ontology/Student.daml and depicted in Figure 3 models the main properties that characterize the student's profile. The functional property *st:hasLearningStyle* indicates the student's cognitive style of learning [15]. The property *st:hasLearning Goal* points to the course the student is taking. The property *st:wantsTutorial* indicates if the student currently prefers to work in a tutored mode.
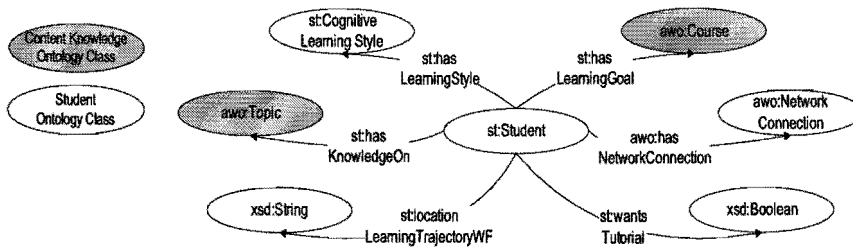
Fig.3. Student Model

The student's knowledge in each topic is indicated by instances of relation *st:has KnowledgeOn* pointing to the topics in which the student has knowledge. The functional property *awo:hasNetworkConnection* indicates the current student's network connection. The property *st:locationLearningTrajectoryWF* indicates the URL where the current learning trajectory for the student is. The remaining elements in the model are defined in the Content Knowledge Ontology and the XML Schema namespace.
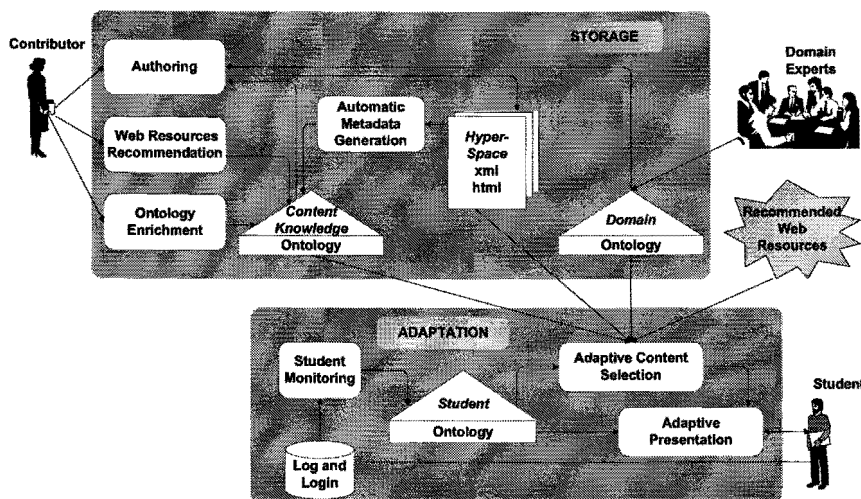
6 Adaptation Scenario

Fig.4. System Architecture

The AdaptWeb architecture showing the adaptation scenario is depicted in figure 4. During the authoring process, the author can consult the Domain Ontology and the Content Knowledge Ontology to be aware of existing learning objects concerning a given subject to eventually reuse them. Each time new content is authored, the Automatic Metadata Generation wrapper generates its fundamental metadata as RDF descriptions that are instances of the Content Knowledge Ontology. The *Student Monitoring* agent continuously updates the Student Model according to the student's

352

activities. The *Adaptive Content Selection* agent selects the contents to be presented creating a learning trajectory tailored to the student's profile based on the knowledge available about the student and the educative content. The *Adaptive Presentation* module determines the presentation style according to the student's preferences.

7 Conclusions

This paper describes how Semantic Web technologies were applied to manage metadata describing learning objects in the AdaptWeb project, delving into the definition of an application profile of the Learning Object Metadata (LOM) standard and the representation of the Student, Content and Domain models as Web ontologies. Reasoning support is possible in order to implement a powerful adaptation mechanism.

References

[1] Brusilovsky, P. Developing Adaptive Educational Hypermedia Systems: From Design Models to Authoring Tools. in T. Murray, S. Blessing and S. Ainsworth (Eds.), 2002.

[2] Silva Muñoz, L. Ontology Based Metadata for e-learning Content. Master's Thesis. Federal University of Rio Grande do Sul, Porto Alegre, Brasil, 2004.

[3] Learning Technology Standards Committee of the IEEE. Draft Standard for Learning Object Metadata (LOM) IEEE 1484.12.1-2002.

[4] Guarino, N. Formal Ontology and Information Systems. In N. Guarino (Ed.) Formal Ontology and Information Systems. pp-15, 1998, Amsterdam, Nederlands.

[5] Connolly, D. van Harmelen, F. Horrocks, I. McGuinness, D. Patel-Schneider, P. Stein, L. DAML+OIL (March 2001) Reference Description. W3C Note 18 December 2001.

[6] Duval, E. Hodgins, W. Sutton, S. Weibel, S. Metadata Principles and Practicalities. D-Lib Magazine 8(4), 2002.

[7] Ariadne. http://www.ariadne-eu.org.

[8] Heal – Heath Education Assets Library. http://www.healcentral.org.

[9] Cancore – Canadian Core Learning Resource Metadata. http://www.cancore.org.

[10] Lassila, O. Swick, R. Resource Description Framework (RDF) model and syntax specification. W3C Recommendation, 1999.

[11] Brickley, D. Guha, R. RDF Vocabulary Description Language 1.0: RDF Schema. W3C Working Draft 10 October 2003.

[12] Nilsson, M. The semantic web: How RDF will change learning technology standards. CETIS, September 27, 2001 http://www.cetis.ac.uk/.

[13] Nilsson, M. Palmer, M. Brase, J. The LOM RDF binding – principles and implementation. The 3rd Annual Ariadne Conference, 20-21 November 2003, Belgium.

[14] Nilsson, M. IEEE Learning Object Metadata RDF binding. May 2001. http://kmr.nada.kth.se/el/ims/metadata.html.

[15] Souto, M. Verdin, R. Wainer, R. Madeira, M. Wapechowsky, M. Beschoren, K. Zanella, R. Correa, J. Vicari, R. Palazzo, J. Towards an Adaptive Web Training Environment Based on Cognitive Style of Learning: an Empirical Approach. AH'2002 Conference..

A Proposal to Define Adaptive Learning Designs

Adriana Berlanga, Francisco J. García

University of Salamanca, Spain
{solis13, fgarcia}@usal.es

Abstract. In this paper we outline a framework to describe adaptive learning designs where definitions as the instructional design method, the type of tests, the learning style approach, and the adaptive rules are not prescribed. IMS LD is used to guarantee the reusability and interoperability of the elements. The framework also proposes to adjust the learning design taking into account the knowledge and learning style of the learner, and the learning style of the activities by means of adaptive rule definitions.

1 Introduction

Adaptive Educational Hypermedia (AEH) is a challenging research area that may help to improve the learning of the students, adjusting contents and navigation alternatives to their characteristics. However, to teach implies more than deliver content and paths; it is a process where learners gain knowledge and skills interacting with learning resources, activities, and other students. Learning designs details this process, considering learning goals, prerequisites, and expected outcomes to indicate learning activities, sequences and learning materials.

We intend to use learning designs as the key element to perform adaptivity in AEH, where the same learning goal can be reached by every student using learning strategies tailored to her/his knowledge and learning styles, and also, to define those strategies as semantic elements –guided by a standardized metadata– in order to make it possible their exchangeability and reusability.

For these reasons, we are defining a framework –based predominantly on the IMS Learning Design specification [4]– to configure adaptive learning designs, where the instructional design method, the type of tests, the learning style approach, and the adaptive rules are not prescribed, but open to be defined by authors of the learning experience. This framework is within an ongoing research towards the definition of AEH based on learning technology specifications [2].

In the next section we outline the framework we are developing. In section 3, we expose conclusions and describe further work.

2 Adaptive Learning Designs

We propose to define adaptive learning designs modularizing their (1) learning styles, (2) tests, (3) learning designs, and (4) adaptive rules. In the rest of this section we introduce these definitions.

2.1 Learning Style Definition

Learning styles, which establish indicators on how learners perceive and process information, might be helpful to design learning materials suitable to the way each learner learns. The Kolb's Experiential Learning Theory [6] is a well-known example of a learning style approach. It proposes four dimensions to characterize the way the student perceives information (theorist and activist dimensions) and the way s/he process it (reflectors and pragmatist dimensions).

Nevertheless, the proposed framework does not prescribe any learning style. We argue that different learning style approaches should be used for different fields of knowledge and types of students. Therefore, authors will use the learning style definition to specify the approach they judge is more appropriate for content and context. A learning object (based on the IMS LD {itemmodel}[1]) will be created for every learning style definition, in order to make it available to be (re)used in other learning designs.

For instance, Fig.1 shows the learning style element of the Kolb's Theory and its four dimensions. Later on, authors will use this learning style definition to depict the learning style of the students and learning style of the activities, as well as to define learning style tests.

```
<learning-style>
  <item identifierref="RES-ExpKolb" identifier="LSD_Kolb">
    <title>Kolb's Learning Style</title>
    <item identifier="LSD_Kolb_Theorist"><title>Theorist</title></item>
    <item identifier="LSD_Kolb_Pragmatist"><title>Pragmatist</title></item>
    <item identifier="LSD_Kolb_Activist"><title>Activist</title></item>
    <item identifier="LSD_Kolb_Reflector"><title>Reflector</title></item>
  </item>
</learning-style>
```

Fig. 1. Definition of a learning-style element

2.2 Test Definition

In the definition of tests, authors will describe assessments to measure the knowledge and learning style of the students. There are four types of tests: learning style, initial knowledge, current knowledge, and final knowledge. The students' results on these tests will set values that could be stored in the student model, or be used to define adaptive rules (see adaptive rule definition below), and connect them with the learning style of the activities. Also, they can be included, at run-time, in the IMS LD element <globpers-property>[2] to represent the learner's learning style and knowledge.

For instance, to define the learning style tests, we can say that the CHAEA [1] instrument will be used. The other test could be defined using IMS QTI [5].

---

[1] Group element that contains three main elements: title, item and metadata.

[2] Global personal property (portfolio-property) element used for personalization that has a different value for every user. Property operations can refer to it to operate on the value [4].

355

2.3 Learning Design Definition

The learning design definition will be modelled in IMS LD. Therefore, authors describe the pedagogical approach of the adaptive learning design defining its learning objectives, prerequisites, roles, outcomes (learning and support activities), environments (learning objects and services), and the method of instruction.

Effective instructional strategies might involve learning styles [7]. Consequently, they are included in the definition of activities and integrated in the learning design definition. For instance, Fig.2 shows, partially, the learning design definition of the "adaptive hypermedia lesson". It contains the learning activity "AH taxonomy" annotated a Kolb's learning style definition.

```
<learning-design identifier="LD-Adaptive-Hypermedia">
  <learning-objectives>
    <item identifier="LOB-AH-lesson" identifierref="RES-LOB-AH"/>
  </learning-objectives>
  <components>
    <roles>
      <learner identifier="R-learner"/>
    </roles>
    <activities>
      <learning-activity identifier="LA-AH-taxonomy">
        <learning-style>
        <item identifierref="RES-ExpKolb" identifier="LSD_Kolb">
        <item parameters="value,70%" identifier="LSD_Kolb_Theorist"/>
        <item parameters="value,10%" identifier="LSD_Kolb_Pragmatist"/>
        <item parameters="value,10%" identifier="LSD_Kolb_Activist"/>
        <item parameters="value,90%" identifier="LSD_Kolb_Reflector"/>
        </item>
        </learning-style>
  . . . .
```

Fig. 2. The definition of the learning activity "AH taxonomy"

2.4 Adaptive Rule Definition

The proposed framework is intended to make use of the authors' pedagogical approach and expertise on the knowledge field, and give them freedom to decide what characteristics and variables should be considered to perform adaptivity.

Therefore, authors will be provided with a formalism to define adaptive rules, which adjust the learning design to the students' characteristics and to the nature of the knowledge. The definition of adaptive rules starts with the description of adaptive statements that can be saved as adaptive techniques or students stereotypes [2]. Adaptive statements are defined as (BNF notation):

$$\textbf{<adaptive-statement>} ::= \text{IF <condition> THEN <action>} \qquad (1)$$

$$\textbf{<condition>} ::= \text{<element-set> [<unitary-op-set>] "("<expression> ")"[<binary-op-set>} \qquad (2)$$
$$\text{<condition>]}$$

$$\textbf{<expression>} ::= \text{[<spec-element> ","] [<value> | <binary-op-set> "," <value>]} \qquad (3)$$
$$\text{["," <relational-op-set> "," <value>]}$$

$$\textbf{<action>} ::= \text{<action-set> "(" <expression> ")" [<binary-op-set> <action>]} \qquad (4)$$

$$\text{<spec-element>} ::= \text{specific-element-identified-by-its-id (learning-design-structure-set;} \quad \text{(5)}$$
$$\text{student-set)}$$

$$\text{<value >} ::= [\text{<data-set>} |\text{<integer>} | \text{<string>} | \text{<percentage>}] \quad \text{(6)}$$

Table 1 shows the sets that can be included in the adaptive statement definition. These elements have been defined based on the IMS LD schema group {expression}[3]. Likewise, other IMS LD elements had been considered as, for instance, prerequisites, learning-objectives, or learning activities. Furthermore, we also considered actions like show-hide (from the <conditions> element), and attributes of the <activity-structure> element as sort and number-to-select.

Table 1. Collection of sets to describe Adaptive Statements

Name of the set	Sub-set	Elements
element-set	learning-design-structure	Prerequisite; Learning-objectives; Learning-activities; Activity-sequence; Support-activity
	student-element-set	Student
data-set	learning-style-set	Learning-style
	student-data-set	Initial-knowledge; Current-knowledge; Final-knowledge
	attributes-data-set	Completed; Visited; Recommended; Sequence; Selection
	time-data-set	Time-unit-of-learning-started; Date-time-activity-started
logic-set	binary-op-set	And; Or
	unitary-op-set	Not
relational-set	relational-op-set	Greater-than; Less-than ;Equal; Greater-or-equal-than; Less-or-equal-than
action-set		Show; Hide; Show-menu; Hide-menu; Sort-ascending; Sort-descending; Number-to-select

The objective to define these sets is twofold. First, to take advantage of IMS LD possibilities, and be able to exchange and reuse the definition of adaptive rules within different learning designs. Second, to give authors a simple formalism to define adaptive statements.

For instance, by means of the collection of sets, authors could create an adaptive statement that establishes that, if the initial knowledge of the student is less than 50%, a menu will show the prerequisites of the learning activity, as in the following statement:

IF Student (initial-knowledge, less-than, 50%) THEN show-menu (prerequisites)   (7)

Adaptive statements could also consider the learning style of students and activities. For example, in the following rule, the initial knowledge of the student, her/his learning style, and the learning style of the activity (i.e. 10% of the Kolb's theory dimension "Pragmatist") are taken into account:

IF Student (initial-knowledge, less-than, 50%) AND Student (learning-style,   (8)
   "Pragmatist", greater -than, 10%) AND learning-activity (learning-style,
      "Pragmatist", greater-than, 10%) THEN show-menu (prerequisites)

Afterwards, authors could use an adaptive statement as an adaptive technique or student stereotype. For instance, an adaptive technique, which configure the

---
[3] It includes operators (calculation, logical), references (learning activity, activity structure, etc.) and other elements to define conditions (If-then-else statements) [4].

behaviour of the system when students are interacting with the learning design, could consider the student knowledge to show a menu with the prerequisites (as in formula 7):

$$\text{TECHNIQUE <guidance>} = \text{IF Student (initial-knowledge, less-than, 50\%)} \qquad (9)$$
$$\text{THEN show-menu (prerequisites)}$$

Likewise, a student stereotype, which allows authors to group students considering one or more characteristics, could be defined for formula (7) as:

$$\text{STEREOTYPE <beginner>} = \text{IF Student (initial-knowledge, less- than, 50\%)} \qquad (10)$$

3 Conclusions and further work

In this paper we sketched a framework to describe adaptive learning designs where its description is open to define learning style approaches, tests, adaptation rules, and learning designs.

Currently, we are extending the functionality of HyCo, an application we developed for authoring hypermedia books, to utilize it as the learning design authoring tool [3]. The next steps are to analyze if test will be modeled with IMS QTI, and to design how the adaptive rule definitions will be generated and integrated into an IMS LD file. Then, we will test if adaptive rule definitions could work in learning designs compliant with IMS LD and vice versa.

Acknowledgments

References

1. Alonso, C., Gallego, D., Money, P.: *Los estilos de aprendizaje: procedimientos de diagnóstico y mejora*. Mensajero, Bilbao, Spain. 2002.
2. Berlanga, A., Garcia, F.: An Open Model to define Adaptive Educational Hypermedia Systems based on Learning Technology Specifications. In *Int. Workshop Web Semantics, (WebS 2004), in conjunction with DEXA 2004* (Spain, 2004) IEEE (forthcoming).
3. Garcia, F.J., Berlanga, A., Moreno, M., Garcia, J., Carabias, J.: HyCo – An Authoring Tool to Create Semantic Learning Objects for Web-based E-Learning Systems. In *Int. Conference Web Engineering, (ICWE 2004)* (Germany, 2004) LNCS Springer-Verlag.
4. IMS Learning Design Specification v.1.1. 2003. <www.imsglobal.org>.
5. IMS Questions and Test Interoperability Specification v.1.2. 2002. <www.imsglobal.org>.
6. Kolb, D.: *Experiential Learning: Experience as the Source of Learning and Development*. Prentice-Hall, Inc., Englewood Cliffs, N.J. 1984.
7. Merrill, D.: Instructional strategies and Learning Styles: Which takes Precedence? In *Trends and Issues in Instructional Technology*. Reiser *et al.* (Eds.), Prentice Hall. 2000.

Semantic Annotation Tools for Learning Material

Faical Azouaou[1], Weiqin Chen[2] and Cyrille Desmoulins[1]

[1] CLIPS-IMAG & Joseph Fourier University
BP 53, 38041 Grenoble cedex, France
{Faical.Azouaou, Cyrille.Desmoulins}@imag.fr

[2] Department of Information Science and Media Studies, University of Bergen
PostBox 7800, 5020 Bergen, Norway
weiqin.chen@infomedia.uib.no

Abstract. This paper aims at providing the specification for semantic annotation tools for e-learning. From the specific requirements of annotating learning material, we categorize and evaluate the existing annotation tools, mainly general purpose ones. We illustrate two research prototypes of annotation tools we developed, and evaluate to what extend the specific requirements of annotating learning material are reached by these research prototypes.

1 Introduction

Many uses of annotations and metadata on learning material have been described, in ecological use reports or in research project, in various contexts and various roles [1, 2]. However before people or software agents can use them, such annotations of learning material have to be created, automatically or manually. Currently few tools exist dedicated to this particular task of annotating learning material.

This paper[1] aims at explaining the specificity of annotating learning material and providing specifications for automated and manual annotation tools for e-learning. To come to such specification, we start from two different viewpoints. The first is the specific requirements that the e-learning context brings for annotation tools. The second is a review of existing annotation tools, mainly general purpose ones. As most of these tools are quite similar, we analyse their characteristic properties and categorise them to three most important factors as regard to semantic web and e-learning. We then evaluate the strength and weakness of each category regarding the requirements we have specified for annotating learning material.

We further illustrate on two examples of annotation tools we have developed in France and in Norway. We demonstrate how it is possible to define the functionalities of annotation tools for a specific use taking into account our requirements and adapting functionalities of general purpose tools of the same category.

---

2 Requirements for e-learning annotation tools

General annotation tools usually provide domain-independent annotation supports. They are designed to fulfill the general requirements such as ease of use, efficiency, etc.[3]. However, these tools do not take into considerations of special requirements for special domains. For example, in the context of e-learning, the annotation of learning material has different requirements. Below we list the requirements for e-learning annotations tools:

Usefulness: takes into account teaching/learning context
    1.1. Teaching/learning domain (topics to be taught).
    1.2. Teaching/learning objectives and the addressee of the annotation.
    1.3. Teaching/learning activities (exercise, lab work, lesson, field studies, etc.).
Shareability: enables teaching/learning actors to communicate through annotation.
    2.1. With an explicit semantic related to the teaching/learning context.
    2.2. By complying with e-learning standards (LOM, IMS-LD, etc.).
    2.3. By the means of the visual form of the annotation are used to.
    2.4. By enabling to share annotation with others in the same e-learning context
Usability
    3.1. Annotation made manually does not disturb teaching/learning activities
    3.2. Annotators are put in their usual teaching/learning context while annotating.

3 Characterizing and evaluating existing annotation tools

In this section we discuss the different definitions of annotation in various contexts. We further review existing tools, mainly general purpose ones, based on the requirements of annotating learning material.

As there are many annotation tools and most of them are quite similar, our method is to extract properties characterising them. Focusing on the three most important ones as regard to semantic web and e-learning, we obtain a reduced number of categories on which we can situate each annotation tool.

3.1 Annotation definition and properties of annotation tools

According to the Merriam-Webster on-line dictionary [4], an annotation is *a note added by way of comment or explanation or the act of annotating.* This definition, as many definitions from research literature, specifies that an annotation is both an object added to a document and the activity that produces this object. This twofold view on annotation is also reflected in the formal definition we present hereafter.

Euzenat [5] formalized semantic annotation in the context of the Semantic Web. From two sets of objects, documents and formal representations, two functions can be created: a function from document to formal representations, called *annotation* and a function from formal representations to documents called *index.* The corresponding

activities are annotation and indexing. So, we can also formalize non-semantic annotation as a function from documents to non-formal representation, and the activity to create this function.

To extract properties characterising annotation tools, we studied the annotation activity and what characterises it. We established that the annotation activity on a computer depends on three main factors:

- The author of the annotation (the annotator).
- The addressee of the annotation (the user of the annotation).
- The fact that the annotation is semantic or not (see previous section).

These three factors provided us four properties of annotation tools:

Automatic versus manual annotation: Annotating is the process that creates a function from a document to a representation, formal or not formal, creating such a function involves three sub-processes. To choose a document or a part of document to be annotated (source); to choose the element of representation that is the result of the function (target) and finally to define the properties of the function itself. Consequently, automatic annotation means that the three annotation sub-processes are performed automatically by a software agent; manual annotation means that they are performed by a human agent, even if he/she uses software tools for that and semi-automatic annotation means that the human agent is helped by the software tools to perform at least one of the three annotation sub-processes.

Cognitive versus non cognitive annotation: Two properties describe the annotation addressee. The first is the cognitive aspect of the annotation, representing whether annotation can be handled by human, in this case, annotation has a visible shape, we call it "cognitive annotation" [6].

Computational versus non computational: The second aspect describing the annotation addressee is whether the annotation is aimed to be used by a software agent (computational) or no (non computational).

Semantic versus non semantic annotation: The third factor characterising annotation activity on a computer is the fact that it has an explicit semantics for the computer, and not only for the human that created it or handle it.

3.3 Evaluating annotation tools

The three main factors provided us with four dimensions to group and evaluate annotation tools:

- The author: automatic, manual or semi-automatic annotation.
- The addressee: cognitive versus non cognitive annotation and computational versus non computational annotation
- Computational semantics: explicit semantics for the computer.

The combination of these four dimensions makes a table of 24 cells. Each annotation tool can be categorized by one of the cells.

A second table shows in each cell of the table to what extends each of the three requirements in Section 2 are reached. "R" indicates realized requirements and "P" possibly realized requirements, which means that users could use the tool to somehow reach the requirements although the tool does not realize the requirement.

361

Table 1. Existing annotation tools by categories

Semantics	Author Adressee	Manual	Semi-automatic	Automatic
Non semantic annotation	Cognitive and non computational annotation	Imarkup, Acrobat , Web-Notes , CoNote, WebAnn, Epost		Google's ToolBar
	Non cognitive and computational annotation	Manual index in libraries	MyAlbum Annotate	Google search engine
	Cognitive and computational annotation	Knowledge Pump, Xlibris		Cached Google Links
Semantic annotation	Cognitive and non computational annotation	Annotea + Amaya, Yawas [7], ThirdVoice Mark-Up		
	Non cognitive and computational annotation	Edutella, OntOmat, SHOE, HTML-A, WebKB, Karina		AeroDAML
	Cognitive and computational annotation	Mangrove, SMORE	MnM,Melita, Teknowledge, IMAT	KIM, MnM, Magpie, COHSE

Table 2. Evaluation of existing tools based on requirements for annotating learning material

Semantics	Author Adressee	Manual	Semi-automatic	Automatic
Non semantic annotation	Cognitive and non computational annotation	P: 2.3 R: 3.1		R: 3.1
	Non cognitive and computational annotation	Nothing	P: 2.2 R: 3.1	Nothing
	Cognitive and computational annotation	R: 2.4, 3.1		Nothing
Semantic annotation	Cognitive and non computational annotation	P: 1.1 1.2 1.3 2.1 2.2 2.4 3.2		
	Non cognitive and computational annotation	P: 1.1 1.2 1.3 2.1 3.2 R or P: 2.2, 2.4		P: 1.1 1.2 1.3 2.1 2.4 3.2 R or P: 2.2
	Cognitive and computational annotation	P: 1.1 1.2 1.3 2.1 2.2 2.4 3.2	P: 1.1, 1.2, 1.3, 2.2 2.4 R or P: 2.1, 3.1	P: 1.1, 1.2, 1.3, 2.2 2.4 R or P: 2.1, 3.1

This evaluation table points out the following interesting results:

- All the non semantic cognitive tools realize the 3.1 requirement (does not disturb the activity) but it is not the case for semantic tools.
- Some non cognitive computational semantic tools already use the e-learning standards (mainly LOM).
- Very few other e-learning requirements are currently respected but some could be reached with an adaptation of semantic tools: usefulness, shareability and usability concerning teaching context (2.1, 2.4, 3.2).
- The 2.1 and 3.1 requirements are yet respected by some tools that provide annotation with ontologies of teaching topics.

4 Research annotation tools

As we explained in section 3, annotation tools depend on the use of the annotation, both the creating use (the means provided to the annotator) and the annotation end-user (its addressee). Therefore to specify an annotation tool dedicated to e-learning means to clarify to which one of the 18 tools categories it belongs to, describe the specificities of the learning context and specify the functionalities provided by the tool to its users. We illustrate this method with two research tools dedicated to annotating learning material.

4.1. MemoNote

MemoNote is an annotation tool developed at the CLIPS laboratory (Grenoble). Although many learning and training activities are now supported by e-learning systems, users have usually no means (or very poor means) to manage the note of events and knowledge they want to memorize during these activities and to retrieve in the future. The MemoNote project aims at formalizing and implementing computerized external memories made of notes added directly and voluntary on the training material by its user.

MemoNote is cognitive, semantic and manual or semi-automatic annotation tool. It enables the user to annotate pedagogical documents. For a specific teaching activity, MemoNote can adapt the user's context by selecting a set of ontologies which describes the users, the teaching domain, the pedagogical activities (content, location, time) and the pedagogical objectives.

This ability to change its context with a set of ontologies makes MemoNote both a generic tool, which can be used in every context, and a specific one, once the context is fixed by ontologies.

The user has two annotation means:
- Manual annotation. The user himself/herself must define the three facets.
- Semi-automatic annotation. The annotator defines the source of the annotation by selecting an annotation tool and the annotation anchor. An annotation pattern is attached to each tool enabling MemoNote to deduce partly or entirely the semantic and episodic facets

The user interface in both cases is the same. It has three main parts. The first part is a reader (reading software) embedding MemoNote annotation tools. It provides reading facilities quite similar to paper ones. In this reading interface, the user can choose an annotation tool (for example red underlining) and put it on the document surface (on the touch screen). The second part is the annotation interface where the user can define (or not) each semantic fields (addressee, objective, content, importance and confidence). The third part is the ontology browsing interface. For each attribute, the user want to define, this interface pops up until the ontological value of the field is fixed. For some entirely automatic patterns, the interface for annotation and ontology browsing does not open and fields are filled in automatically.

4.2. AnnForum

AnnForum is an annotation tool developed at the University of Bergen (Norway) to support the annotation and reuse of collaborative knowledge building forum as new learning resources. According to [5], annotation is not always productive if it hasn't been designed in close relation to its use, it will produce limited benefits. AnnForum is a computational, cognitive, semantic, manual and semi-automatic annotation tool.

FLE3 [8] is a web-based groupware for computer supported collaborative learning (CSCL), which is used in a university course INFO281 (Introductory Artificial Intelligence). It is based on progressive inquiry learning, a type of activity where students engage in a research-like process by posting messages to categories (problem, hypothesis, scientific material, etc). There is a large amount of messages posted in each semester on FLE3. With AnnForum, by reusing FLE3 as new learning resources, future students can benefit from former students' knowledge and experiences.

A conceptual domain model is used in AnnForum to describe the domain concepts (Artificial Intelligence) and the relationships among them, which collectively describe the domain space. Once the conceptual domain model is available, annotations can be created by the teachers linking previous knowledge building to elements of this model. To support teachers in creating such annotations, we designed a keyword recognizer and an algorithm to determine the relevance of a message to a concept in the domain model. The keyword recognizer identifies the occurrence of the topics, including their names and variants of the names in the domain model. Relevance is determined using an algorithm that applies a weight to the keywords in the messages. The annotation of the messages from the system is then shown to the teacher who can add or remove the related topics on the interface and then elaborates the annotation manually. The semantic information added into the forum enables the reusing facility to detect messages and teaching material from the previous knowledge building which are relevant to current discussion topics and present them to the students.

4.3 Evaluation of Memo Note and AnnForum against the requirements

MemoNote tool as a cognitive, non computational and semantic annotation tools, respects the 2.2 requirement using OWL to represent ontologies and RDF to represent annotations. The 1.1, 2.1 and 3.2 requirements that were potential for general purpose tools are respected by MemoNote. This is made using the set of ontologies defining the annotation context and from which values are taken to specify the content of an annotation. Currently the 2.4 requirement is not yet implemented. We have started to formalize how a group could share manual annotations and create a collective manual annotation.

AnnForum allows teachers to create a domain model (1.1). This model has an explicit semantic network to support the annotation (2.1). Teachers can make annotation with teaching objectives in mind (1.2). The annotation can be created manually or semi-automatically. The annotation process does not disturb the teaching activities (3.1). By adding a learning model that complies with LOM or IMS-LD, it is possible to use AnnForum to annotate teaching/learning activities (1.3). Since the annotation is based on explicit semantics, it is also possible for teachers to share the annotations.

Conclusion

In this paper we first presented the specific requirements of annotating learning material. Based on these requirements, we categorized and evaluated the existing annotation tools. We have also presented two annotation tools which are under development particularly for learning material.

Although each of these annotation tools fulfills some of the requirements for learning material annotation, there are still some problems that need further investigation.

First, the requirements we presented might not cover all the requirements. Teachers, learners, and other actors may have their own needs when they annotate learning material. We should look more into the special requirements from different parties.

Second, in order to take into consideration teaching/learning context, annotation tools should be able to combine domain and teaching/learning ontologies.

Finally the categorization we provided is a first mean, for a particular use, to illustrate what new directions research should be followed. The tools respecting the most of the requirements are computational, cognitive and semantic, meaning that the promising direction could be that the user can let the software compute inferences for him. It means to make MemoNote also a computational tool with which the annotator would be able to create annotations that will automatically remind him/her annotations at a certain time in the future, depending on its current learning/teaching task. For AnnForum, the emphasis will be on the semantic use of e-learning standards (LOM, IMS-LD) in order to be able to annotate teaching/learning activities and support the share and reuse of the annotations.

References

1. Marshall C: Toward an ecology of hypertext annotation, in ACM Hypertext. Pittsburgh, PA, 1998, pp 40-49
2. Marshall C, Price M, Golovchinsky G, Schilit B: Designing e-Books for Legal Research, in Joint IEEE and ACM Conference on Digital Libraries (JCDL01). Roanoke, Virginia, 2001
3. Handschuh S, Staab S: Annotating of the Shallow and the Deep Web, in Annotation for the Semantic Web. Edited by (Eds.) SH-sSS. Amsterdam, IOS Press, 2003
4. Webster M: Merriam Webster: On-line dictionnary, 2004
5. Euzenat J: Eight Questions about Semantic Web Annotations. IEEE INTELLIGENT SYSTEMS 2002; 17(2):55-62
6. Caussanel J, Cahier J-P, Zacklad M, Charlet J: Cognitive Interactions in the Semantic Web, in SemantivWeb. Hawai, 2002
7. Denoue L, Vignollet L: An annotation tool for Web browsers and its applications to information retrieval, in Content-Based Multimedia Information Access (RIAO 2000). Paris, France, 2000
8. Hakkarainen K, Muukkonen H, Lakkala M: Collaborative technologies for facilitating progressive inquiry: Future Learning Environment Tools, in The 3rd International Conference on Computer Support for Collaborative Learning. Palo Alto, California., 1999, pp 406-415.

User Modeling for
Modular Adaptive Hypermedia

Vadim Chepegin[1], Lora Aroyo[1], Paul De Bra[1], Dominik Heckmann[2]

[1] Eindhoven University of Technology, Computer Science Department,
Den Dolech 2, P.O. Box 513, 5600 MB
Eindhoven, the Netherlands
[2] Universität des Saarlandes
Postfach 151150, D-66041
Saarbrücken, Germany
{vchepegi, laroyo, debra}@win.tue.nl, heckmann@dfki.de
http://wwwis.win.tue.nl/, http://www.5cm.de/dominik/

Abstract. More and more users work simultaneously with multiple applications, to perform various tasks. This situation puts high demands on the user adaptive systems (UAS), which traditionally support users' work in a single isolated domain, and which now shift towards personalization in multi-task and cross-application contexts. In their attempt to meet the increasing demands, UAS grow in complexity, but they do little about their compatibility and interoperability. We propose a Component-based Architecture for UAS: (*CompAS*). The key feature of *CompAS* is modularization of knowledge models and as a consequence allowing existing UAS to share their user models by means of a centralized user model service. As a proof of concept we show how two existing applications, AHA! [1] and UserModelService [2] can achieve interaction based on the extracted user model.

1 Introduction

The current boost in the field of wireless and ubiquitous computing has a great impact on many aspects of system engineering, and especially on the design and development of User Adaptive Systems (UAS) [3]. The provision of personalized and user-centered information services becomes a multifaceted task in an open and distributed world of mobile users and smart systems. It becomes a formidable challenge for UAS to cope with this rising complexity of interactions and to provide the appropriate adaptation to the numerous user goals. A critical factor for the increase in the complexity is the fact that in this context tasks of various nature are carried out in parallel and/or sequentially.

Consider the following scenario. Ann is a trainee in a program for art critics. In her training she uses an Adaptive Hypermedia (AH) Art Critics Course and an Intelligent Tutoring System (ITS) for Artifacts Classification simultaneously. The following collaboration acts between the applications can appear in this scenario in order to support Ann in achieving her learning goals.

1. Ann starts her work with the AH course. At some point the AH application does not have enough information about Ann's knowledge on a particular topic related

to Artifacts Classification and delegates the following steps to the ITS in Artifacts Classification in order to collect more assessment information about Ann during her interaction with the ITS.

2. Ann works with the ITS for Artifacts Classification and perform various training tasks. When she has achieved the level of knowledge indicated as needed by the AH course the control is turned over to the Art Critics course again.

The educational application is only one example of possible areas, where we can observe collaboration among systems and multi-task environments for the users. The systems in the given scenario as a rule do not share the same understanding of the domain, user modeling, adaptation technologies, and they also articulate tasks in different terms. Thus, the UAS illustrated here are not compatible with each other, which causes problems for their collaboration. As a consequence they cannot adaptively support the user's flow of activities as a seamless sequence of interrelated tasks within an overall process.

In Section 2 we propose a Component-based Architecture for User Adaptive Systems (*CompAS*) to serve as a reference model for UAS and in this way to facilitate the process of the creation, communication and integration of such systems. In Section 3 we illustrate some of the implementation issues involved in the realization of such an architecture. We show how two existing applications (AHA! [1] and UserModelSer-vice [2]), built independently, can cooperate within the context of common user tasks. Conclusions and discussion for further development are finally presented in Section 4.

2   *CompAS* Architecture

In this section we briefly describe features of the *CompAS* architecture, which was initially introduced in [8], [9]. The architecture follows earlier hypertext / hypermedia models [4], [5], knowledge-based systems architectures [6] and intelligent tutoring systems architectures [7] by having a Domain (Expert) model, User (Student, Learner) model and Adaptation (Teaching, Tutoring) model. Additionally, it is extended with a separate Application model that extracts all the application dependent knowledge from the Domain, User and Adaptation models in order to allow for a strict separation of concerns between general adaptation techniques and application-specific strategies. This way it also facilitates the definition of the adaptation in a task-oriented manner. The *CompAS* architecture also emphasizes on the role of an external User model, which becomes a central point for communication among user adaptive systems since all their decisions are based on the state of the user and her environment.

Separation of Knowledge Models. One of the key aspects of *CompAS* is modularization of knowledge models. The main stress in this architecture is given by the fact that the developers have to put various different types of knowledge into specific models and then encapsulated them into single software components. Here we provide an informal definition of architectural building blocks with their functionality.

1. The Domain Model is a conceptual representation of the real world; it consists of concepts and relations between them. It is, in principle, application independent. In particular, it is not concerned with problems, tasks or their solutions.

2. The Application Model contains a generic description of the user tasks in the context of a particular application. It contains a description of the application in terms of Role-Goals-Tasks-Methods hierarchies, and represents user long-term goals in order to support dynamic, knowledge-based application selection, which can facilitate the user in solving her current task [6].

3. The User Model in *CompAS* consists of two parts: a User Modeling Service (keeps track of user's interaction with various applications, stores stable user characteristics and various environmental aspects) and a User Agent (that is a reflection of the user in the system and can move together with the user from one device and application to another).

4. The Adaptation Model is responsible for the application of special procedures to plan and perform the adaptation. The adaptation model realizes adaptation based on the users tasks, environmental conditions, preferences, etc. and relationships between concepts of the Domain Model, like prerequisites.

In *CompAS* architecture we separate the knowledge about the user from the knowledge about the user's tasks and subject domains. Thus, we introduce four types of ontologies, which support the population and sharing of various types of knowledge: User Model ontology, Application (Task) ontology , Adaptation ontology, and Domain ontology.

Centralized User Modeling. User models are an essential part of every adaptive system. In order to adaptively to support the user flow of activities as a sequence of interrelated continuous processes through multiple applications, UAS cannot be isolated entities any longer. Instead they would operate better if they exchanged their knowledge about the user. There are two ways to approach this problem and to establish *quid pro quo* communications among systems: (1) peer-to-peer communication [10], and (2) a centralized model [11]. The former is more concrete in the sense that when you decide to share knowledge with a particular application you can create a specific bridge between them. The second approach, the centralized UM, means that several applications establish communications among themselves via a single user model service. This method has well known benefits, e.g.,

1. Sharing knowledge among applications leads to a synergetic effect, when an application takes advantage from the user interaction with several applications;

2. A User Modeling Service can support important functions such as: scrutability, privacy, history of changes, multiple views and resolution of conflicts;

3. And last, but not least, is the decreasing number of bridges between every two applications from order of N^2 to order of N, between each application and a User Model Service

We have chosen the centralized user model approach, but there are a number of obstacles that must be overcome when doing so. We have divided the problems into several facets as follows: (1) Communication between applications; (2) Collaboration between applications; (3) Sharing structures and components; (4) Collaboration between users.

We distinguish between the syntactic level and the semantic level of integration. To solve the communication problem between applications entails applications speaking

the same language and using the same format and protocol when communicating. The solution can be found in the recently established query and mark up languages for user modeling: UserQL and UserML respectively [12].

Turning to the second problem of the semantic integration of applications, this requires the first problem to be solved first. It brings with it an additional requirement in terms of sharing the same view to the user modeling process and problem domain. The area of ontological engineering provides us with ideas for further research when we come to this point. In the broader context the integration of ontologies and problem solving methods can support knowledge model interaction within the existing architecture [6], [13].

We have already discussed (in Section 2) the problem of sharing components within the proposed *CompAS* architecture. Due to limited space, we will not be addressing the fourth problem in this particular paper. In the next section, we present some considerations for implementation and supply examples for solving the above problems. We further illustrate communication realization for an application and a UserModelService.

3   Implementation Issues

The general-purpose adaptive engine AHA! [1] developed at the Eindhoven University of Technology, aims at bringing adaptivity to a wide variety of applications such as on-line information systems, on-line help systems, museum and shopping websites, in addition to the area of on-line textbooks. We would like to isolate the internal User Model of AHA! and extract it in order to achieve a sharable user model.

The "u2m.org" UserModelService (UMS), developed at Saarland University, is a system that supports user modeling processes by storing user models (and context models), providing access to them, and offering strategies for conflict resolution. As a first step, we are using this UserModelService to extract the internal AHA! user model by using the exchange language UserML [12]. As a next step we target the semantic level of integration of several independent applications.

AHA! information model. The AHA! information model consists of values of all user-specific attributes associated with every concept of the Domain Model. In other words, every concept has its own reflection in the User Model. The current realization of AHA! does not have a Domain Model in a traditional meaning. All attributes associated with concepts serve user modeling purposes only. In a user profile these attributes usually have meaning of knowledge, interest, etc. This is a realization of the so called 'overlay user model'.

Concepts are described by attribute/value pairs, which are represented in the system by the 'attribute' tables. For each attribute of each concept from the domain the system keeps a value. This information is stored in the 'profrec' table.

An action can be associated with each attribute. An action is fired when the special precondition of the rule (IF part) is true. A table with the name 'action' is in charge of keeping this sort of data. The action part of the rule (THEN or ELSE part) is defined in the table 'assignment'. By assigning 'true' or 'false' value to the 'truestat' attribute of that table we determine whether this particular table contains the THEN part or ELSE

part of a rule. For user modeling issues only 3 tables are relevant: 'profrec', 'concept' and 'attribute' since they define the User Model.

Communication between AHA! and UserModelService. This subsection illustrates the communication between AHA! and UMS. The active part of AHA! is its adaptation engine, which generates the best next page for the user to visit. The tailoring process is based on the user model. The actual adaptation is performed by the rule-based system. Rules, using by the adaptation engine, utilize knowledge about user performance and characteristics, which the engine extracts from an internal user model (database). When we externalise or extract the user modeling functionality from AHA!, the engine has to request knowledge about a user from a separate service. This can be done by formulating HTTP requests to a special URI of a PHP script, which is the frontend of the UserModelService, responsible for answering questions coming from applications:

```
http://www.u2m.org/service.php?subject=Alex&auxiliary=
knowledge&predicate=aha.tutorial&range=aha.statement
```

This UserQL/URI represents the query "Tell me all about Alex's knowledge on the topic 'aha.tutorial' of which the range of values should be 'aha.statement'". AHA! will receive an answer in UserML. It applies its adaptation strategy in the light of new received data and shows the new content to the user. AHA! interprets the next user action and decides how this new knowledge influences the internal state of the user. At the end of the interaction loop AHA! updates the user model (through UserModelService) with new values by means of one of its interfaces called 'adder.php'.

```
http://www.u2m.org/adder.php?subject=Alex&auxiliary=
knowledge&predicate=aha.tutorial.desinger&range=
aha.statement&object=75
```

What we have described above is the communication between a typical AHA! application and the UserModelService, as it is being implemented in a first prototype. It is important to note that the separation of domain, adaptation and user model is advocated by the AHAM [4] reference model, but thus far not realized in AHA!. The current work on using AHA! with UserModelService brings AHA! one step closer to being an implementation of AHAM.

4 Conclusions and Further Work

This paper aimed to demonstrate the first steps towards a generic architecture for User Adaptive Systems (*CompAS*), which will support the integration of existing adaptive software and will facilitate their further development. We extracted the internal user model of AHA! and transfered it to a shared UserModelService. The great challenge is the higher level integration, which we call integration on a semantic level, and is the next step on the way towards cross-application adaptation.

References

1. De Bra, P., Calvi, L.: AHA: a Generic Adaptive Hypermedia System, Proc. of the 2nd Workshop on Adaptive Hypertext and Hypermedia, pp. 5-12, Pittsburgh, 1998.
   http://wwwis.win.tue.nl/ah98/DeBra.html
2. Dominik Heckmann: Reference Manual to the U2M User Model Server Dominik Heckmann (January 2004) Technical Report, Saarland University
3. Anthony Jameson: Modelling both the Context and the User, Personal and Ubiquitous Computing, 5, 2001, 29–33.
4. De Bra, P., Houben, G.J., Wu, H.: AHAM: A Dexter-based Reference Model for Adaptive Hypermedia, Proceedings of the ACM Conference on Hypertext and Hypermedia, pp. 147–156, Darmstadt, Germany, 1999.
   http://wwwis.win.tue.nl/ debra/ht99/ht99.ps
5. Koch, N. and Wirsing, M.: The Munich Reference Model for Adaptive Hypermedia Applications, in Proceedings of the Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems, 2002, pp. 213–222.
   http://www.pst.informatik.uni-muenchen.de/personen/kochn/munich-koch-wirsing-final.pdf
6. Motta, E., Domingue, J., Cabral, L., and Gaspari, M.: IRS-II: A framework and Infrastructure for Semantic Web Services. In 2nd International Semantic Web Conference 2003 (ISWC 2003), 20-23 October 2003, Sundial Resort, Sanibel Island, Florida, USA.
   http://kmi.open.ac.uk/people/domingue/papers/irs-iswc-03.pdf
7. Wenger, E.: Artificial Intelligence and Tutoring Systems. Computational approaches to the communication of knowledge. - Los Altos: Morgan Kaufmann, 1987. – 486p.
8. Chepegin, V., Aroyo, L., De Bra, P., Houben, G.: CHIME: Adaptive Framework for Semantic Web Service Integration. In InfWet'03 Conference, pp. 29-36, 2003.
   http://wwwis.win.tue.nl:8080/infwet03/proceedings/3.pdf
9. De Bra, P., Aroyo, L., Chepegin, V.: "The Next Big Thing: Adaptive Web-Based Systems" // Journal of Digital Information (in press)
10. W. Nejdl, B. Wolf, Ch. Qu, S. Decker, M. Sintek, A. Naeve, M. Nilsson, M. Palmr and T. Risch. EDUTELLA: A P2P Networking Infrastructure Based on RDF , Edutella White Paper, November 2001
    http://edutella.jxta.org/reports/edutella-whitepaper.pdf
11. Tomaz Klobucar, Vanja Senicar, Borka Jerman Blazic: Privacy Issues of a Smart Space for Learning, In: Proceedings of ICALT 2004 (The 4th IEEE International Conference on Advanced Learning Technologies), August 2004.
12. Heckmann, D., Krüger, A.: A User Modeling Markup Language (UserML) for Ubiquitous Computing. In Proceedings of User Modeling 2003, 9th International Conference, UM 2003, Johnstown, PA, USA, June 22-26, 2003, 393–397.
    http://www.sigmod.org/sigmod/dblp/db/conf/um/um2003.html
13. Bylander T, Chandrasekaran B.: Generic tasks for knowledge-based reasoning: The "right" level of abstraction for knowledge acquisition. In: Gains B, Boose J (eds). Knowledge acquisition for knowledge-based systems. London: Academic Press, 1988; p.65–77.

Partial Generation of Contextualized Metadata in a Collaborative Modeling Environment

Niels Pinkwart, Marc Jansen, Maria Oelinger, Lena Korchounova, Ulrich Hoppe

University of Duisburg-Essen, Faculty of Engineering,
Institute for Computer Science and Interactive Systems
Lotharstr. 63, 47048 Duisburg, Germany
Phone: +49 / 203 / 379-1403, Fax: +49 / 203 / 379-3557
{pinkwart,jansen,oelinger,korchounova,hoppe}@collide.info

Abstract. In asynchronous collaboration scenarios, document metadata play an important role for indexing and retrieving documents in jointly used archives. However, the manual input of metadata is usually an unpleasant and error prone task. This paper describes an approach that allows the partially automatic generation of metadata in a collaborative modeling environment. It illustrates some usage scenarios for the metadata within the modelling framework – including concepts for document based social navigation and ideas for tool embedded archive queries based on the current state of the user's work.

1 Exploiting Task Context in a Modeling Environment

Document metadata play an important role for indexing, retrieving and thus re-using material in collaborative learning scenarios. Yet, one critical problem concerning metadata is the reliability of user provided data. Users tend to minimize their efforts describing their documents. So incompleteness and inconsistency of metadata are frequent; incompleteness results from partially skipping of information, different understandings by various users cause inconsistency. Using standards may help, but this demands additional effort from the users, namely to learn the terminology. Yet there is a need for annotated, classified material with a rich context, which supports retrieval on a higher level than a just content based text search. An automation of metadata generation would disburden the user from these problems. A general solution seems out of reach. Our approach is based on using task (esp. tool) information available in a multifunctional collaborative modeling framework. Beyond metadata generation it also supports certain forms of content based awareness in a user community.

Cool Modes (COllaborative Open Learning and MODEling System) is a collaborative tool framework designed to support discussions and synchronous cooperative modelling in various domains. Like some other environments [e.g., 1], Cool Modes supports synchronous cooperation by a shared workspace environment with coupled objects. In Cool Modes, these objects can be defined externally, which offers the option to develop domain dependent plug-ins. These consist of five different elements (see [2] for details):

- Primitive element types (atomic elements of the constructed representations)
- Connection types that can be used to link different primitive elements
- Usage rules to restrict the syntactic structures a user can create
- Interpretation patterns (like rules and algorithms) that can be applied on constructed graphs in a workspace – the means to e.g. realize simulations
- A UI that offers the elements for direct manipulation and may contain specific control elements for the plug-ins (e.g., start buttons for simulations)

These system extensions can differ considerably with respect to the underlying formal semantics (e.g., Petri nets vs. handwritten annotations), but all can be used synchronously in an integrated way, mixing and combining different conceptual representations (see [3] for details).

2 Archiving and Retrieval Functions in Cool Modes

Some of the metadata slots we use have been inspired by existing standards like Dublin Core [4]. The basic standard conform set of metadata is enriched by adding tool dependent metadata like the used plug-ins which indicate a domain context of the activity, e.g. the use of the stochastics plug-in would indicate a probability theory activity in a math course. Thus the usage within an educational context is possible as well as in the specific group of Cool Modes users. Several of the educational scenarios for the system design originate from the European project COLDEX[1] which enables scientific modeling and simulation in distributed collaborative settings. The learning domain here is the study of various phenomena from a scientific and a subjective experiential perspective. Tools like Cool Modes can contribute to forming integrated (a)synchronous access to a "group memory" on different levels. In this context, the development of scenarios for the automation system has been motivated by pedagogical scenarios of COLDEX, based on the following use cases: A teacher organizes and supervises learning groups, i.e. he creates new projects, or groups. He assigns projects, students, and groups. A student collaborates with his group using Cool Modes. After registration, any user can retrieve documents using a query form.

Based on the standards and use cases as identified in the previous section and specific features available by the use of Cool Modes as a collaborative and customizable framework, we have defined the metadata types to be used. Some of these are independent of the tool that generated the data, some are specific to Cool Modes. Another dimension to categorize the entries is in how far they can be generated automatically. Some possible levels are "completely and deterministically", "inferable under certain conditions" or "not at all". The following table systematically classifies the entries with their attributes.

It is observable that most of the entries are independent of the concrete tool that is used and that for all the metadata entries, at least a heuristic or a calculation based on previous document versions is possible. Furthermore, the fields which build the core for the querying scenarios can be generated automatically.

Table 1. Properties of metadata information types

Entry	Dependency	Possible generation type
Name	independent	proposal inferable for higher versions of documents
Description	independent	proposal inferable for higher versions of documents
Keywords	independent	heuristics based on keyword comparisons with the archive possible; proposal inferable for higher versions of documents
Write flag	independent	manual input needed, yet "false" is a reasonable default
Creation date	independent	fully automatic
Version	independent	fully automatic (1.0 for initial versions, increment for follow-ups); manual conflict resolution may be needed
Language	independent	heuristics based on user profile and previous versions of documents
Used plug-ins	customizable tools	fully automatic
Authors	independent	fully automatic
Cooperators	collaborative tools	fully automatic
Project	independent	proposal inferable for higher versions of documents
Activity	independent	proposal inferable for higher versions of documents; heuristics based on project and user information

Based on this metadata structure, we have implemented a number of search and retrieval mechanisms that work on the archive. The guiding principles and central features can be summarized as follows:

The core consists of *generic archive queries*. These can be formulated in an SQL style syntax and allow the flexible access of the archive in an expressive language. However, for most users (considering the intended educational context), the manual formulation of queries is definitely too complicated. Thus, some of our developments aimed at realizing an *associative lookup strategy* (cf. [5]) that is visualized in figure 1: The user can take any document that has metadata information attached to it and *generate a query from this document* in one simple generalization step – the system creates a query template in which the attribute values are taken from the source document and all the attributes are marked as "relevant". The user can then modify the content of slots to modify the search query, "free" specific slots (to make them return values rather than search parameters) or label specific slots as "not relevant", which hides these slots in the result. The modified query is then run against the community database and returns a set of matching document metadata. These can be used to form new queries, or the documents can be opened in Cool Modes. As the slots that were used for the search process represent information that holds semantics and is related to the educational ontology, this allows for navigation and retrieval which considers educational and domain related contexts.

Based on this retrieval function, we have added tool embedded support for *task contextualized queries*: A user working within the Cool Modes environment has the option of asking "is there something in the archive similar to what I am working on" without providing additional manual information. The needed system side knowledge about the domain and task context the user is currently in is generated by the approaches described above. Especially under the condition that a user is working with material that (at least in parts) originates from the archive, semantically rich queries that take into account domain and task context are enabled.
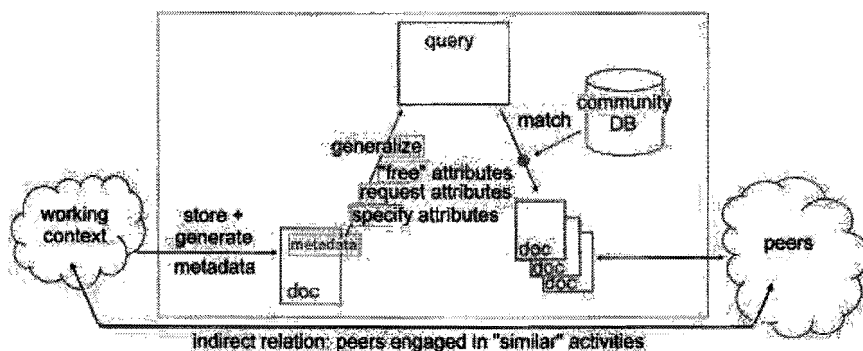
Fig. 1. The use of documents as search query templates

With the retrieval strategies described above, it is possible to allow users to take their current document as a query template, search for related content in the archive and display to the user not just the found documents themselves but a ranked list of other users that created these documents. Under the assumption that the automatic generation of metadata works sufficiently, this approach enables finding peers or groups of similar interest and, iterating this process, to realize *social navigation* [6] based on the document archive (see illustration in right part of figure 1).

Furthermore, the retrieval strategies as presented build a good base to personalize the system by a *what's interesting* feature, either on a web page (this is the way we realized it) or tool embedded. This feature performs some of the queries as presented above automatically, considering additional constraints like language, time, and organizational proximity of persons and is thus able to propose documents of potential interest to the user that log into the system.

3 Architecture and Implementation

Cool Modes enables the upload of documents to a central database which contains not only the documents themselves, but also metadata information about them. Additionally, metadata are stored within the document itself. This approach allows the metadata to be used without the document itself, and the user can also work offline. The retrieval of the documents is either possible via a web interface or directly from Cool Modes. A WebService is used to evaluate queries against the database.

A high degree of flexibility is gained by using an XML structure to describe general "query patterns". A query pattern can contain two types of slots: slots with values which are used as filters, slots without values which represent "requested" attributes. Irrelevant attributes are not included. The example in figure 2 shows such a pattern which abstracts from the author but fixes the "plug-in" feature as an indicator of task semantics. A possible result is shown on the right side. After sending the request the user has the choice of either downloading one of the presented documents or to refine her query based on the results she received, e.g. she may want to refine her query if the result does not fit her needs.
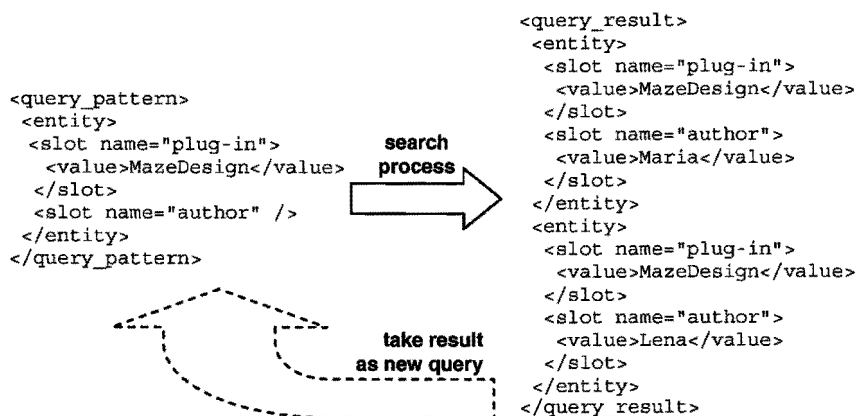
375

```
                                    <query_result>
                                     <entity>
                                      <slot name="plug-in">
                                       <value>MazeDesign</value>
<query_pattern>                        </slot>
 <entity>                              <slot name="author">
  <slot name="plug-in">      search     <value>Maria</value>
   <value>MazeDesign</value> process    </slot>
  </slot>                              </entity>
  <slot name="author" />               <entity>
 </entity>                              <slot name="plug-in">
</query_pattern>                         <value>MazeDesign</value>
                                        </slot>
                                        <slot name="author">
                                         <value>Lena</value>
                          take result    </slot>
                          as new query  </entity>
                                     </query_result>
```

Fig. 2. XML representations of retrieval queries and answers

4 Outlook

To consider the balance of automation and human control, the metadata mechanism will be further enriched. The possibility to change the automatically generated metadata suggested by the system is one of the factors for this balance, another is the adjustment of the automation grade. User profiling will be a means to adjust these parameters.

References

1. Suthers, D., Connelly, J., Lesgold, A., Paolucci, M., Toth, E., Toth, J., & Weiner, A. (2001). Representational and Advisory Guidance for Students Learning Scientific Inquiry. In D. Forbus & P. Feltovich, P. (eds.): Smart Machines in Education, pp. 7-35. AAAI Press, Menlo Park
2. Pinkwart, N. (2003). A Plug-In Architecture for Graph Based Collaborative Modeling Systems. In U. Hoppe, F. Verdejo & J. Kay (eds.): Shaping the Future of Learning through Intelligent Technologies. Proceedings of the 11th Conference on Artificial Intelligence in Education, pp. 535-536. Amsterdam, IOS Press.
3. Pinkwart, N., Hoppe, H.U., Bollen, L. & Fuhlrott, M. (2002). Group-Oriented Modelling Tools with Heterogeneous Semantics. In Cerri et al (eds). Proceedings of the International Conference on Intelligent Tutoring Systems. pp. 21-30. Springer.
4. Dublin Core Metadata Initiative [Homepage] 2003. http://www.dublincore.org
5. Hoppe, H., Ammersbach, K., Lutes-Schaab, B., Zinßmeister, G. (1990). EXPRESS: An Experimental Interface for Factual Information Retrieval. In J.-L. Vidick (ed.), Proceedings of the 13th annual international ACM SIGIR conference on Research and development in information retrieval (ACM SIGIR '91). pp 63 - 81. New York, USA, ACM Press.
6. Munro, A. J., Höök, K. & Benyon, D. (1999) (eds). Social Navigation of Information Space. London et al., Springer.

WORKSHOP 6:

Authoring Adaptive and Adaptable Educational Hypermedia

Workshop Co-Chairs:

Alexandra Cristea
Franca Garzotto

Preface

The workshop will focus on the issues of design and evaluation of adaptive and adaptable (Educational) Hypermedia applications and authoring tools.

The goals of the workshop are: to attract the interest of the related research communities to the important issues of design and authoring in adaptive hypermedia; to discuss the current state of the art in this field; and to identify new challenges in the field. Up to now, the focus of adaptive hypermedia research has been on delivery rather than authoring. Only recently have we noticed a shift in focus. Therefore, important issues to discuss are:

- (Why) should we look at the authoring process in adaptive educational hypermedia design?
- (How) does detecting authoring patterns help the process?
- (Why) do we need to consider cognitive styles in adaptive hypermedia?
- What do these seemingly unrelated topics have in common?

The workshop will also lead to a better understanding and cross-dissemination of patterns extracted from existing design and authoring processes in AH. The results of the workshop should feed back in the European Community project ADAPT, carried out with the support of the EC in the framework of the Socrates programme: http://wwwis.win.tue.nl/~acristea/HTML/Minerva/index.html Moreover, the workshop should be seen as a platform that enables the cooperation and exchange of information with other related European and non-European projects.

The workshop is targeted at all people working towards the discovery of patterns in adaptive hypermedia with special focus on the domain of education. The necessity of these patterns can be as a result of authoring push or AH system interfacing or ultimately open (adaptive) hypermedia or pull. This means that patterns can emerge from repetitive structures used by AH authors; alternatively, patterns can emerge from interface programs or interface languages between different adaptive hypermedia systems, or from trying to interface to the open adaptive hypermedia. This includes researchers that are active in all these fields, as well as representatives of larger projects or networks dealing with these issues.

Moreover, the workshop is also targeted at people who are interested to hear and discuss the state of the art and the future of this important domain of adaptive hypermedia patterns. We encourage these researchers to participate actively in the discussions for which time will be especially allocated.

The workshop's main aim is to bring together researchers working or interested in the emerging field of adaptive patterns for adaptive educational hypermedia authoring. We expect to extract and discuss these emerging patterns, smoothening the transition towards standard proposals in the field. Participants are expected to leave with a better knowledge of the state of the art of the field, as well as to have a fruitful brain-storming session generating new ideas and opening new paths.

As this is a new field, we do not expect final results, but pointers towards some existing solutions and better approaches. Results of the discussions and questionnaire processing will be posted after the workshop on-line on the workshop site, as is the case with the first edition of this workshop.

.

<div align="right">
August, 2004
Alexandra Cristea and Franca Garzotto
</div>

Program Committee

Helen Ashman, *University of Nottingham (UK)*
Paul De Bra, *Technische Universiteit Eindhoven (Netherlands)*
Tim Brailsford, *University of Nottingham (UK)*
Licia Calvi, *University of Pavia (Italy)*
Cristina Conati, *University of British Colombia (Canada)*
Olga De Troyer, *Vrije Universiteit (Belgium)*
Hugh Davis, *Southampton University (UK)*
Rik Min, *Twente University (NL)*
Marc Nanard, *University of Montpelier (France)*
Toshio Okamoto, *University of Electro-Communications (Japan)*
Oscar Pastor, *Universidad Politécnica de Valencia (Spain)*
Simos Retalis, *University of Piraeus (Greece)*
Gustavo Rossi, *La Plata University (Argentina)*
Daniel Schwabe, *PUC - Rio de Janeiro (Brazil)*
Wieland Schwinger, *University of Linz (Austria)*
Carlo Strapparava, *IRST (Italy)*
Lorna Uden, *Staffordshire University (UK)*

Supporting Adaptive Hypermedia Authors with Automated Content Indexing

Sergey Sosnovsky, Peter Brusilovsky, Michael Yudelson

University of Pittsburgh, School of Information Sciences
135 North Bellefield Avenue, Pittsburgh, PA 15260, USA
{sas15, peterb, mvy3}@pitt.edu

Abstract. The main hindrance to expanded use of adaptive educational hypermedia systems is the need for content to be properly described in the terms of domain concepts. This requirement slows down the authoring process and creates an obstacle to the broader distribution of such systems. In the current paper, we propose an approach to providing automated content indexing for adaptive educational hypermedia systems. Both stages of automated content indexing (content parsing and prerequisite/outcome identification) are described here in detail. The approach we have developed has been implemented by indexing the content of the NavEx system and has proven itself by creating meaningful recourse for adaptive example navigation support.

1 Introduction

More and more adaptive hypermedia systems [2] are reaching the point where they can be used in the context of real education, an area that is now almost exclusively served by traditional non-adaptive web-based educational (WBE) systems [4]. Thanks to years of research, the problems of representing the domain model, knowledge about the student, as well as development of the interface can now be solved in a number of domains by relatively small research teams. The choice of the Web as an implementation platform can help a small team solve problems of delivery, installation, and maintenance, expanding the systems availability to hundreds and thousands of students. Yet, there "the last barrier" exists: The traditional static, non-adaptive WBE systems and courses have something that almost no intelligent system developed by small research teams can offer – large amounts of diverse educational material. A high-quality traditional WBE course may have thousands of presentation pages, and hundreds of other fragments of learning material – examples, explanations, animations, and objective questions created by a team of developers. In comparison, the number of presentation items in the best adaptive web-based educational systems is well under two hundred and the number of other fragments of learning material, such as problems or questions is usually no more than a few dozen. These numbers are certainly sufficient for a serious research study of the system in classroom use, but the number is still small for the needs of practical web-based education, i.e., the ability to support reasonable fragments of practical courses which can be taught to large numbers of students, semester after semester.

We think that the key to solving this last problem is teacher-oriented authoring tools for providing the content for adaptive educational hypermedia systems. The pioneering paper (describing the PAT Algebra tutor [17]) provides a good analysis of problems and a set of design principles developed to use when authoring problems for a cognitive, rule-based tutoring system. The situation described in this paper is when the content to be created is really "intelligent content." The power of intelligent content is that knowledge is hidden behind every fragment of it. Even the simplest "presentation" fragments of external content should be connected to the proper elements of domain knowledge (concepts) so that an intelligent educational system (IES) can understand what it is about, when it is reasonable to present it, and when it is premature. More complicated content format, such as examples and problems, require additional coding in order to enable an IES to run the example or to support the student's ongoing solution of a problem.

There are very few domains where the knowledge behind a fragment of educational content can be deduced automatically by the system from the problem statement. For example, straightforward representations might be used in an IES which teaches derivation in calculus [6], expression evaluation in C [5], or equation-solving in algebra [16]. In these domains it is quite easy to identify rules or concepts behind a problem or an example and no other knowledge except core domain knowledge is required to support the problem solving process. In these "lucky" domains, authoring of additional problems or examples is easy; the author only needs to provide the problem statement in a traditional form. Yet, even in such simple domains, teacher involvement is required for the advanced hypermedia systems to distinguish multiple-concept sequences, such as those including prerequisites or outcomes [3]. In less formalized domains, the knowledge behind a content fragment can't be easily extracted and has to be provided during the authoring process, such as in adaptive hypermedia systems like KBS-Hyperbook [12] or SIGUE [10].

In this paper, we present a collaborative approach to authoring intelligent content for adaptive hypermedia. In our approach the work is distributed between an intelligent authoring system and a teacher. The teacher informs the system about his or her preferred way of teaching by grouping prepared content into a sequence of topics or lecture sets. An intelligent authoring system extracts concepts from the provided fragments of content and classifies them as either prerequisite or outcome concepts on the basis of the teacher's preferred method of teaching. We have applied this approach in our recent system, NavEx.

2   Lack of Authoring Support in the Context of a Programming Course

We have used a number of different web-based educational systems in the context of an undergraduate course "Introduction to Programming" being taught at the University of Pittsburgh's School of Information Sciences. The results of every semester's evaluation and students' feedback led us to assume that the pedagogocal value of at least two of them could be increased by providing a system with

metaknowledge about its content, thus an implementation of adaptive hypermedia technologies. Two of these systems are briefly described below.

The WebEx system serves out interactive, explained examples of programming solutions, via the Web. An author of an example or a later teacher can provide textual explanations for every line of the program code. The students can browse these comments at their own pace and order by selectively clicking on the commented lines (see Fig. 1). The first version of WebEx has been implemented and was reported on in 2001 [9]. Since that time, WebEx has been heavily used. Each semester it has offered an incrementally larger subset of examples from the classroom lectures. The results of evaluation demonstrated that a solid fraction of students wanted to see more explained examples than just the examples from the lecture. Moreover, the proportion of students who wanted "more examples" was growing, even though we were incrementally making more and more lecture examples available each semester. Typically, our course has grown to about 60 examples. This is a relatively large amount, but students have no trouble finding the relevant examples because each example is linked to a specific lecture. In contrast, examples from another class or a digital library are a navigational burden to the student. With no clear guidelines as to which of these examples should be accessed and when, students may easily choose examples that are either too complicated or too simple for the student's current progress.
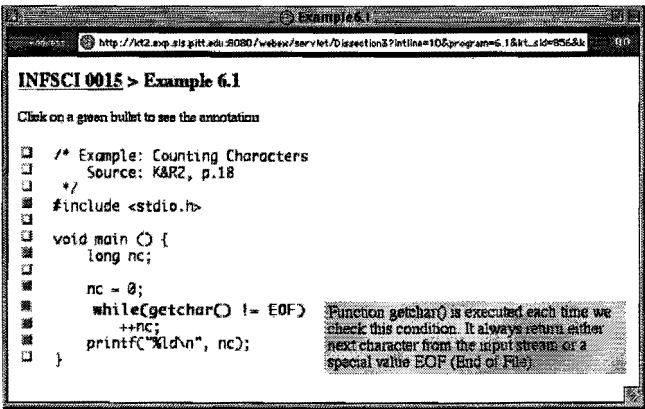

Fig. 1. Interactive example in WebEx.

Another application is QuizPACK. This system authorizes and delivers parameterized web-based quizzes for C-programming courses. The detailed description of QuizPACK can be found in the example for [15]. Figure 2 demonstrates the student interface of the system. QuizPACK evaluation and individual feedback, though positive, showed that students suffer from lack of guidance. Since QuizPACK is used mostly for self-assessment, students need to estimate what their weakest topics are and then decide what quiz is necessary to take, on their own. However, they often get lost "in space" containing about 50 quizzes, which was necessary to develop in order to cover all of the course material. To assist students system needs to provide a valuable feedback which helps them to locate

themselves in the course-knowledge space. Need in adaptive navigation support leads to the necessity of creating "intelligent content."
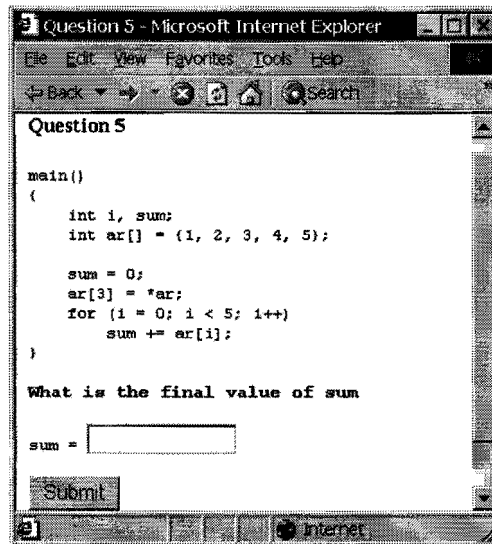

Fig. 2. Typical question in QuizPACK.

3 Automated Content Indexing

There are no universally-accepted recommendations as to which level is best to use when defining a concept in computer programming domains. Some authors suppose that it has to be done on the level of programming patterns or plans [13], other believe, that the concepts is to be closer to the elementary operators [1]. According to the first point of view, the notion of pattern is closer to the real goal of learning programming, since the patterns are what programmers really use. However, the second way is more straightforward and makes the burden of indexing more feasible. With the notable exception of ELM-PE [18], all adaptive sequencing systems known to us work with operator-level concepts. Current implementation of the proposed indexing algorithm also uses the operator-level approach.

This algorithm has two main stages. In the first stage, it extracts concepts from the content elements (examples, questions, presentation pages) combined by the teacher into activity pool. For example, all WebEx examples form one pool; all QuizPACK quizzes belong to another pool. In the second stage, the prerequisite/outcome structure of the course is built in terms of concepts, describing content elements. This sequential structure, along with the indexed content, provides the basis for adaptation. The following two subsections explain both stages in detail.

3.1 On-line Content Parsing

Traditionally, the extraction of grammatically meaningful structures from textual content and the determination of concepts on that basis is a task for the special class of programs called parsers. In our case, we have developed the parsing component with the help of the well-known UNIX utilities: lex and yacc. This component processed source code of a C program and generates a list of concepts used in the program. Currently, fifty-one concepts have been determined for the subset of C language studied during our course. Each programming structure in the parsed content is indexed by one or more concepts, depending upon the amount of knowledge students need to have learned in order to understand the structure. For instance, the parser generates the following list of concepts for the program code in Fig. 1, the WebEx example:

> *include, void, main_func, decl_var, long, decl_var, assign,*
> *ne_expr, pre_inc, while, compl_printf*

It is necessary to mention that each concept here represents not simply a keyword, found in the code, but a grammatically complete programming structure. For instance, concept *while* is recognized by the parser only after the whole while-loop, including the keyword *while*, the iteration condition and the loop body, is found. This is why the concept *while* in the index list above must come after the concepts *ne_expr* (not-equal expression: *!=*) and *pre_inc* (pre-increment: *++identifier*).

The parsed code is accessed through the http-protocol. It can be represented as a simple source file in text format or as a properly formatted HTML-file, which distinguishes the code samples from the rest of the HTML content with one of these commonly accepted tag pairs: <code> – </code>, <pre> – </pre>, or <tt> – </tt>. Usage of other HTML-tags, such as the nesting of <b>, <a>, <div>, etc. between the pair of code-tags does not influence the result of the parsing. These tags are simply ignored; at the same time an HTML escape-sequences (like   < & etc.) are processed and converted into corresponding symbols or symbol sequences. For example, Table 1 demonstrates two code samples, which present alternative ways to format HTML code for the QuizPACK question showed in Fig. 2. The parsing component processes all three samples (including the pure C source code of QuizPACK question) in the same way and generates for them the same list of concepts:

> *main_func, int, decl_var, decl_var, int, decl_array, init, assign,*
> *assign, derefer, assign, l_expr, post_inc, add_assign, for*

Hence, the web-parser we have developed could be used for indexing the great amount of created on-line C content, such as code libraries and web-based tutorials. Given the URL of the content resource it generates list of concepts, extracted from the C code used in this resource.

384

Table 1. Two alternative html formats for a simple C program.

`<html>` `...` `<code>` `main()` `{` `  <b>int</b> i, sum;` `  <b>int</b> ar[] = {1,2,3,4,5};` `  sum = 0;` `  ar[1] = *ar;` `  <b>for</b> (i = 0; i < 5; i++)` `    sum += ar[i];` `}` `</code>` `...` `</html>`	`<html>` `...` `<pre>` `main() ` `{   ` `int i, sum;    ` `int ar[] = {1,2,3,4,5};` `    ` `sum =0;    ` `ar[1] = *ar;    ` `<a href = "for.html">` `for</a>(i = 0; i < 5; i++)` `     ` `sum += ar[i];  ` `} ` `</pre>` `...` `</html>`

3.2 Prerequisite/Outcome Identification

The outcomes of the parsing stage are index lists for all content elements. However, it is not enough for our purposes, since these lists are not yet connected to each other and the content still does not possess any structure on which we could base the adaptation process. In the next stage, all concepts related to each content element are divided into prerequisite and outcome concepts. Prerequisites are the concepts that the student needs to master before starting to work with the current element. Outcomes denote concepts that the element leads one toward learning, i.e. the learning goals of the element.

We use an original algorithm for the automatic identification of outcome concepts (see Fig. 3). This algorithm is flexible enough to be influenced by an instructor-specific way of teaching the course. The source of knowledge for this algorithm is a sequence of groups of content elements. Each group is formed by the elements introduced in the same lecture. Groups are ordered according to the order of lectures in the course, forming a sequential structure of the learning goals of the course. The prerequisite/outcome division algorithm is based on the following assumptions:

- While analyzing content element from some lecture, concepts corresponding to this element and introduced in a preceding lecture are considered to be already learned.
- In each content element, all concepts introduced in the previous lectures are considered as prerequisites, while the concepts first introduced in the current lecture are regarded as outcomes.
- The set of new concepts found in all content elements associated with the lecture becomes the learning goal of the lecture.

The direct outcome of this algorithm is a fully-indexed set of content elements belonging to each lecture and a sequence of learning goals associated with the

lectures. This sequence represents the specific approach to teaching C-programming that is employed by this specific instructor [3]. Once the content elements are indexed and the goal sequence is constructed, any future additional element can be properly indexed by the algorithm and even associated with a specific lecture in the course. More precisely, an association with a specific lecture is the first step in this process. The element is associated with the last lecture that introduces its concepts (i.e., the latest lecture, whose learning goal contains least one concept belonging to this element's index). After that, the element is associated with this lecture. It is important to stress that the outcome identification is adapted to a specific way of teaching a course "mined" from the original sequence of content elements. It is known that different instructors teaching the same programming course may use a very different order for their concept presentation [14]. Naturally, content sequencing in a course is to be adapted to the instructor's way of teaching.

```
learnt_concepts =∅
for i = 1 to no_of_chapters
{
    for j = 1 to chapter[i].no_of_examples
    {
        chapter[i].example[j].prereq =learnt_concepts    chapter[i].example[j].all_concepts
        chapter[i].example[j].outcome = chapter[i].example[j].all_concepts \ learnt_concepts
    }
    for j = 1 to chapter[i].no_of_examples
        learnt_concepts =learnt_concepts    chapter[i].example[j].all_concepts
}
```

Fig. 3: Pseudo-code for prerequisite/outcome identification.

Although, the described indexing approach, using a parsing component, is specifically for programming and for the learning content based on the programming code (questions, code examples), we believe that the proposed general idea is applicable for a broad class of domains and types of content. In less formalized conditions, where concepts do not have a salient grammatical structure, the classic information retrieval approach could be used instead of parsing.

Currently, the described approach is implemented in the NavEx system, which provides adaptive annotations for programming code examples. The indexed content elements in NavEx are the same programming examples used in WebEx (see Fig. 1). Preliminary evaluation shows that implemented indexing algorithm along with the mechanism for building inter-concept hierarchies from the given, flat content provides meaningful recourse for adaptive example-navigation support in NavEx. The NavEx mechanism of adaptation as well as the system interface will be briefly described in the following section.

4   Adaptive Navigational Support in NavEx

The interactive window of the NavEx system is divided into 3 frames (see Fig. 4). The leftmost frame contains a list of links to all examples/dissections available to a

student in the current course. The links are annotated with colored icons. A red bullet means that the student has not mastered enough prerequisite concepts to view the example. The link annotated with the red bullet is thus disabled. A green bullet means that the student has enough knowledge to view the example. A green check mark denotes that the example has already been seen by the student. A green "play" bullet means that this line of code in the example is currently being viewed. The order of links to examples is fixed, so that students can find them in the same place, no matter what the student's progress through the course has been.
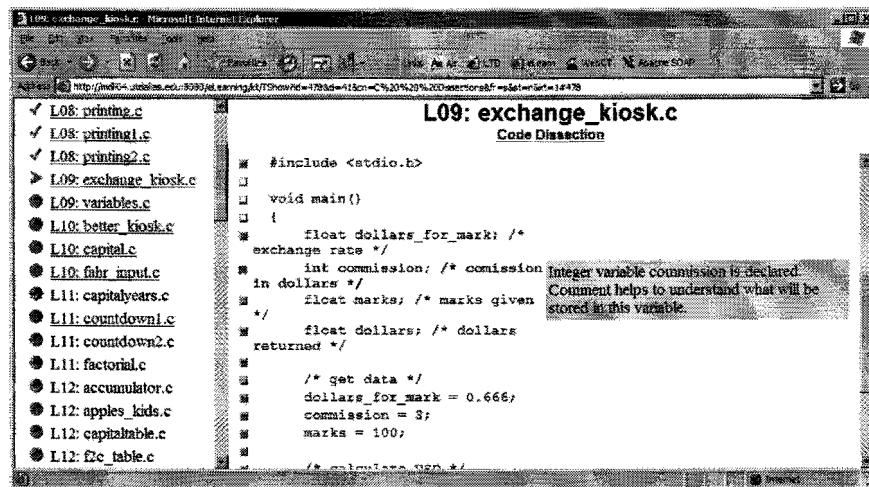
Fig. 4: The interface of NavEx.

The central frame displays the name of the current example. Underneath it are two links: one loads the source code of the example into the central frame (where it will be copied, compiled, and explored); the other link loads interactive example dissection (served directly by the WebEx system). Dissection means that one takes the original source code and comments on it. These comments address the meaning and purpose of this line of code and help the student to understand the example better. Extended comments are shown to the left of the code and can be activated by clicking on the bullet next to the line of the code. If the comment is available, the bullet is green; otherwise, it is white.

NavEx is considered a value-added service of the KnowledgeTree architecture [8], and implements several common protocols including student modeling and transparent authentication. As a typical value-added service, NavEx stands between e-Learning portals and reusable content elements and provides additional value for both teachers and students who use this content through the portal.

Adaptive navigational support in NavEx is done on the basis of the overlay student model [11]. Student's knowledge is represented as a binary vector k, where $k_i = 1$ means that the student has successfully mastered concept i, and $k_i = 0$ means the opposite.

When the student logs into the system a new session is created and information about the current state of his/her knowledge is retrieved from the student model. This information contains concepts the student has mastered and a list of examples the student has reviewed.

Knowing the student's knowledge of each domain concept and the prerequisite-outcome profile of examples, the sequencing mechanism can dynamically compute the current educational status for each example, which is then presented to the student in the leftmost frame of the system window (Fig. 4) in the form of adaptive annotations with the colored icons.

When the student clicks on an example link and reviews the example code, the outcome concepts of the example change their state to "learned" ($k_i = 1$). The changes in the knowledge state of the student are then propagated to the student model. The availability of each new example is determined by checking whether any of the previously unavailable examples now have all of their prerequisite concepts mastered. As the student reviews examples, newer examples become available. The knowledge-based adaptive annotation approach used in NavEx is a variation of a popular adaptive annotation approach introduced originally in the ISIS-Tutor system [7].

5 Summary and Future Work

We have discussed the development of an approach for the automated indexing of content based on C programming code. The first stage of this approach is performed by the implemented parsing component, which is able to extract C concepts from on-line content formatted as HTML or as pure C code. Hence, this tool could be used for indexing the great amount of created on-line C code which is contained in on-line libraries and web-based tutorials.

The second stage is the prerequisite/outcome identification and, building on its base, the inter-concept hierarchical structure of the content. The outcome we receive is the instructor-adaptive structure of the course reflecting his/her way of teaching the course.

The designed approach has been implemented for the NavEx system development. NavEx content being indexed consists of the programming code examples. Preliminary evaluation shows that the implemented indexing algorithm along with the mechanism of building inter-concept hierarchies of the content provide meaningful recourse for adaptive example navigation support in NavEx.

Our next goal is to build-in this algorithm as part of the authoring interface for the next adaptive version of QuizPACK system. Since every QuizPACK question is simply a small C program, we expect our algorithm to work successfully for this application and considerably facilitate the authoring process in QuizPACK.

References

1. Barr A., Beard, M., & Atkinson, R. C.: The computer as tutorial laboratory: the Stanford BIP project. International Journal on the Man-Machine Studies 8, 5 (1976) 567-596.

2. Brusilovsky, P.: Adaptive hypermedia. User Modeling and User Adapted Interaction 11, 1/2 (2001) 87-110, available online at http://www.wkap.nl/oasis.htm/270983
3. Brusilovsky, P.: Developing Adaptive Educational Hypermedia Systems: From Design Models to Authoring Tools. In: Murray, Blessing and Ainsworth (eds.): Authoring Tools for Advanced Technology Learning Environments: Toward cost-effective adaptive, interactive, and intelligent educational software. Ablex, Norwood (2003) 377-409
4. Brusilovsky, P. and Miller, P.: Course Delivery Systems for the Virtual University. In: Tschang, T. and Della Senta, T. (eds.): Access to Knowledge: New Information Technologies and the Emergence of the Virtual University. Elsevier Science, Amsterdam (2001) 167-206.
5. Brusilovsky, P. and Su, H.-D.: Adaptive Visualization Component of a Distributed Web-based Adaptive Educational System. In: Intelligent Tutoring Systems. Vol. 2363. Springer-Verlag, Berlin (2002) 229-238
6. Brusilovsky, V.: Task sequencing in an intelligent learning environment for calculus. In: Proc. of Seventh International PEG Conference, Edinburgh (1993) 57-62
7. Brusilovsky, P. & Pesin, L.: Adaptive navigation support in educational hypermedia: An evaluation of the ISIS-Tutor. Journal of Computing and Information Technology 6, 1 (1998) 27-38.
8. Brusilovsky, P. & Nijhawan, H.: A Framework for Adaptive E-Learning Based on Distributed Re-usable Learning Activities. In: Driscoll, M. and Reeves, T. C. (eds.) Proc. of E-Learn 2002, Montreal, Canada, AACE (2002) 154-161.
9. Brusilovsky, P.: WebEx: Learning from examples in a programming course. In: Fowler, W. and Hasebrook, J. (eds.) Proc. of WebNet'2001, World Conference of the WWW and Internet, Orlando, FL, AACE (2001) 124-129.
10. Carmona, C., Bueno, D., Guzman, E., and Conejo, R.: SIGUE: Making Web Courses Adaptive. In: De Bra, P., Brusilovsky, P. and Conejo, R. (eds.) Proc. of Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'2002) Proceedings, Málaga, Spain (2002) 376-379
11. Greer, J. & McCalla, G. (eds.): Student modelling: the key to individualized knowledge-based instruction. NATO ASI Series F, Vol. 125, Springer-Verlag, Berlin (1993).
12. Henze, N. and Nejdl, W.: Adaptation in open corpus hypermedia. International Journal of Artificial Intelligence in Education 12, 4 (2001) 325-350, available online at http://cbl.leeds.ac.uk/ijaied/abstracts/Vol_12/henze.html
13. Lutz, R.: Plan diagrams as the basis for understanding and debugging pascal programs. In: Eisenstadt, M., Keane, M. T. and Rajan, T. (eds.): Novice programming environments. Explorations in Human-Computer Interaction and Artificial Intelligence. Lawrence Erlbaum Associates, Hove (1992) 243-285.
14. Moffatt, D. V. & Moffatt, P. B.: Eighteen pascal texts: An objective comparison. ACM SIGCSE bulletin 14, 2 (1982) 2-10.
15. Pathak, S., Brusilovsky, P.: Assessing Student Programming Knowledge with Web-based Dynamic Parameterized Quizzes. In Proceedings of ED-MEDIA'2002, Denver, Colorado, USA: AACE, 1548-1553.
16. Ritter, S. and Anderson, J. R.: Calculation and strategy in the equation solving tutor. In: Moore, J. D. and Lehman, J. F. (eds.) Proc. of the Seventeenth Annual Conference of the Cognitive Science Society, Hillsdale, NJ, Erlbaum (1995) 413-418
17. Ritter, S., Anderson, J., Cytrynowicz, M., and Medvedeva, O.: Authoring Content in the PAT Algebra Tutor. Journal of Interactive Media in Education 98, 9 (1998), available online at http://www-jime.open.ac.uk/98/9/
18. Weber, G. & Bögelsack, A.: Representation of programming episodes in the ELM model. In: Wender, K. F., Schmalhofer, F. and Böcker, H.-D. (eds.): Cognition and Computer Programming. Ablex, Norwood, NJ (1995) 1-26.

Developing Active Learning Experiences for Adaptive Personalised eLearning

Declan Dagger, Vincent P. Wade, Owen Conlan

Knowledge and Data Engineering Group, Department of Computer Science, Trinity College Dublin, Ireland
{Declan.Dagger, Vincent.Wade, Owen.Conlan}@cs.tcd.ie
http://kdeg.cs.tcd.ie

Abstract. A pedagogical underpinning is a fundamental requirement for any learning activity or event. Many personalized eLearning systems, however, focus primarily on adaptive content retrieval based on a user profile and neglect the pedagogical requirements of educational systems. This form of intelligent search and insertion is effective at assembling personalized manuals, but not necessarily suitable for creating pedagogically sound eLearning offerings. This paper introduces a methodology for developing adaptive personalized eLearning experiences and the Adaptive Course Construction Toolkit, a tool built on this methodology, for creating pedagogically-based personalized eLearning solutions.

1 Introduction

Typically the approach to adaptive eLearning is to perform adaptivity of the content retrieval mechanism based on the user's personal preferences, prior knowledge, etc. The pedagogical considerations in terms of presentation, structure and narrative in some cases is completely absent and in others very weakly applied. In such adaptive eLearning courses where pedagogy exists it is inherently embedded in the content itself making it difficult to reuse or apply different pedagogies across the same adaptive content. This level of inflexibility leads to the development of pedagogically static and restricted courses.

However, eLearning research in the past 10 years has had one constant unambiguous finding; that pedagogy is absolutely fundamental to the success of a course and must be considered first and foremost when developing learning experiences [1]. The adaptivity should therefore support the appropriate selection of pedagogical strategy(s) and then apply adaptivity to the content and activities within the scope of the selected strategy(s). With today's courses built on Adaptive Hypermedia Systems (AHS) it could be argued that pedagogy is less directive in ensuring the overall experience of the course and much greater effort seems to be expended on accurate selection of subject areas.

This paper argues that next generation adaptive eLearning systems will increase their effectiveness when the adaptivity is applied to the selection of an appropriate (personalized) pedagogy and to the activities, communication and content within pedagogical elements of the course. This leads to adaptive pedagogically-driven

390

eLearning where the pedagogy is central to the learning experience and not accidental and where the power of adaptivity enhances the effectiveness of the pedagogy.

2 Adaptive Course Construction Methodology

During the development of an adaptive online learning experience, several key processes must be realized as illustrated in Fig. 1. Firstly we must identify the goals and objectives of the course. Theses goals and objectives will form the base requirements and initial evaluation scale of the evaluation process. When we are happy with the specified course goals and objectives we must identify and select the appropriate pedagogical strategy(s) for the course based on the goals and objectives. Next we must model the knowledge domain within which the course will reside. Once the subject matter area is recognized and described it can be applied to the chosen pedagogical strategy(s). The next logical phase is to begin the content selection and grouping process whereby the appropriate learning resources are grouped with the pedagogical elements. The customized pedagogical strategy can now be made adaptive by applying the appropriate adaptivity to the pedagogical structure based on the goals and objectives of the course, the selected content of the course and the pedagogical strategy(s) of the course. The next phase of the development process is to test the semantics and the functionality of the adaptive course by verification through the Adaptive Personalized eLearning Service (APeLS). This cyclical approach supports an expandable course construction process.
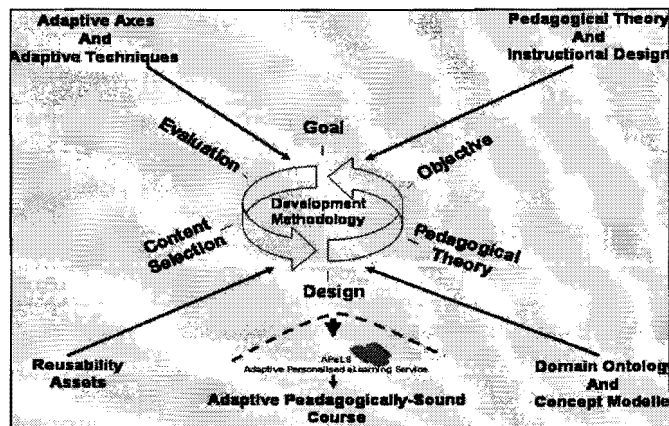
Fig. 1. A Sample Adaptive Course Construction Methodology

3 Creating Adaptive Courses with ACCT

The Adaptive Course Construction Toolkit (ACCT) was developed to address the complex and time-consuming nature of adaptive course construction methodology.

The ACCT supplies the pedagogical foundation of an adaptive course developer-support framework. The design-time nature of the ACCT allows the course developer to construct customized domain ontologies to represent the subject matter expert's view of the knowledge domain. It facilitates the design of customized course narratives (the embodiment of pedagogy, abstract course overview and adaptive axes as applied) based on sound pedagogical models. Adaptivity models allow the course developer to create customized adaptive pedagogy through a support oriented drag and drop type association mechanism. The course developer can search for and select learning resources based on keywords, types, modes, contextualized prior usage, etc. The ACCT provides a course verification service, allowing the pedagogically-driven adaptive course to be viewed and verified prior to publication. The ACCT provides a publication mechanism allowing the course developer to export and publish their pedagogically-formed adaptive course.

3.1 Describing the Knowledge Domain

An integral part of a course creation process is the representation of a knowledge domain. Knowledge domain representation allows the subject matter expert to model their understanding and experience of an information domain. The ACCT provides an environment where the course developer can describe the knowledge domain as a collection of abstract concepts with descriptions and usability guidelines and relationship definitions. The ACCT provides the course developer with a set of predefined relationships which can be applied to concept pairs or groupings. The ACCT allows the course developer to create new custom relationship definitions. This flexibility to describe and customize relationship definitions and subject matter concepts during the development of the domain ontology supports the course developer during the initial phase of course production, knowledge domain representation.

The ACCT provides an environment through which the course developer can graphically create, edit and distribute these knowledge domain representations. In this way, the ACCT actively promotes and supports the sharing of subject matter expertise between peer collaborators.

3.2 Developing an Adaptive Course

The key process of creating online adaptive learning experiences is the creation of pedagogically sound courses. By using the custom narrative editor the course developer can create a custom pedagogical strategy based on sound and expandable pedagogical models provided by the ACCT (fig.2). The course developer can choose, customize and create pedagogical elements based on the palette of tools provided by the ACCT (fig.2). The pedagogical models provided are supported by usability guidelines and best practice descriptions. As the course developer builds the custom pedagogical strategy for their online learning experience they can specify and assemble learning activities within the supported pedagogical structure. The ACCT provides an interface whereby the course developer can place concepts from their

previously defined knowledge domain ontology into this customized pedagogical structure to form a pedagogically sound online course framework (fig.2). The ACCT allows the course developer to graphically assemble the concepts (both Narrative and Subject Matter) and learning activities of their course (fig.2).

The ACCT supports the course developer by allowing them to search and select learning resources from multiple remote learning resource repositories (fig.2). The ACCT graphically supports the selection of learning resources by allowing them to be dragged and dropped from the tools palette to the pedagogical course structure.

To make this pedagogical online course adaptive, the course developer must associate Narrative Attributes with the concepts and learning activities of the course (fig.2). By applying these Narrative Attributes to a pedagogical learning structure, the course developer is describing a requirement for certain aspects of the course to be delivered "adaptively". This ability to apply "adaptivity" to concepts and learning activities uses the approach of Candidacy [2]. When the learning resources are selected they form abstract candidate groups which the adaptive technique, chosen through the adaptive axes rendering process, uses during the reconciliation of the adaptive course.
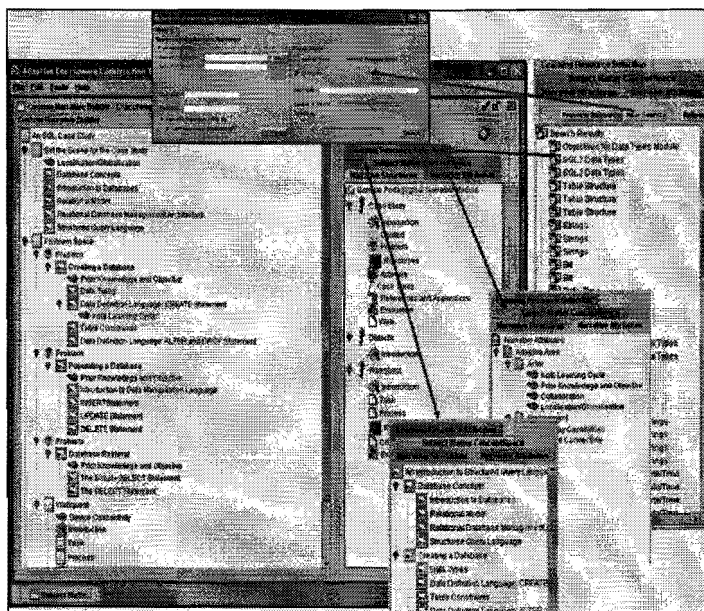
Fig. 2. ACCT Custom Narrative Builder

3.3 Publishing an Adaptive Course

One of the key advantages of the ACCT is its ability to allow the course developer to verify their adaptive course in real time. The ACCT provides a mechanism by which the course developer can test their adaptive course as a real web application. The

393

ACCT exports a course package and application framework to APeLS (Adaptive Personalized eLearning Service). Included in the course package are the subject matter concept space, the custom narrative model with associated narrative attributes and all other related models, all transforms and class definitions required to run the adaptive course.

Through the ACCT application framework generically defined classes provide varying levels of interaction with respect to the learner and the teacher. It allows the course developer to view the learner model schema, the teacher domain scoping mechanism and the overall adaptive course structure. The produced adaptive course is independent of the content that may be used to render it. This allows for the rapid prototyping of adaptive course structures prior to the availability of the learning content. The ACCT produced course can also interact with physical content. Through the Candidacy architecture the ACCT produced course can adaptively render either concept descriptions or the concepts associated candidate learning resources.

4 Modeling Pedagogy

The ACCT is a pedagogy-driven course developer support environment. The pedagogy that is supplied by the ACCT forms the basis for fully customizable pedagogical strategies. The modeling approach involves the creation of XML models to represent the chosen pedagogical strategies, initially case-study, problem/enquiry, didactic and web-quest. The model contains descriptive information for each of the high level concepts/activities of the pedagogical strategy and suggests a possible sequencing of these pedagogical elements. Through the models the ACCT can provide guidelines on how to use the provided pedagogical strategies, how they might be extended and the types of adaptivity that might be applied. This modeling of pedagogy provides the course developer with a solid foundation on which they can create adaptive pedagogically-driven eLearning in a support-oriented environment.

4.1 Representing Pedagogical Models

Narrative Structures are created to describe how the pedagogical strategy(s) can be realized, e.g. defining types of activities, suggesting possible sequencing of activities, opportunities for communication and collaboration and content selection. They represent the (re)usable elements of pedagogical strategies in a model-based (XML) form. These models can be used as a pedagogically sound foundation on which the construction of adaptive pedagogically sound courses can be based.

The rapid construction of online courses consisting of different "flavors" of pedagogy is facilitated through the use of these Narrative Structures. For example, case based learning, web-quest learning, discovery-based learning and didactic based learning pedagogical models can be combined to form the basis of a customized blended pedagogy. This allows the potential course developer to create customized courses based on "flavors" of the modeled approaches thus actively promoting and facilitating the reuse of not only learning content but also the strategies and pedagogy behind the delivery of such learning experiences.

4.2 Describing Pedagogical Elements

Pedagogical strategies, typically, can be represented as a series of high-level descriptive concepts representing learning activities to be undertaken. Pedagogical strategies are usually accompanied by a set of guidelines and scenarios intended to strengthen the course developers' confidence in using the strategy(s).

Narrative Concepts facilitate the abstract description of pedagogical elements within a content-independent context. Narrative Concepts allow the pedagogical expert to create and customize elements of pedagogical strategies in the process of creating pedagogically-sound adaptive online learning experiences.

4.3 Enabling Adaptive Pedagogy

To make a customized pedagogy adaptive, Narrative Attributes, which consist of adaptive axes (prior knowledge, learning styles, etc.), adaptive techniques (object inclusion/exclusion, link annotation, etc.) and usability/guideline descriptions, must be applied. The course developer can decide on which adaptive technique(s) is to be applied based on the selected adaptive axes. For example, they could use either object inclusion/exclusion or link hiding in adaptivity based on prior knowledge depending on content granularity.

Through the modeling of adaptivity, Narrative Attributes representing adaptivity based on learner preference, tutor scope preference, learning context and learning device have been created.

5 Related Work

Current Adaptive Hypermedia (AH) systems and authoring tools for AH, in the educational domain, concentrate on developing and providing adaptive content retrieval and display capabilities. To this, adaptive content retrieval/delivery, elements of pedagogy are added in an effort to create online adaptive learning. For educationally effective adaptive eLearning however, the pedagogy must be the focus of development. Once the pedagogy has been customized (i.e. selected and extended if required) based on the subject matter area and learner goals, adaptivity can be applied to the pedagogically sound online course structure to produce adaptive personalized pedagogically-driven eLearning.

Currently, there are a range of tools available to create online pedagogy. For example, the REDEEM system [3] allows the teacher to create pedagogical online courses by describing the structure and flow of the content of the course and also the sequencing of the content. It allows the teacher to divide the course into sections and describe the content that the course will use. REDEEM has been quite successful in construction courses however it supports no elements of adaptivity and dynamic personalization. From an active learning perspective the LAMS system [4], which is built upon the emergent Learning Design standard (Previously Educational Markup Language EML), allows the teacher to create, describe and sequence learning

395

activities. However, LAMS likewise provides no support for adaptivity of pedagogical structure and content selection.

Due to the complex and dynamic process of authoring Adaptive Hypermedia, the need for author support in creating adaptive pedagogically sound personalized eLearning is evident [5], [6]. The reach and effectiveness of adaptive personalized eLearning systems is also limited due to the cost of application development. The large initial setup cost of adaptive hypermedia is too high for the mass adoption of AHS in education. From current work in adaptive hypermedia [7], [8] in personalized eLearning it is evident that there are two areas of research which need future development, the design of pedagogically sound adaptive courses and the support offered to the course developer during the process of developing pedagogically sound adaptive courses. Pedagogy can be supported by specifying a requirements-based framework in which pedagogy can be described, used, reused and distributed in an effort to actively promote the cost reduction of adaptive course creation. The course developer can be supported by offering structural support and guideline support during the process of creating adaptive and non-adaptive courses.

Based on the state of the art in adaptive hypermedia and online pedagogy authoring, the ACCT will support and provide innovative ways of applying adaptivity to pedagogy to produce personalized eLearning.

6 Conclusion

From our experience with adaptive and personalized eLearning in the past, several key points should be noted. It is critically important that the teacher/tutor be empowered within the learning experience and not disenfranchised. As a blended teaching approach, the adaptive and personalized eLearning does not replace the teacher. It transforms and enriches their role in the learning experience. Adaptive personalized eLearning is a tool which the teacher/tutor can use to increase the potential educational effectiveness of the entire learning experience. Adaptive eLearning is not just about adaptive content retrieval and construction. It is a mixture of pedagogy, domain knowledge (subject matter expertise) and adaptivity. The production of personalized courses is realized at the concept level not content level. Specific content selection is an aspect of learning experience development that should not concern the teacher/tutor.

References

1. Laurillard, D. Rethinking University Teaching: A Framework for the Effective Use of Educational Technology. London: Routledge, 270pp, (1993)
2. Dagger, D.; Conlan, O.; Wade, V. An Architecture for Candidacy in Adaptive eLearning Systems to Facilitate the Reuse of Learning Resources. E-Learn 2003, World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education, Phoenix (2003) pp. 49-56 (2003)
3. Ainsworth, S.E., Grimshaw, S.K. & Underwood, D.J. Teachers implementing pedagogy through REDEEM Computers and Education, 33(2/3),171-188. ISSN 0360-1315 (1999)

4. Dalziel, J. Implementing Learning Design: The Learning Activity Management System (LAMS), ASCILITE (2003)
5. De Bra, P., Aerts, A., Berden, B., De Lange, B., Escape from the Tyranny of the Textbook: Adaptive Object Inclusion in AHA!. Proceedings of the AACE ELearn 2003 Conference, Phoenix, Arizona, November 2003, pp. 65-71.
6. Eklund, J. and Brusilovsky, P. (1999) InterBook: An Adaptive Tutoring System Universe Science News Vol. 12. March 1999. p. 8-13.
7. Aroyo, L., Cristea, A., & Dicheva, D. (2003) A Layered Approach towards Domain Authoring Support, ICAIí02, Las Vegas, US
8. Apted, T and J Kay, (2002) Automatic Construction of Learning Ontologies, Aroyo, L and Dicheva, D, (eds) Proceedings ICCE Workshop on Concepts and Ontologies in Web-based Educational Systems, ICCE 2002, International Conference on Computers in Education

Yet Another Approach to Support the Design Process of Educational Adaptive Hypermedia Applications

Symeon Retalis[1] and Andreas Papasalouros[2]

[1]University of Piraeus, Department of Technology Education and Digital Systems, 80
Karaoli & Dimitriou 185 34 Piraeus, Greece
retal@unipi.gr
[2]National Technical University of Athens, Software Engineering Laboratory, 157 80
Zografou, Greece
andpapas@softlab.ntua.gr

Abstract. Educational Adaptive Hypermedia Applications (EAHA) provide personalized views on the learning content to individual learners. They also offer adaptive sequencing (navigation) over the learning content based on rules that stem from the user model requirements and the instructional strategies. EAHA are gaining the focus of the research community as a means of alleviating a number of user problems related to hypermedia. However, the difficulty and complexity of developing such applications and systems have been identified as possible reasons for the low diffusion of Adaptive Hypermedia in web-based education. Experience from traditional Software Engineering as well as Hypermedia Engineering suggests that a model-driven design approach is appropriate for developing applications where such requirements and constraints occur. This paper presents on a model-driven design process of EAHA. This process accords to the principles of hypermedia engineering and its innovation is the use of a formally specified object oriented design model.

1 Introduction

An Educational Adaptive Hypermedia Applications (EAHA) is a dynamic web-based application, which provides a tailored learning environment to its users, by adapting both the presentation and the navigation through the learning content. Such an application is comprised of learning resources that have specific learning objectives and they are interrelated in order to facilitate the learning process. The learning resources are designed based on pedagogical rules (or teaching rules) that combine the (domain) model of the content with the user model and the instructional strategies.

EAHAs are currently a 'hot' topic of research in the broader field of adaptive hypermedia applications and several AHES systems have been built during the past years [3], [4], [5], [9]. The design and implementation of EAHA are complex, if not overwhelming, tasks. This is due to the fact that it involves people from diverse backgrounds, such as software developers, web application experts, content developers, domain experts, instructional designers, user modeling experts and pedagogues, to name just a few. Moreover, these systems have presentational,

behavioral, pedagogical and architectural aspects that need to be taken into account. To make matters worse, most EAHA are designed and developed from scratch, without taking advantage of the experience from previously developed applications, because the latter's design is not codified or documented. As a result, development teams are forced to 're-invent the wheel'.

Therefore, systematic and disciplined approaches must be devised in order to overcome the complexity and assortment of EAHA and achieve overall product quality within specific time and budget limits. One such approach is the use of a systematic design method to support the whole design process.

Two candidate approaches exist in this direction, software engineering and hypermedia engineering design methods. Software Engineering methods fail to deal with the particular requirements of hypermedia applications, their user interface intensive nature and their complex node-and-link structure. Although the discipline of Hypermedia Engineering [10], [13], [16], [17] emerged to address this issue, existing Hypermedia Engineering methods are not adequate for properly dealing with the design of educational hypermedia applications. Since educational applications deal with learning, the specification of such applications is a planned set of carefully designed activities and tasks, assessment procedures, selection of proper resources that will support these activities and procedures, that is, the outcome of instructional analysis. According to [13], in the design phase, the specification of a hypermedia application is converted into a description of how to create the application. Existing hypermedia engineering methods do not provide adequate constructs for capturing this specification. This is the main reason why a new approach, specialized in the educational domain is needed. Thus, designing Educational Adaptive Hypermedia Applications is an open research issue [7].

The structure of this paper is as follows: In the following section, the CADMOS-D hypermedia design method is outlined. The steps and the outcomes of each step of the design method are presented next. The paper ends with some concluding remarks.

2 The CADMOS-D design method

In this paper, we propose the CADMOS-D design method which captures the outcomes of instructional analysis and drives the development of the whole EAHA. CADMOS, which stands for a CoursewAre Development Methodology for Open instructional Systems, proposes a sequence of phases for the development of web-based educational applications. These phases are requirements capturing, design, implementation and evaluation. CADMOS proposed a specific method, named CADMOS-D, to support the design phase. We are in the process of extending CADMOS-D in order to support EAHA design.

CADMOS-D, as a design method, provides two distinct models for educational web applications development: A process model, that pertains to the detailed definition and specification of the various design steps, their temporal relationships and sequencing and a list of the outcomes of each step, and a product model [13] that refers to the detailed specification of the outcomes of each step, capturing the design decisions, the relationships and dependencies between these outcomes and the

mechanisms that allow these outcomes to drive the development of the actual application. Furthermore, the product model can form the basis for the description of existing applications, provide the blueprints that depict knowledge and common understanding for particular applications, either completed or under development, much in the way that the blueprints of a building can both drive its development and depict its form, structure and function. The product design model can be decomposed into three sub-models: conceptual, navigational and user interface (presentation) models.

2.1 The Conceptual Model

The *Conceptual Model* defines the learning activities that will happen during the instructional process of a specific subject with their semantic interrelationships. The learning activities are applied to the various thematic concepts-topics of the domain. In fact the thematic topics should be considered as the Ontology of the subject domain to be learned by the students. The Conceptual Model provides an objective definition of the knowledge subject. This definition is provided by the author of the educational application who is considered as a subject matter expert. They have arranged that body of knowledge hierarchically, subdividing the field into areas, which are then broken down further into units and individual topics. An overview of the body of knowledge appears in
http://www.computer.org/education/cc2001/final/chapter05.htm.
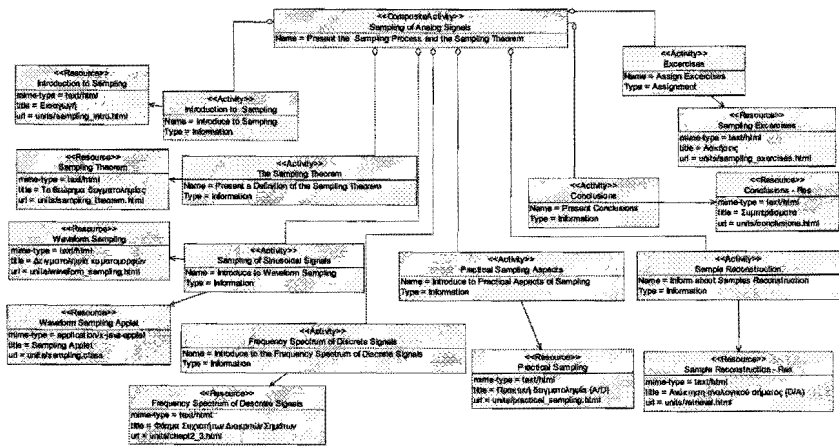
Fig. 1. Extract of the Conceptual Model of a course on digital signal processing which shows the relationships among learning activities and resources

Each learning activity is related to particular learning objectives, notions and terms to be taught, etc, according to the syllabus. The hierarchy of activities corresponds to the hierarchy of learning objectives, that the learner has to meet via her/his interaction

with an educational application under design. Different types of activities exist: Information activities, where the learner access new information, interactive activities, where the learner is dynamically interacts with the educational content, and assessment activities during which the assessment or self-assessment of the learner's knowledge or achievement of the learning objectives is evaluated. Apart from their hierarchical organization, activities can be associated with each other with specific interrelationships thus forming a semantic network that provides an abstract representation of the solution of the problem of instruction of a specific topic. This particular view can be reused per se, thus promoting the reusability of educational applications at an abstract level, apart from navigation and presentation issues. This way, the proposed method incorporates the principle of separation of concerns and promotes reusability. The activities are associated with specific learning resources. The resources align with the notion of Learning Object. These resources are physical, reusable, binary entities, either static fragments of digital content, e.g. text, image, video, simulations etc, or dynamic content generated 'on the fly' from proper scripts in the context of a web-based application environment or Learning Management System. For facilitating the construction of these diagrams, CADMOS-D has proposed an abstract object oriented meta-model, an instantiation of which is shown in Fig. 1 which concerns a hypermedia course on digital signal processing. The order of activities is defined by traversing the graph of activities from left to right in the conceptual model diagrams. A composite activity precedes its children, in the fashion of 'in-ordered' traversal of trees.

The elements of this sub-model are expressed as stereotyped UML classes and they are actually attribute-value pairs connected with proper association relationships. The concepts are mapped to specific learning resources. The modeling elements of this submodel are:

- *Courseware*. This is the top-level element in the hierarchy of activities that compose the conceptual view of the application.
- *Activity*. This defines a simple activity which is an atomic one. This activity may contain specific attributes. Predefined attributes are the title and the type of the activity (information, assessment, etc).
- *CompositeActivity*. This element defines a composite activity, which contains others, either atomic or concept, thus forming a hierarchy of activities into the educational application.
- *Relationship*. This refers to the association between two activities, atomic or composite.

2.2 The Navigation Model

The Navigation Model captures the decisions about how Concepts, Relationships and Resources of the Conceptual Model are mapped to actual hypertext elements Pages and Links, and how the conceptual relationships defined in the Conceptual Model are driving the structuring of the learning content. The *Navigation Model* is composed by two sub-models:

The Navigation Structure Model. This model defines the structure of the EAHA and defines the actual web pages and the resources contained in these pages. An example of this model is shown in Fig. 2.

This structure is composed of the following elements:

– *Content*, which is the top-level container in the hierarchy of an electronic content organization.
– *Composite* entities that are used as containers, thus composing the hierarchical structure of learning content. The chapters and subtopics in which an electronic tutorial or book are organized are examples of composite entities.
– *Access structure* elements, namely indexes and guided tours, which are related to Content or Composite components
– *ContentNodes*, which are the actual pages of the learning content. Content, Composite and ContentNodes are associated with Concept elements, or directly with Resources, in the Conceptual Model.
– *Fragments* that are contained into the ContentNodes. Fragments correspond to Resource elements in the Conceptual Model.
– *Links* between ContentNodes as well as between Fragments. Note that these links are associative links [10, 16] implementing domain specific relationships of the conceptual model. They are not structural links denoting, for example, the transition from a page in the learning content to the next one.
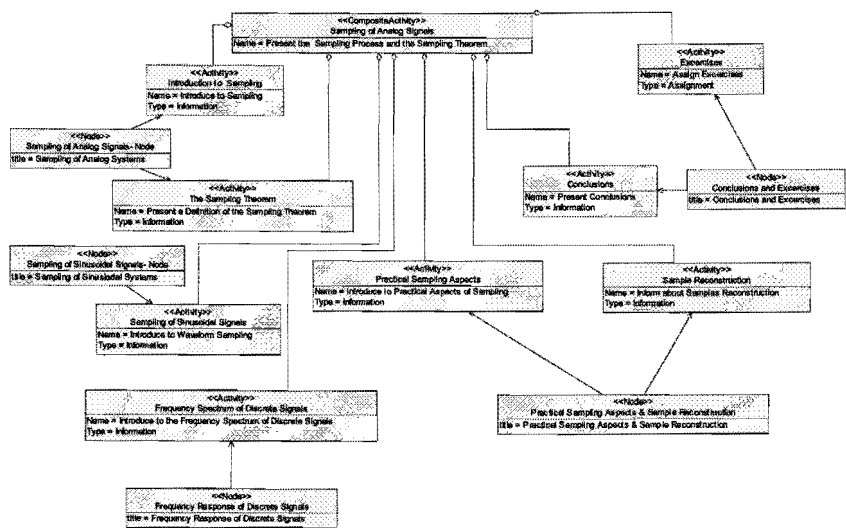
Fig. 2. An extract of the navigational structure model which shows the relationships of learning activities and hypermedia nodes

As shown in Fig. 2, a node will incorporate one or more learning activities. For example, a designer could decide a hypermedia node to incorporate both the

presentation of a theoretical part of the subject domain along with an assessment task. Another designer might want to separate those two learning activities. It is obvious that the learning activity model remains intact in two different aforementioned cases. This fact allows the reusability of design models and the separation of concerns. CADMOS-D advocates that we should not think of "nodes" from the beginning. "Nodes" are the realisation in the hypermedia space of learning activities which should be designed first and which entail the decisions of the instructional design.

The Navigation Behavior Model. The Navigation Behavior Model defines the runtime behavior of the EAHA in terms of navigation. In this sense, this model supports adaptive navigation, which is the method of adaptation that is currently supported by CADMOS-D. Earlier research attempts, such as [14], have proposed the use of statecharts for the modeling of hypertext and web based applications. The Navigation Behavior model uses statecharts, as they are incorporated in the UML in order to specify the dynamic transitions of the hypertext structures as the user interacts with the EAHA. Every containing element of the Navigation Structure Model (Content, or Composite) is associated to a composite state in the Navigation Behavior Model, while every ContentNode corresponds to a simple state. Thus, the hierarchy of the navigational elements defined in the Navigation Structure Model corresponds to the hierarchy of nested states in the Navigation Behavior Model. The events that fire the transitions in the Navigation Behavior Model correspond to structure links into the ContentNodes: next, previous, up level, etc. In addition, guard conditions in these transitions can define alternative navigational transitions, which correspond to conditional behavior of the EAHA, thus implementing content sequencing and adaptive navigation. An example of such a design model is shown in Fig. 3.
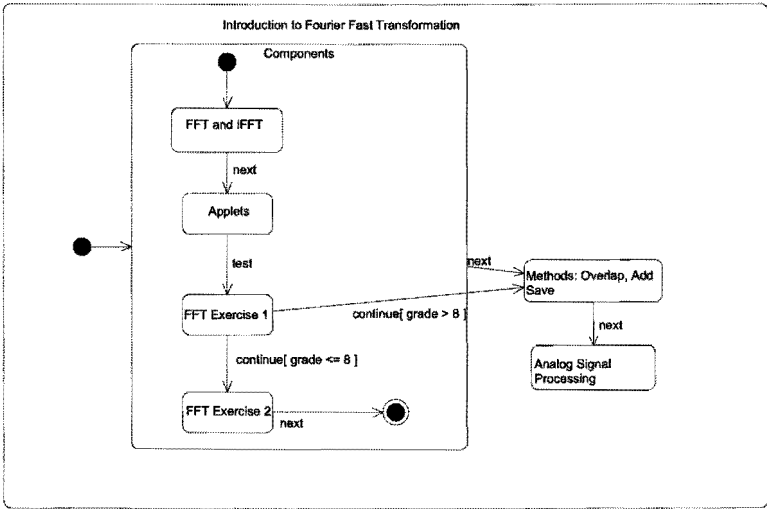

Fig. 3. Example of Navigation Behavior Model

2.3 The User Interface Model (or Presentation Model)

The *User Interface Model* deals with the presentation aspects of the elements defined in the Navigation Model. In particular, each Node in the Navigation Model and its resources is associated with a presentation model element. Note that a multitude of navigation elements can be associated with the same presentation specification, thus promoting uniformity and ease of maintenance of the user interface. The Presentation Model elements have their counterparts in corresponding web technology specifications elements such as HTML and CSS [http://www.w3.org] elements. More specifically, the Presentation Model contains the following stereotyped UML classes: "html", that represent HTML elements, or aggregations of HTML elements and "css" that actually represent Cascading Style Sheet classes.
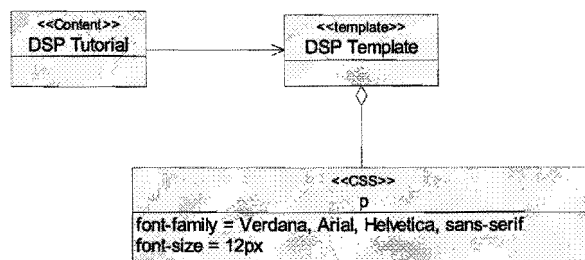
Fig. 4. Example of the basic templates that have been used in the DSP courseware

3 From the design models to automated generation of courseware

The design model of an AEHA can be created with CASE tools like the IBM Rational Rose tool. CADMOS-D suggests the utilization of such tools because UML models can be stored in XMI file, the OMG standard XML metadata interchange format files [15]. In that way, it is possible to process and manipulate that files by standard XML processing tools (e.g. XML parsers). With the use of a specially developed tool, called CGA (Courseware Generation Application), the XMI description is transformed into a structured hypermedia educational applications. More specifically, the CGA tool accepts as entry the XMI description with the relevant learning resources (HTML pages, pictures, files of sound and video, active objects as Applets, ActiveX, Flash, etc.) and produces as output the real AEHA.

   The produced web pages are accompanied by a description of their structure in the form of a XML manifest file. The XML manifest file conforms to the IMS Content Packaging learning technology specification.

An extract of the Content Packaging XML manifest file of the DSP coureware

```
<imsmanifest version="1.3" identifier="TEST">
   <organizations default="TOC1">
      <organization identifier="TOC1">
```

404

```
<title>DSP Courseware</title>
<item identifier="S.10269"
identifierref="S.10269_RES">
    <title>Elements of Discrete Systems</title>
</item>
<!-- ...-->
</organization>
</organizations>
<resources>
<resource identifier="S.10269_RES"
href="units/intro_1.html">
   <title>Elements of Discrete Systems</title>
</resource>
<!-- ... -->
<resource identifier="S.10319_RES"
href="S.10319.html">
   <title>IIR Design</title>
</resource>
</resources>
</imsmanifest>
```

This XML manifest file accompanied by the learning resources can be "uploaded" to any Learning Content Management Systems that support the IMS Content Packaging specification. We experimented with the SCORM Sample Run-Time Environment (RTE) version 1.3 and we produced a hypermedia application for a course on Digital Signal Processing.

At the moment, the CGA tool cannot make use of the information about the dynamic navigational behaviour, i.e. the state-transition diagrams. At the moment, the designer creates distinct design models per user type (users with different stereotype). Thus, we create an EAHA that provides a variety of personalised views of the domain per user type focusing on composition and structural relationships between the learning activities and the respective nodes. For each view, the designer can associate templates in order to specify the look and feel of the nodes.

The lack of dynamic navigational structure is a limitation of our approach, but not an unsolved problem. Actually, it is a matter of time to produce the new release of the CGA tool. We are going to extend approaches like the one presented in [8]. More specifically, the UML activity diagrams will be transformed into IMS Simple Sequencing schema that will accompany the manifest content packaging file.

4 Conclusions

A design method like CADMOS-D, can be used as a framework [10] for authors of hypertext applications to develop and apply methodologies in order to create adaptive applications in a disciplined and controlled fashion. It incorporates the principle of separation of concerns in the design of hypermedia applications, dividing the design of the application in three stages: conceptual, navigational and presentational. We also claim that this separation of concerns aligns with the three types of adaptation, navigation and presentation.

Beyond the design model, the development of open, portable, and maintainable EAHA can be facilitated with the adoption of learning technology standards. In this paper we are proposing the CADMOS-D design method that produces models that accord to the IMS content packaging. With the use of the CGA tool that has been developed, the EAHA is automatically generated by using the XML manifest file and the learning resources.

This work aspires the bridging of the gap between the conceptual description and the implementation of web applications as it is also suggested in [1]. Like approaches such as WebML [6], WCML [11], UWE [12], etc. it maintains the classical, in hypermedia engineering, discrimination of the design of web applications into structure, navigation and presentation design, and uses XML as the product model for the implementation of actual applications. The use of XMI and the focus of the current method on the specific domain of education, which sets certain constraints in the structure of applications makes it different from the aforementioned methods. The current work has also close similarities to [8], which also uses the same model representation, XMI, and the same method for application generation, XSLT for adaptive applications. The main difference with this method is the provision for navigation and presentation issues, which is not covered in [8], and the support for Learning Technology Standards.

Acknowledgements

References

1. Aroyo, L., Dicheva, D. & Cristea, A.: Ontological Support for Web Courseware Authoring. In: Ceri, S., Guardères, G., Paraguaçu, F. (eds): Proceedings of Intelligent Tutoring Systems, 6th International Conference, ITS 2002, Biarritz, France and San Sebastian, Spain, June 2-7, 2002. Lecture Notes in Computer Science, Vol. 2363. Springer-Verlag, Berlin Heidelberg New York (2002) 270–280
2. Booch, G., Rumbaugh, J., Jacobson, I.: The Unified Modeling Language User Guide, Addison Wesley (1999)
3. De Bra, P., Houben. G., Wu, H.: AHAM: A Dexter-based Reference Model for Adaptive Hypermedia. In: Proceedings of the tenth ACM Conference on Hypertext and hypermedia: returning to our diverse roots, Darmstadt, Germany. ACM Press, New York (1999) 147–156
4. Brusilovsky, P.: Methods and techniques of adaptive hypermedia. User Modeling and User Adapted Interaction, 6 (1996) 87–129
5. Brusilovsky, P.: Adaptive and Intelligent Technologies for Web-based Education. In: Rollinger, C., Peylo, C. (eds.): Special Issue on Intelligent Systems and Teleteaching. Kunstliche Intelligenz, 4 (1999) 19–25
6. Ceri, S., Fraternali, P., Bongio, A.: Web Modeling Language (WebML): a modeling language for designing web sites. Computer Networks and ISDN Systems, 33 (2000) 13–157

7. Brusilovsky, P., Maybury, M.: From adaptive hypermedia to the adaptive web. Communications of the ACM, **45** (2002) 30–33.
8. Dolog, P., Nejdl, W.: Using UML and XMI for Generating Adaptive Navigation Sequences in Web-Based Systems. In: Stevens, P., Whittle, J., Booch, G. (eds.):UML 2003 - The Unified Modeling Language, Modeling Languages and Applications, 6th International Conference, San Francisco, CA, USA, October 20-24, 2003. Lecture Notes in Computer Science, Vol. 2863 Springer-Verlag, Berlin Heidelberg New York (2003)
9. Fischer, S.: Course and Exercise Sequencing Using Metadata in Adaptive Hypermedia Learning Systems. ACM Journal of Educational Resources in Computing, 1 (2001)
10. Garzotto, F., Schwabe, D., Paolini, P.: HDM- A Model Based Approach to Hypermedia Application Design. ACM Transactions on Information Systems, **11** (1993) 1–26
11. Gomez, J., Cachero, C., Pastor, O.: Conceptual modeling of device-independent Web applications. IEEE Multimedia, **8** (2001) 26–39
12. Hennicker, R., Koch, N.: Systematic Design of Web Applications with UML. In: Siau,K., Halpin, T., (eds.): Unified Modeling Language: Systems Analysis, Design and Development Issues, Idea Group Publishing, Hershey, PA, (2001)
13. Lowe, D., Hall, W.: Hypermedia & the Web, an Engineering Approach, John Wiley & Sons, West Sussex, England (1999)
14. De Oliveira, M., Turine, M., Masiero, P.:. A Statechart-Based Model for Hypermedia Applications, ACM Transactions on Information Systems, **19** (2001) 28–52
15. OMG. UML Version 1.4 Specification. Available at
http://www.omg.org/technology/documents/formal/uml.htm
16. Rossi, G., Schwabe, D., Lucena, C., Cowan, D.: An Object-Oriented Model for Designing the Human-Computer Interface of Hypermedia Applications, In: Proceedings of the International Workshop on Hypermedia Design (IWHD'95), Montpellier, 5, Springer Verlag (1995)
17. Schwabe, D., Rossi, G.: The Object-Oriented Hypermedia Design Model. Communications of the ACM, **38** (1995) 45–46

Authoring and Delivering Adaptive Courseware

Craig Stewart[1], Alexandra Cristea[2], Adam Moore[1],
Tim Brailsford[1] and Helen Ashman[1]

[1] School of Computer Science and Information Technology, University of Nottingham
NG8 1BB, Nottingham, U.K.
{cds,axm,tjb,hla}@cs.nott.ac.uk
[2] Department of Computer Science Eindhoven University of Technology
P.O. Box 513, Eindhoven, The Netherlands
a.i.cristea@tue.nl

Abstract. Adaptive Educational Hypermedia (AEH) may be the answer to the imperative need of personalization in web-based education. Up to now, however, adaptive hypermedia environments have focussed more on end-delivery, and less on the authoring problems. This paper addresses the complex issue of creation and delivery of personalized material by examining two aspects of existing AEHs: the authoring system of MOT, and the delivery system of WHURLE, with the aim of establishing a "write once, use many" methodology for the creation of content and adaptation within current AEH environments.

1 Introduction

Personalisation of presentation has always been important in any consumer industry. With the expansion of the WWW into our everyday life, education has become increasingly a consumer commodity. Today's learners expect high quality, relevant educational materials, delivered to them in a timely and appropriate manner. Adaptive educational hypermedia (AEH) [1],[2] systems aim to personalise the delivery of educational materials to the needs of the user – both to their stated requirements as well as to their less obvious desires. This has led to the development of many on-line educational delivery systems (e.g., Interbook [3], AHA! [8], TANGOW [4], WHURLE [11]). Many of these systems adapt their educational content to different *dimensions* of each learner, such as: current knowledge levels, computed user goals, immediate tasks, educational context (e.g., are they in school, university, or learning from home?), and more recently learning styles in adaptive hypermedia (e.g., LSAS [10]). Each of these AEH systems uses its own content model, coding methodology, and style. This leads to an unnecessary and undesired level of complexity for the content or lesson author. Ideally, the author would create materials once and then use these materials in any AEH system. Transfer between these educational environments would be simple. This would also encourage cost-effective re-use of materials in a variety of ways. Authoring for adaptive hypermedia education systems has not been addressed until recently. This paper describes the translation of educational materials between two AEH systems, My Online Teacher (MOT) [12] and WHURLE. We discuss how using MOT as the authoring system and WHURLE as the delivery environment fosters a 'create once, use many' approach to educational content. A previous paper addresses similar issues in translating from MOT to AHA! [13].

Please note that these systems have been developed totally independent of each other and this type of conversion exercise also is a test of the systems' expressivity and flexibility.

2 Designing Instructional Strategies in MOT

2.1 MOT Basics

MOT is an online environment for the authoring of adaptive educational hypermedia. It is based on the theoretical framework LAOS [5], and aims at providing maximum flexibility whilst concomitantly reducing the author load.

2.2 MOT Static Components

MOT allows authors to either create content, using adaptation dynamics written by others, or to design their own adaptation dynamics (and, e.g., use contents created by others). The static part is layered, based on the information type stored (as explained below), so that each layer can have different authors.

The first static layer is the *domain concept model*, containing the learning resources organized hierarchically as concept maps and their descriptions (i.e. metadata, organized as concept attributes). The default attribute set contains: *title*; *keywords*; *introduction*; *pattern*; *text*; *explanation*; *conclusion* and *exercise* (although only the title is obligatory). In Figure 1, an author has created the attributes *text_adv* and *text_beg* for advanced and beginner learners respectively.
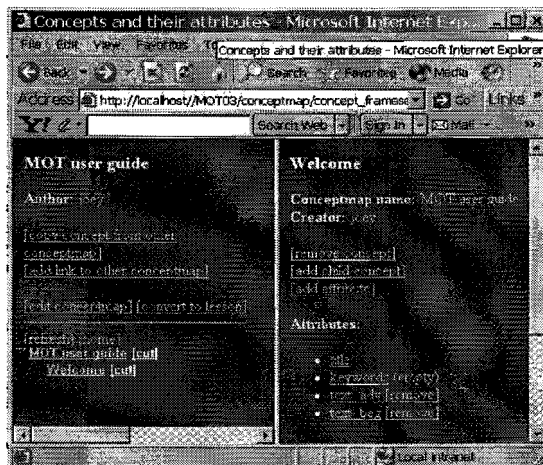

Fig. 1. A MOT domain concept map (left frame) with an example concept, called 'Welcome' (right frame) with 'text_beg' and 'text_adv' attributes

409

The second static layer is the *goal and constraints* (also called *lesson*) *model*. It contains selections filtered from the domain model based upon instructional views and goals [9] (such as expected timeframe, level, background knowledge, learner styles, etc.). For instance, an introductory short lesson on 'Neural Networks' contains, among others, the selection of 'beginner' concepts 'The Von Neuman computer versus the human brain' and 'The biological neuron' (Figure 2). The objective is to separate purely domain-dependent information (such as learning resources) from additional pedagogic information added by the teacher. For instance, weight information about the relevance of the resource to the different types of learner (adv: advanced or beg: beginner) may be stored here.
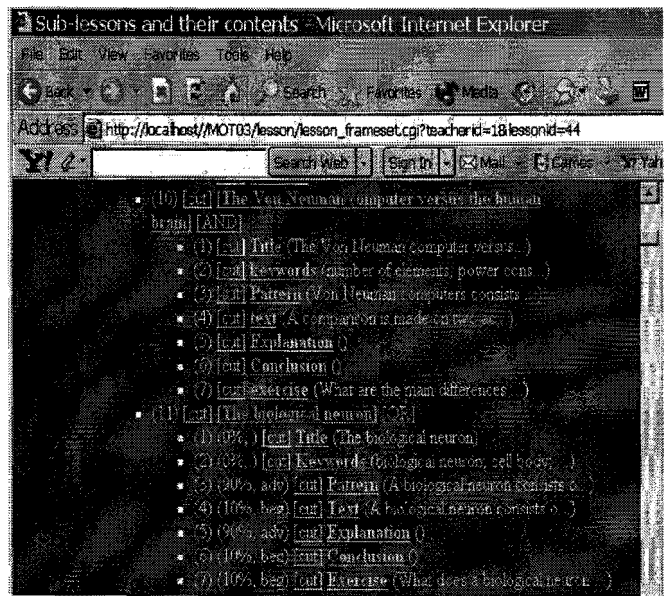
Fig. 2. A section of a MOT Lesson Map (sampled from a course on Neural Networks), showing the concept 'The biological Neuron' with the weights attached to each of that concept's attributes (e.g., '90%, adv' for 'Pattern': only advanced learners see this)
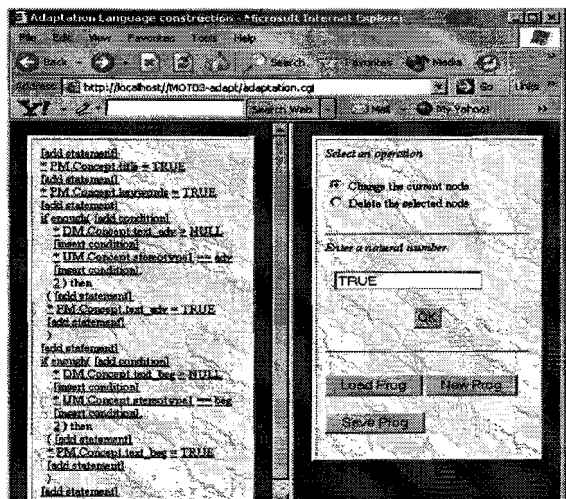
2.3 MOT Dynamic Components

Fig. 3. A strategy for the example of a concept map in Figure 2. The strategy checks if the special attributes text_adv and text_beg exist, and then shows text_adv for advanced users and text_beg for beginners. Title and keywords are shown for all

The dynamic, adaptive behaviour of the courseware elements (in accordance with the learner characteristics determined by a user model), is designed in MOT using an *Adaptive Strategy Interface* (Figure 3). This environment is built based on the *3-Layers of Adaptation Granulation* theoretical framework (LAG) [7]. MOT has a frame interface that allows the author to use a specifically designed adaptive language, which enables the building of adaptive strategies that correspond to instructional strategies [5]. Figure 3 shows a small instructional strategy corresponding to the new attributes text_adv and text_beg (introduced in Figure 1). The power of this adaptive instructional strategy is not that it can be used on the concept map in Figure 1, but that it can be used on *any* concept map that has the attributes text_adv and text_beg.

3 WHURLE

3.1 WHURLE Basics

WHURLE is a flexible, discipline-independent integrated learning environment, designed to deliver adaptive content over the web. The learner is presented with a lesson, which is constructed from a collection of underlying educational resources, according to a default narrative that is defined by a lesson author in a *Lesson Plan,*
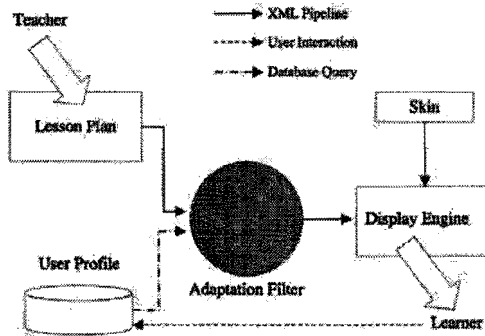
Fig. 4. The modular WHURLE system, modified from Zakaria et al [15]

and filtered according to rules specified in the user model. WHURLE uses an XML-pipeline (i.e. the results of one process are fed into the next) where components are present in a modular fashion – this means that any particular user or pedagogical model can be utilised within the pipeline, as an appropriately designed adaptation filter (Figure 4) [15]. The list of resources defined in the *Lesson Plan* is passed to the *Adaptation Filter*, which passes those deemed necessary, according to information in the user profile, to the *Display Engine* which, in turn, creates the *Virtual Document* – rendered in a user interface defined in a skin.

3.2 WHURLE Static Components

WHURLE content resources are called *chunks*. Each *chunk* is a conceptually discrete piece of information (i.e. there are no interdependencies between chunks, and no links to other resources). An example of a WHURLE chunk would be a captioned image or a self-contained paragraph of text on a single topic. Owing to the flexibility provided by WHURLE's use of chunks, adaptation may be implemented at the content level (using conditional transclusion [14]) to determine which chunks are made available to the learner. Another static resource used in WHURLE is the *Linkbase*, which describes links between a chunk, in any given context, and other learning resources (e.g. other chunks or an external WWW page). These links are robust, bi-directional, and multiply typed as described in [14].

3.3 WHURLE Dynamic Components

WHURLE's dynamic adaptation is implemented by the adaptation filter, which determines the chunks that are delivered to the learner (Figure 5). This decision is determined by rules defined in the user model acting upon metadata in the *Lesson Plan* and data contained in the user profile. The current implementation allows for domain knowledge based adaptation [16]; where each chunk reference in the lesson

plan contains the information that the adaptation filter uses to determine inclusion in the virtual document. Hence, in producing a lesson for WHURLE, not only does an authoring system have to produce the content but the lesson plan must contain the metainformation used as the basis for adaptation.

4 Conversion from MOT to WHURLE

In the following, we explain three ways of conversion of some of the MOT components presented previously. The main process being that the MOT interface feeds WHURLE information about what content should be provided to the learners, as well as how this content should be filtered and adapted.

4.1 Conversion of Concepts

The Domain Concept Model used by MOT is a hierarchical structure organised by 'concept' (Figure 1). The Lesson Plan used in WHURLE is also a hierarchical structure, organised by 'level' (Figure 5). Each MOT concept has 'attributes' and each WHURLE level has 'chunks' (collected into a 'page') that define the actual content. From this basic description we can begin to derive a conceptual mapping of MOT to WHURLE. MOT has several default standard attributes, of which 'title' and 'keywords' are common to WHURLE chunks. Therefore, in any conversion it is necessary that these common elements are included in every chunk created. We shall illustrate the process of conversion using the example shown in Figure 1. The MOT concept in Figure 1 will be converted into two chunks, as the contents of the 'text_beg' and 'text_adv' attributes can be seen as pedagogically separate. The 'title' and 'keyword' attributes, as common elements, are included in both chunks. The conversion process so far would produce two discrete chunks (content) but no surrounding structure tying them together into a single pedagogic unit. The next part of the conversion process is the production of a WHURLE Lesson Plan to provide this structure. At this stage each MOT concept is equivalent to a WHURLE 'page' (see Figure 5). For example, the concept in Figure 1 would transform into the WHURLE Lesson Plan shown in Figure 5. This adaptive behaviour is an instance description and can only be applied on the resources from the specific concept map in Figure 1.

```
<level name="user" title="Welcome">
    <page>
        <chunk domain="100"
               stereotype1="beg">MOT-12-324</chunk>
        <chunk domain="100"
               stereotype1="adv">MOT-12-325</chunk>
    </page>
</level>
```

Fig. 5: a section of a WHURLE Lesson Plan, the result of the conversion of the 'Welcome' concept shown in Figure 1

Of course for this process to be meaningful the conversion engine needs to be informed of the semantic relationship between the MOT attribute name and the

WHURLE stereotype value, for example, that 'text_beg' is equivalent to 'stereotype1 = "beg"'. The value of the WHURLE 'domain' attribute (in Figure 5, this is '100'), is linked to a table of values in a database. When transforming a MOT Domain Concept Map, the root concept title is registered in the database as the domain name. This value will thus be the same for all chunks produced from the same Domain Map. Figure 6 shows the outcome of such a conversion with a beginner and an advanced view.
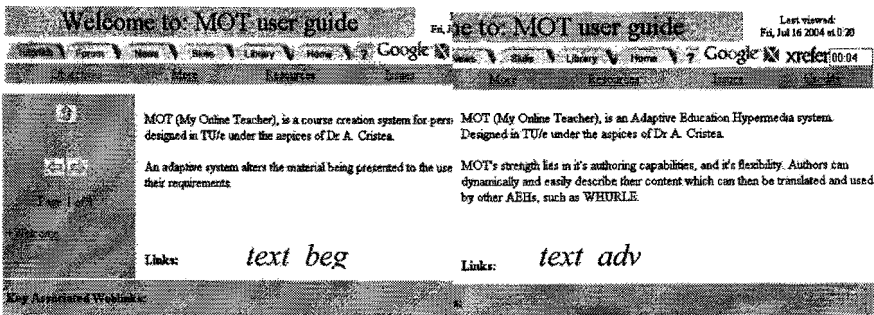

Fig. 6. WHURLE rendering of the beginner (a) and advanced (b) user version conversion from the structure in Figure 1

4.2 Conversion of Lessons

One of the benefits of MOT is the ability to create any attribute the author requires to fully describe a concept. This feature cannot be fully exploited when involving the conversion described in section 4.1, since the conversion engine needs to be altered each time an author creates a new conceptual relationship between a MOT concept attribute and the WHURLE 'stereotype' attribute. An attribute in a MOT Lesson Map can have a weight and a label attached to it. When translating from a MOT Lesson Map to a WHURLE Lesson Plan we can use these weight values to our advantage. Figure 2 shows a simple lesson concept, its attributes and their assigned weights. The conversion engine can determine the WHURLE stereotype from a table of weight values. Table 1 shows an example of such a table (a '0' weight represents a common element; so is not shown in the table). Alternatively, the labels attached to the weights can be interpreted. This allows greater flexibility for the author, since they can create/modify/delete their own common elements – although with the stipulation that the 'title' and 'keyword' elements are always present and common.

Table 1. A simple table of MOT weight values to WHURLE stereotype value

Weight	Stereotype
1-49	beg
50-89	int
90-99	adv

Table 2 shows how the concept 'The biological neuron' from Figure 2 is processed to produce four WHURLE chunks. Chunk 'C1' from the conversion in Table 2

includes *only* the common elements. Chunks 'C2', 'C3' and 'C4' are produced by combining the common elements with each successive attribute. This is done irrespective of weight value. Even though attributes may share the same weight, they may nevertheless be pedagogically distinct.

Table 2. A stylised version of the concept shown in Figure 2, alongside a representation of which attributes are included in the chunks produced (C1-C4). As the attributes 'Explanation' and 'Conclusion' are empty, they will not result in a chunk being produced

MOT attributes		WHURLE chunks			
Attribute	*Weight*	*C1*	*C2*	*C3*	*C4*
Title	0	✓	✓	✓	✓
Keywords	0	✓	✓	✓	✓
Pattern	90		✓		
Text	10			✓	
Explanation	90	No attribute contents			
Conclusion	10	No attribute contents			
Exercise	10				✓
		✓ = included in the chunk			

For example: chunk 'C2' would only be relevant to an advanced learner (in the current domain of Neural Networks) and chunk 'C3' relevant to a beginner learner. Creation of the chunks is, of course, still only the first step in the conversion process. A WHURLE Lesson Plan must also be produced. Using the hash table (Table 1) and the chunks C1-C4 from Table 2 would result in the Lesson Plan shown in Figure 8 (note that it only shows a subset of the complete Lesson Plan resulting from the conversion of the concept in Figure 2).

```
    . . . .
<level name="neuron" title="The Biological Neuron">
   <page>
      <chunk domain="general"
            stereotype1="">C1</chunk>
      <chunk domain="110"
            stereotype1="adv">C2</chunk>
      <chunk domain="110"
            stereotype1="beg">C3</chunk>
      <chunk domain="110"
            stereotype1="beg">C4</chunk>
   </page>
</level>
    . . . .
```

Fig. 7. A section of a WHURLE Lesson Plan resulting from the conversion of the 'The Biological Neuron' concept shown in Figure 2. Note: a 'domain' value of 'general' indicates that a chunk C1 (our generic *title* chunk) will be seen by every user; a 'domain' value of '110' is the value WHURLE uses to indicate the Neural Network domain

Another feature of the MOT Lesson Map is that it combines concepts from multiple Domain Concept Maps, so the WHURLE 'domain' attribute has to be drawn from the root 'title' attribute of the parent Concept Map for each concept in the lesson, stored in the relevant table and assigned a value. It is this value that is inserted into the WHURLE chunk attribute 'domain'.

4.3 Conversion of Adaptation Dynamics

Whilst the conversion described in section 4.2 is far more flexible than that described in section 4.1, it is still limited. The author is restricted to a specific table, which itself

only describes a single pedagogical model. In the example given in section 4.2, this conversion is restricted only to domain knowledge.

The rule set described in the LAG model [7] is far more flexible and powerful. For instance, an author can create their own adaptation rules or use pre-existing adaptation rule templates.

For the two example conversions previously presented (Figures 5&7) there doesn't have to be a hardwired MOT-to-WHURLE interpretation. By using the MOT adaptation strategy editing interface (section 2.3), rules can be created specifying the presentation conditions and order related to specific conceptual model structures. These can be used to do the actual conversion, the result for the cases above being the same: Figure 5 would be the result of the conversion of the domain concept map in Figure 1 with the interpretation given by the adaptive strategy in Figure 3. Respectively, Figure 7 would be the result of the conversion of the domain lesson map in Figure 2 with the interpretation given by the following adaptive strategy (Figure 8). The current conversion programs, however, follow the models given in sections 4.1 and 4.2.
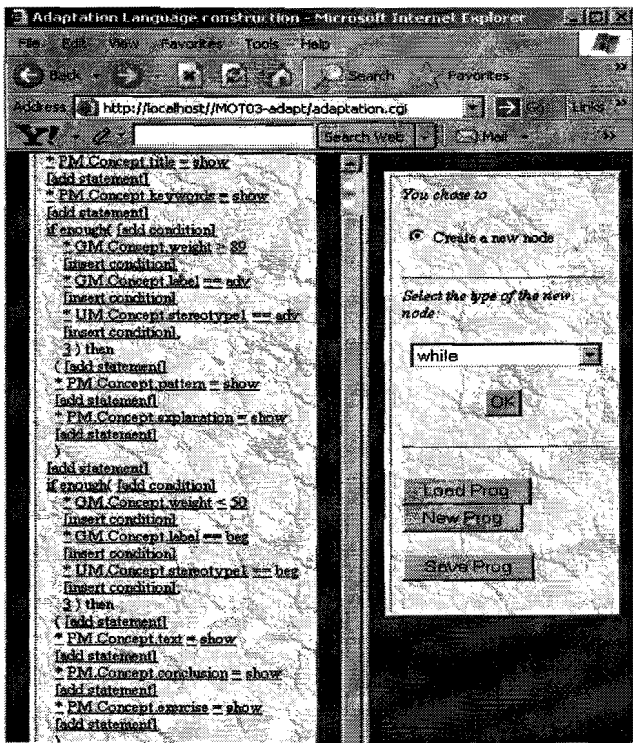

Fig. 8. A strategy for the example of the lesson in Figure 2. The procedure interprets weights and labels for advanced & beginner users in the Lesson map (adv, beg); then shows adv for advanced users and beg for beginners. Title and keywords are shown for all

Future development of our AEH authoring system will involve using these adaptation rules and templates. A 'teacher' would declare the rules they wished to employ, and use these as the basis of the adaptation of their lesson and its conversion into a WHURLE Lesson Plan.

5 Conclusion

Most traditional on-line learning environments have a serious pedagogic limitation, in that they are unable to adapt to the requirements of the user. The 'lesson' content is presented in a simple, static manner and the user is expected to use these materials until they have completed whatever the objectives of the lesson may be. Whilst there is often a help system in place to aid the student, the presentational and pedagogic structure always remains the same. Research has shown [1], however, that learners differ in their ability to learn. Although it may seem trite to state that every student is unique, many systems ignore this simple fact.

In this paper we have briefly presented MOT, focussing on its capabilities as an AEH authoring system and WHURLE, focussing on its capabilities as an AEH delivery system, and we have described the first steps towards interfacing these two systems. We have shown, with the help of examples, how, from the generic level of authoring for any concept map (as in MOT) we can obtain an instance representation (as in WHURLE). There is still much work to be done to be able to use more of the MOT flexibility in WHURLE. Moreover, both systems are still growing, so this interfacing exercise also provides pointers to future development possibilities, as well as necessities. At first glance, the delivery systems in today's AEHs are quite different. For instance, the main difference between WHURLE and AHA! v. 3.0 is that in AHA! the adaptive behaviour of the concepts is contained in the concept description itself. This means that the same concept will behave the same way given the same variable instantiations, no matter where and when it is called. WHURLE doesn't have concepts, just 'chunks' and these behave as specified by the lesson plan, and thus can behave differently when used with different lesson plans. More importantly, AHA! allows an overlay approach to user model variables, whereas one instance of user modelling implemented in WHURLE works with a hybrid of stereotypes and domain knowledge. Commonalities, however, can be found. For instance, WHURLE chunks would correspond somewhat to AHA! XHTML resources (although these also historically contained some adaptive inclusion information, which is now becoming obsolete). This would make AHA! concepts behave somewhat like WHURLE lesson plans. Other, more general commonalities are that both systems implement user models, basic educational resources, adaptive rules for adaptive behaviour, etc. It is constructive to strive towards being able to create material in one system, e.g., MOT, and being able to deliver it on various platforms. In this way we tackle the important problem of authoring for adaptive educational hypermedia. By examining the challenges and problems of translation between AEH systems first *pair-wise*, then *one-to-many*, we can, in principle, determine the elements needed for a generic interface. This is one of the necessary steps towards

extracting patterns of adaptive authoring and being able to reuse not only the static, but also the dynamic material created within any system, into any other system.

Acknowledgements

References

1. P. Adey, R. Fairbrother, D. Wiliam, B. Johnson, and C. Jones, *Learning styles & strategies: a review of research* London, King's College, Centre for the Advancement of Thinking, 1999.
2. P. Brusilovsky, Adaptive Educational Hypermedia. *Proc. of 10th Tenth Intl PEG Conference*. Tampere, Finland. pp 8-12, 2001.
3. P. Brusilovsky, J. Eklund & E. Schwarz, Web-based education for all: A tool for developing adaptive courseware. Computer Networks and ISDN Systems, In *Proc. of 7th Intl World Wide Web Conference*, 30 (1-7), 291-300, 14-18 April 1998.
4. R. M. Carro, E. Pulido, P. Rodríguez, Designing Adaptive Web-based Courses with TANGOW. *Proc. of the 7th Intl Conference on Computers in Education, ICCE'99*, Chiba, Japan, V. 2, 697-704, November 4 - 7, 1999.
5. A. Cristea, Adaptive Course Creation for All, *Proc. of the International Conference on Information Technology*, Las Vegas, US, IEEE, April, 2004.
6. A. Cristea, & A. De Mooij, LAOS: Layered WWW AHS Authoring Model and its corresponding Algebraic Operators. *Proc 14th Intl. World Wide Web Conference*, Budapest, ACM, Hungary 20-24 May 2003.
7. A.I. Cristea, & L. Calvi, The three Layers of Adaptation Granularity. *Proc UM'03*, Springer.
8. P. De Bra, A. Aerts, B. Berden, B. De Lange, B. Rousseau T. Santic D., Smits & N. Stash, AHA! The Adaptive Hypermedia Architecture. *Proc. of the fourteenth ACM conference on Hypertext and Hypermedia*, Nottingham, UK, 81-84, 2003.
9. F. Garzotto and A. Cristea, ADAPT Major Design Dimensions for Educational Adaptive Hypermedia, *Proceedings of ED-MEDIA'04*, AACE (to appear).
10. LSAS, Learning Style Adaptive System, described at: http://www.archives.ecs.soton.ac.uk/users/nb99r/intro_short/frame.htm
11. A. Moore, T. J. Brailsford and C. D. Stewart, Personally tailored teaching in WHURLE using conditional transclusion. *Proceedings of the twelfth ACM conference on Hypertext and Hypermedia*, Denmark., 2001
12. MOT, My Online Teacher, described at: http://wwwis.win.tue.nl/~acristea/mot.html
13. N. Stash, A. Cristea & P. De Bra, Authoring of Learning Styles in Adaptive Hypermedia: Problems and Solutions. *Proc. 13th Intl WWW Conference*, NY, 2004.
14. A. Moore, C. Stewart, D. Martin, T. Brailsford, H. Ashman, Links for Learning: Linking for an Adaptive Learning Environment. IASTED Intl Conference on Web-Based Education, Innsbruck, Austria, Feb 2004.
15. M.R. Zakaria, A. Moore, C.D. Stewart, T.J. Brailsford, "Pluggable" User Models for Adaptive Hypermedia in Education. *Proceedings of the Fourteenth ACM Conference on Hypertext and Hypermedia (Hypertext '03)*, 2003, pp 170-171.
16. M. R. Zakaria and T. J. Brailsford, User modeling and adaptive educational hypermedia frameworks for education, New Review of Hypermedia and Multimedia (NRHM 2002), 8 (2002), 83-97.

An authoring environment for adaptive testing[1]

Eduardo Guzmán, Ricardo Conejo, Emilio García-Hervás

Departamento de Lenguajes y Ciencias de la Computación.
E.T.S.I. Informática. Bulevar Louis Pasteur, 35. 29071, Málaga. SPAIN
{guzman, conejo, egarcia}@lcc.uma.es

Abstract. SIETTE is a web-based adaptive testing system. It implements Computerized Adaptive Tests. These tests are theoretically based tailor-made tests, where questions shown to students, the finalization of the test, and the student knowledge estimation is accomplished adaptively. To construct these tests, SIETTE has an authoring environment. It is a suite of tools that help teachers to create questions and tests properly, and to analyze of the students' performance after taking a test. In this paper, we present this authoring environment in the framework of adaptive testing. As will be shown, this set of tools, that own some adaptable features, can be useful to help teacher without too much skills on this kind of tests.

1 Introduction

Testing is among the most widely used tools in higher education [1]. The main goal of testing is to measure the student knowledge level in one or more concepts or subjects, i.e. in pieces of knowledge that could be assessed. This kind of assessment has been used for student knowledge diagnosis in adaptive educational systems like in EML-ART [16] or DCG [15], but most of these systems used heuristic-based testing techniques. However, there is another kind of tests, the adaptive tests, which are based on a theoretical-sound theory, the *Computerized Adaptive Testing* (CAT) theory [14]. This theory defines which questions (called *items*) is the most adequate to be posed to students, when the tests must finish, and how the student knowledge can be inferred from students' performance during the test. To this end, CAT uses an underlying psychometric theory called *Item Response Theory* (IRT) [8].

Adaptive test elicitation is a task that requires a special effort from the teacher, since the construction of this kind of tests must be accomplished fulfilling some features. These features must be kept to ensure the correct operating of adaptive tests. For instance, teachers must ensure that the stem of one item does not provide any trail to correctly answer other items, i.e. items must be independent among themselves. Additionally, adaptive testing selection techniques must have available a considerably big set of items with a wide range of difficulties. These requirements demand for adaptive testing system the availability of an authoring environment that helps

---

teachers to construct items and tests. Additionally, this kind of systems needs some tool to analyze data of student test session, in order to study if the set of items owns the properties that it should have. Unfortunately there are only a few set of systems able to generate adaptive tests [1]. Also their authoring interfaces do not include adaptive and/or adaptable features.

SIETTE [3] is a web-based system for adaptive test generation. Moreover, this system is able to deliver conventional (heuristic-based) tests. Through a web interface, students can take tests for self-assessment, where item correction is shown after each item, with optionally some kind of feedback; or teachers can make grading tests in order to assess their students, even for academic purposes. To construct and modify the test contents, SIETTE offers an authoring environment. This is a suite of tools that permits teachers to principally edit tests. In this environment has been included a tool for analyzing the student's performances.

This paper is aimed at showing the authoring environment of the SIETTE system. Next section briefly explains what adaptive tests are. Section 3, shows the components of the SIETTE architecture. Following, section 4, is devoted to the test editor, showing its operation mode and its adaptable capabilities [11]. Section 5 is devoted to the result analyzer, a tool that allow teachers to study the students' performance in the tests they have made. Finally, in section 6, the conclusions of this work are summarized.

2   What is an adaptive test?

CAT theory tries to mimic the usual assessment procedure followed by a human teacher. That is, first to administer the student a medium difficulty item. If the student answers correctly, next administer a little more difficult item, and in other case, administer other less difficult item. This process should be repeated until the teacher considers that he has enough evidences to determine the student knowledge level. Consequently, in CAT theory, this process has been automatized. Items are posed one by one. After posing an item, a temporary student knowledge level estimation is accomplished. In terms of this estimation, the next item to be posed is chosen in such a way that this estimation is more accurate. In more precise terms, an adaptive test can be seen as an iterative algorithm that starts with an initial estimation of the student's knowledge level, and has the following steps:

1. All the items that have not been administered yet, are examined to determine which is the best item to ask next according to the current estimation of the examinee's knowledge level.
2. The item is asked, and the examinee responds.
3. According to the answer, a new estimation of the knowledge level is computed.
4. Steps 1 to 3 are repeated until the stopping criterion defined is met.

IRT postulates that there is a relationship between the student knowledge level and the probability of successfully answer an item. This dependence relationship is

probabilistically expressed by means of a function called *Item Characteristic Curve* (ICC). Accordingly, this function collects, for each knowledge level, the probability of that a student with this level answers correctly. If this probability function is available for every item of a test, the student knowledge can be directly inferred. In CAT theory, IRT is used to estimate the student knowledge level, in order to determine the next item to be posed, and to decide when to finished the test. This theory ensures that the obtained student knowledge estimations do not vary in terms of the items used in the estimation process.

The main advantage of adaptive tests is that they are fitted to students. This means that the number of items posed is different for each student, and depends on his knowledge level. As a consequence, students neither get bored for being administered very easy items, nor feel stressed for being administered very difficult items. In addition, different sets of items are posed for different students. Consequently, this reduces the possibility of cheating. In contrast, the main disadvantage of an adaptive test is that its construction is costly. Each ICC must be determined (calibrated) before an adaptive test could be applied. To this end, a big student population must be administered this test non-adaptively, and after from these data the calibration can be done.

3 The architecture of SIETTE

SIETTE allows CAT elicitation and delivering through web interfaces. It can work as a standalone assessment tool or inside other web-based adaptive systems, as a diagnosis tool. It is a multilingual system, currently available in Spanish and English, but open to include other new languages. Fig. 1 collects the architecture of the system. It comprises two main parts: the student workspace and the authoring environment.

The *student workspace*: This is the place where students can take tests. The main component of this part is the *test generator*, which is in charge of test delivering. Two interfaces can be used to access to generated tests:

- *Student classroom*: Here, students can take tests for self-assessment, and teachers can administer tests for grading.
- *Interface for external connections*: This interface permits SIETTE to work as a diagnosis tool in other web-based adaptive hypermedia educational systems. An own simple protocol [5] has been defined to this purpose.

The *authoring environment*: It is a suite of tools used by teachers. They allow content creation and update, as well as analyzing the performances of students that have taken tests. This suite is composed by the following tools:

- The *test editor*: Through this tool, teachers can create subjects. Related to the topics of each subject, different sets of items can be defined. Teachers can also define different tests that involve the subject topics.
- The *result analyzer*: This tool helps teachers to make analysis of the student performance.
- The *item calibration tool*: As been shown, ICCs functions predict the behavior of students that answer the corresponding item. They are determined by a set of parameters. These parameters are inferred by calibration techniques [4]. In this

part of the architecture, some of these calibrations techniques are being developed. Unfortunately, this tool is currently under development and, therefore will not be approached in this paper.
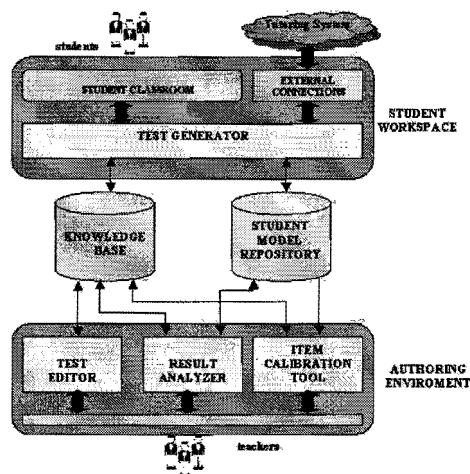

Fig. 1. Architecture of SIETTE

4 The test editor

In SIETTE, teachers can define different subjects. The curriculum of the subjects, the tests and items are stored in the knowledge base. Subject curricula are structured forming acyclic graphs of topics. Therefore, a subject can be divided in topics. Each topic can be also divided in subtopics and so on. As a result, each curriculum can be seen as a granularity hierarchy [10], where topics are related to their subtopics via aggregation relations. Items are assigned to topics in such a way that if an item is assigned a topic, this item is used to assess the student knowledge level in the topic. Items can be assigned to any topic of the hierarchy, included the subject, since it can be seen as a global aggregation of the whole curriculum. At last, tests are defined on topics. If a test involves a set of topics, after a testing session, SIETTE is able to return a student knowledge estimation for each test topic, and for each one of their descendant subtopics at any level.

In order to access to this tool, teachers must be provided with a pair identifier/password given by the system administrator. A snapshot of this tool, after selecting a subject to edit, is shown in Fig. 2. It is divided in two main frames. The left one is the curriculum hierarchy tree. Two different views of this tree can be seen: items or tests. When the "items" option is selected, the tree shows the subject curriculum hierarchy, composed by the topics and their items. Topics are represented by folders, and items by color balls. In terms of the kind of item, the ball color differs. If the "tests" option is selected, the tree shows the tests that have been defined for this subject. Under each test, the curriculum of the test topics is shown. At last, the look of

the right side depends on the element selected in the tree. Subject, topic, item and test information can be added, modified or deleted through this frame.
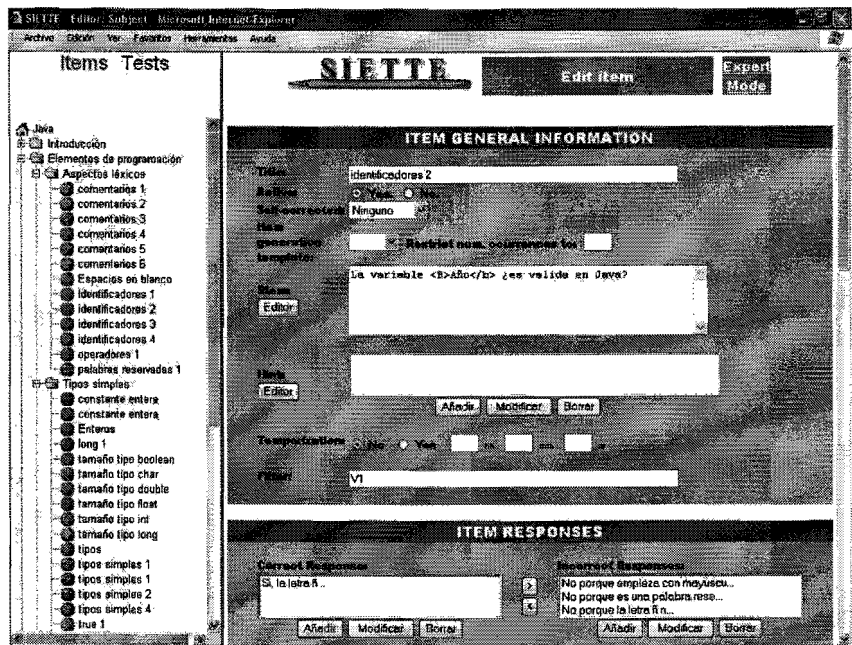

Fig. 2. The test editor

The element parameters of the editor can been seen in two different ways, depending on the teacher profile. The test editor adapts the content presentation in terms of the teacher profile. Two different teacher stereotypes [9] are managed: novice and expert. In terms of his mastery in the use of this tool, teachers can select either one stereotype or the other, and are free to change it at any time. The difference between them rests on the level of detail of the information shown. In novice profile, some information is hidden. When a teacher with this profile is editing an element, some of its parameters will take values by default. Expert profile has been conceived for teachers with more advanced mastery on the system and/or in the use of adaptive tests.

Different teachers can access to the same subject. For each subject, there is a teacher who is its creator, and has all permissions granted. He can grant, through the editor, different permissions to other teachers. As a consequence, the set of actions a teacher can accomplish is adapted to the permission he has on the subject. These permissions are: item reading or item modification, curriculum modification, test addition or test modification, etc.

4.1 Test definition

Chua Abdullah [2] pointed out the types of knowledge that teachers must take into account to get effective testing assessment: (1) *what to test*, that is the parts of the domain knowledge to be tested; (2) *who to test*, this is the student model; (3) *how to test*, that is the item selection criterion and the student assessment method. We have added another one: (4) *when to finish the test*, i.e. the decision of test finalization. In adaptive testing, this last decision is vital, since it will determine the accuracy and, as a result, the reliability of the student assessment. In the test definition stage of SIETTE, all these concerns are expressed by test configuration parameters. The first concern (*what*) is represented by the topics involved in the test, and the number of knowledge levels in which the students will be assessed. Although in IRT, the real number domain is used, in SIETTE, for simplicity, a discrete domain is used. Accordingly, if the number of knowledge levels is equal to K, students will be classified between 0 and $K-1$.

The *who* is clearly the student represented by his student model. Student models in SIETTE are essentially probability distribution curves, which contains, for each knowledge level, the probability of that the student knowledge will be this knowledge level. For each topic assessed in a test, SIETTE keeps a student distribution curve. When creating a test, SIETTE provides teachers the possibility of selecting the prior probability distribution their student will have before posing any item.

Finally, the *how* and *when* concerns will be undertaken in the following three subsections:

4.1.1 Item selection criteria

SIETTE provides two different item selection adaptive criteria:

- *Owen's adaptive criterion*: It uses a discrete version of Owen item selection approach [12]. It selects the item that minimizes the expectation of the variance of the posterior student knowledge distribution.
- *Difficulty-based criterion*: Owen found a simplification of his previous selection criterion (*op. cit.*), whose performance is very near to the former, and which it is very simple to apply. It selects the item whose difficulty (a parameter of the ICC) is the nearest to the current student knowledge level estimation.

4.1.2 Student assessment techniques

In the *how* concern, we do not just have to consider the item presentation order, it is necessary to make the decision of what mechanism must be used to infer the student knowledge level. In SIETTE, the adaptive assessment methods are based on a discrete Bayesian mechanism in which the student knowledge probability distribution is calculated after posing each item i (Equation 1). The estimation made after posing the last test item becomes the final estimation.

$$P(\theta|u_1,..,u_i) \propto P(u_i = 1 | \theta)^{u_i} (1 - P(u_i = 1 | \theta))^{(1-u_i)} P(\theta | u_1,..u_{i-1}) \qquad (1)$$

In Equation 1, $P(\theta|u_1, ..,u_{i-1})$ is the temporary student estimation before answering the item i, and $u_i=1$ represents that student has answered correctly the item. $P(u_i=1|\theta)$ is the ICC for the item i. As mentioned before, it expresses the relationship between the item correct answer and the knowledge levels. Once the new estimation distribution is calculated, the student knowledge level can be inferred in two different ways, in terms of the adaptive criteria used: *modal*, that is the most likely level; or *expectation-based*, where the estimated knowledge level is equal to the probability distribution expected value.

In SIETTE, items are assigned to the topics they assess. If an item Q is used to assess a topic T, applying the aggregation relations defined in the curriculum, item Q can be used to assess all the topics preceding T. In order to manifest this relation, each item has an ICC for each topic it can assess. Accordingly, after a single test, the system is able to return the student knowledge state in the test topics and in all their descendants [6].

4.1.3   Test finalization criteria

In order to ensure the test finalization, and to avoid the item overexposure, an item maximum number is defined for each test. While a test is being administered, every time an item is selected, this upper limit is compared to the number of items already administered. If this last number is equals or greater than the limit, the test is forced to finish. While this condition is not satisfied, test finalization can be decided by one of the following criteria:

- The student knowledge estimation variance is lesser than a certain threshold;
- the student estimated knowledge level probability is greater than a certain threshold;
- or, for temporized tests, the time limit has been reached.

Whereas the two former criteria are purely adaptive, the last one, although it is non-adaptive, it can be applied to adaptive tests as an alternative mechanism to avoid very long tests. SIETTE offers the possibility of configuring tests to be temporized. To this end, teachers only have to set the test time limit through the editor.

Additionally, other configuration parameters can be set for each test: its availability can be restricted to one or more groups of students; filters can be configured to restrict the items that can be administered in each test; teachers can allow students to retake a test at the same stage they left, if the test has been paused for any reason (for instance, connection failure); etc.

4.2   Item definition

In order to construct their tests, in SIETTE, teachers are supplied with several types of items:

- *True/false items*, where students have to select just one answer.
- Multiple-*choice items*, where students must select an answer or no one.
- *Multiple-response items*, where more than one answer can be correct.

- *Self-corrected items*, they are little programs, implemented by means of java applets or flash, which allow teachers to include more sophisticated exercises. They are correct by themselves, and this correction is given to SIETTE.

These types of items can be combined in the same test. The former items have the classical format of a stem and a set of answers. SIETTE offers other kind of item construction scaffoldings, a library of exercises templates. It collects most of the exercises that usually appear in textbooks. They can be added easily to a test, by instating the desired template. Additionally, SIETTE includes a mechanism of item generation. This mechanism has been implemented through item templates written in a web language (e.g. JSP, PHP, etc.). These templates generate questions of any of the previous types, after being pre-processed. For more information about the types of items and the item generation see [7].

5 The result analyzer

Student model repository stores information about the student test sessions. The result analyzer of SIETTE allows teachers to study these data. It contains the following two utilities:

Fig. 3. The student performance facility of the result analyzer

A student performance facility: It contains for each test, the list of students that have taken the test. It shows for each student the identifier of the test session, his

identifier and name, the date of the beginning of the test session, the total number of items posed, the number of items correctly answered and his final qualification. It allows seeing the complete test session, that is, the items that were given to the student in the same order posed, and with the student's response and the correct response. This tool gives detailed statistics of the final student's knowledge level estimation. For each topic, the estimation, the number of items posed and the number of correctly answered items topic, as well as a graphical representation of the estimated knowledge distribution is provided. Additionally, it offers the possibility of deleting student' test information from the student model repository.

An item statistic facility: It supplies statistic information about the student responses to the item in all test sessions in which the item has been posed. These data can be studied for each topic to which the item is directly associated, and for each one of its preceding topics, even including the subject. Once the topic to be studied has been selected, a table is shown. It contains a column for each answer of the item. Each row represents a knowledge level in which the subject can be assessed. Each cell c_{ij} of the table represents the number of students with final estimated knowledge level i that have selected the answer j. In addition, cumulative statistics are shown. That is, taking all the data of the student model repository as sample, the likelihood of that a student selects an answer given his final estimated knowledge level. This information is very useful for calibration purposes.

6   Conclusions

SIETTE is a well-founded testing system that generates adaptive tests for grading or self-assessment. These tests have a lot of advantages: tests are suited to students, the number of items requires for assessment is lesser than in the conventional testing procedures, estimations have high accuracy, etc. In SIETTE contents are structured in subjects. Each subject is composed by a set of topics, structured hierarchically using aggregation relations. Each topic has associated a set of items that can be used to assess it and all its preceding topics. Furthermore, SIETTE provides teacher with an authoring environment. It is a set of tools that allow teachers the knowledge elicitation, i.e. item, topic and test construction. It is a multi-user environment in which teachers can collaborate in the test creation process, although this collaboration can be restricted by applying different permissions on the elements of each subject.

SIETTE has on the one hand adaptive features: the item selection, student assessment and test finalization criteria. These criteria are based on the performance of the students while taking the tests. On the other hand, through the adaptable characteristics, the test editor is personalized to each teacher profile and permissions. For instance, the novice profile is very useful for teacher with no skills about adaptive test configuration. Also, different item construction scaffolding brings teacher the possibility of easily adapting the test presentation to the population that is going to make a test.

Both the student classroom and the test editor are available for any user through the following URL: http://www.lcc.uma.es/SIETTE. In the student classroom, there has been defined a subject "Demo" which includes several demo tests. These tests have

been created to show some characteristics of SIETTE. Moreover, a "demo" teacher account has been created to freely access to the test editor and the result analyzer, in order to show their operability and the adaptable features.

References

1. Brusilovsky, P. and Miller, P. Web-based Testing for Distance Education. De Bra, P. and Leggett, J. Proceedings of WebNet'99, World Conference of the WWW and Internet. 149-154. 99. AACE.
2. Chua-Abdullah, S. Student Modelling by Adaptive Testing - A Knowledge-based Approach. Canterbury, University of Kent. (2003)
3. Conejo, R., Guzmán, E., Millán, E., Pérez-de-la-Cruz, J.L., and Trella, M. SIETTE: A web-based tool for adaptive testing. International Journal of Artificial Intelligence in Education (forthcoming).
4. Glas, C.A.W. Item calibration and parameter drift. In Van der Linden, W.J. and Glas, C.A.W. (eds.) Computerized Adaptive Testing: Theory and Practice. Kluwer Academic Publisher,(2000).
5. Guzmán, E. and Conejo, R. An adaptive assessment tool integrable into Internet-based learning systems. Méndez Vilas, A., Mesa González, J. A., and Solo de Zaldívar, I. Educational Technology: International Conference on TIC's in Education. I, pp. 139-143. Sociedad de la Información. (2002)
6. Guzmán, E. and Conejo, R. Simultaneous evaluation of multiple topics in SIETTE. Cerri, S. A., Gouardéres, G., and Paraguacu, F. Lecture Notes in Computer Science 2363. Proceedings of the 6th International Conference on Intelligent Tutoring Systems ITS 2002. 739-748. Berlin, Springer Verlag. (2002)
7. Guzmán, E. and Conejo, R. A library of templates for exercise construction in an adaptive assessment system. Technology, Instruction, Cognition and Learning (TICL) (forthcoming).
8. Hambleton, R.K., Swaminathan, J., and Rogers, H.J. Fundamentals of Item Response Theory. Sage publications, California, USA. (1991).
9. Kay, J. Stereotypes, Student Models and Scrutability.Proceedings of the International Conference on Intelligent Tutoring Systems (ITS 2000). (2000).
10. McCalla, G. I. and Greer, J. E. Granularity-Based Reasoning and Belief Revision in Student Models. Greer, J. E. and McCalla, G. Student Modeling: The Key to Individualized Knowledge-Based Instruction. 125, 39-62. 94. Berlin Heidelberg, Springer Verlag. NATO ASI Series. (1994).
11. Oppermann, R., Rashev, R., and Kinshuk. Adaptability and Adaptivity in Learning Systems. In Behrooz, A. (ed.) Knowledge Transfer. pAce, London, UK (1997).
12. Owen, R.J. A Bayesian Sequential Procedure for Quantal Response in the Context of Adaptive Mental Testing. Journal of the American Statistical Association 70, 351-371 (1975).
13. Promissor Inc. CATGlobal. http://www.catglobal.com. [2004, July 12].
14. van der Linden, W.J. and Glas, C.A.W. Computerized Adaptive Testing: Theory and Practice. Kluwer Academic Publishers, Netherlands (2000).
15. Vassileva, J. Dynamic Course Generation on the WWW. du Bolay, B. Mizoguchi, R. (eds.). Knowledge and Media in Learning Systems. Proceedings of the 8th AIED'97 Conference. IOS Press, pp. 498-505. (1997).
16. Weber, G. and Brusilovsky, P. ELM-ART: An Adaptive Versatile System for Web-based Instruction. International Journal of Artificial Intelligence in Education 12, pp. 351-383 (2001).

Specification of Adaptation Strategy by FOSP Method

Milos Kravcik

Fraunhofer Institute for Applied Information Technology,
53754 Sankt Augustin, Germany
Milos.Kravcik@fit.fraunhofer.de

Abstract. The aim of this paper is to propose a novel method for collaborative authoring of adaptive educational hypermedia, which can be generalized also for other application areas. It addresses the objective to simplify the authoring process and make it more efficient. Its main idea is to separate the partial results produced by different authors in such a way that they can be reused. This concerns also adaptation strategies that specify how the domain model and the context model attributes should be processed to present the content to the user accordingly. An instruction designer specifies adaptation as sets of content object preferences for different contexts. We have identified a pattern in the adaptation process that consists of four operations – Filter, Order, Select, and Present.

1 Introduction

Relevant authorities [8] have identified as one of the five main challenges in information systems provision of learning environments that can efficiently enable each student to have his or her own teacher. The key research areas in this respect include cognitive tutors, collaborative authoring, and context learning. Efficient learning must be individualized, but systems that adapt to user preferences are not easily available. In the development of electronic documents in general, the main aim was typically to facilitate development and organization of ideas by bringing the medium closer to the cognitive events of the user [14]. To make documents prepared in different ways interchangeable and reusable, we have to deal separately with their various aspects (e.g. logical structure, physical appearance). Then authors can concentrate on document semantics (structure and contents), without having to deal with its layout, which can be created by designers and selected according to the use context. Based on this, standards have been created. *Standard Generalized Markup Language* (SGML) is an ISO standard for document structuring and interchange at the authoring and editorial stages. To associate formatting rules with SGML documents, another ISO standard appeared. *Document Style Semantics and Specification Language* (DSSSL) describes the way that text and graphics should be presented in two-dimensional environment.

In the following, we describe how these ideas have been reflected in formal hypermedia models, but have not been consequently implemented in the systems. Authoring adaptive hypermedia is still a complex process that needs to be simplified. Based on our experience [10, 11] we propose a method for specification of adaptation

429

strategies, which should support collaborative authoring. We focus on adaptive educational hypermedia, but the method can be generalized for other fields as well.

2 Hypermedia Models and Specifications

In 1990 the basic formal hypertext model was presented – *Dexter Hypertext Reference Model* [9]. Its goal was comparison of existing systems as well as development of interchange and interoperability standards. The model distinguishes three layers of a hypertext system and two interfaces between them: *Runtime Layer* (presentation of the hypertext; user interaction; dynamics), *Presentation Specifications,* and *Storage Layer* (a "database" containing a network of nodes and links), *Anchoring, and Within Component Layer* (the content / structure inside the nodes). Based on the Dexter model, a reference model for adaptive hypermedia was developed [6], called *Adaptive Hypermedia Application Model* (AHAM). The model provides a framework to express the functionality of adaptive hypermedia systems by dividing the storage layer into three parts: *Domain model* (describes how the information content is structured), *User model* (describes the information about the user), and *Adaptation model* (adaptation rules defining how the adaptation is performed). AHAM uses Condition-Action rules and due to their complexity, it is not supposed that authors will write all the rules by hand. Some other models build upon AHAM identifying additional relevant layers in the model [5] and particularly in the adaptation model [4]. The objective is to enable reusability at various levels, focusing mainly on adaptation strategies and techniques. Additionally to the new formal models, also the electronic document standards have been adjusted for hypermedia, especially for the web. A simplified version of SGML has been created and named *Extensible Markup Language* (XML). It enables development of user-defined document types on the web and provides meta-data for web-based applications. *Cascading Style Sheets* (CSS) and *Extensible Style Language* (XSL) can specify presentation of XML documents.

3 Authoring Adaptive Educational Hypermedia

A major current shortcoming is that the different layers and factors proposed in the formal models are not clearly separated in real adaptive hypermedia systems. User-friendly tools efficiently supporting the complex process of authoring adaptive hypermedia applications are difficult to find. To simplify the authoring process we need reusability at various levels as well as interoperability between different platforms. The first overview of adaptive hypermedia authoring tools is relatively fresh [1]. Authoring adaptive educational hypermedia is more difficult in comparison with the ordinary hypermedia, as the authors have additionally to create the knowledge structure and its interconnection with the educational materials. The state of the art in this area has become a theme of a specialized workshop [3]. The main objective is to simplify the authoring process. This can be achieved by reusability not only on the level of learning objects, but also concerning adaptation techniques and pedagogical approaches. Better understanding and formulation of possible patterns in

the authoring process can help. A pattern describes an often repeated problem and its solution that can be used always when the problem occurs. Collaborative authoring issues have been seldom addressed [10]. Some tools support authoring on the markup language level (e.g. AHA! [7] by conditional comments in HTML pages), other represent knowledge in the form of teaching tasks, defining their composition by rules (the TANGOW [2] approach). Just a few tools focus primarily on the simplification of the authoring process, without the necessity of programming skills, and provide form based user interface (NetCoach [16] is one of them). ALE [10, 11] offers template based user interface to make the authoring process more intuitive. The systems vary in following the formal models and separating individual layers. This is most critical in the case of the adaptation model, where there is no known satisfactory solution yet. To specify adaptation some tools use a markup language directly in the content (e.g. AHA!), other encode it in the learning environment (e.g. ALE [12]). However, such adaptation specifications are not reusable.

4 Stakeholders

Table 1 shows various parts of an adaptive course together with different professions participating in their authoring. Ideally a typical teacher as the author of an adaptive course should fulfill mostly the composer and annotator role. Although it does not exclude writing of complementary explanatory texts and simple authoring of content fragments (e.g. photos or schemas). So the author chooses from the available basic building blocks those that suit best for the current purpose and composes the individual learning objects from them. The graphical designer creates an appropriate layout for them. Another role of the author is annotation of the learning objects, which should be as automatic as possible. Note that the annotator does not have to be the same person as the composer, as the author can reuse a learning object and change just its metadata, for instance if it is to be used for a different target group.

Table 1. Authors of adaptive educational hypermedia

Content fragments	Expert
	Multimedia author
Learning objects	**Composer**
	Graphic designer
Metadata	**Annotator**
Adaptation strategies	Instruction designer
Exercises (Homework)	Student
Assessments	Tutor

Specification of adaptation strategies should be a task for a specialized instruction designer, taking into account especially the student's learning style. The strategies defined in this way should be universal, thus reusable in various courses and the teacher would just choose the most suitable one from the available offer. Usually also students contribute into a course by exercises (homework) and tutors by their assessments. Neither tutors have to be identical with the authors – an author might be a professor and a tutor his assistent. To realize this, it is necessary to separate

adaptation strategies from the course content, but on the other hand to interconnect them with the used metadata and context attributes.

5 System Architecture

Following the Dexter model, the architecture of hypermedia systems consists of three levels: *Physical level* (storage, shared data, network access), *Logical level* (nodes and links), and *Presentation level* (user interface). Based on our experience [11], we are proposing a technique for specification of adaptation strategies. It enables flexible and context dependent presentation of educational hypermedia. Similarly to AHAM, we suggest that an efficient adaptive hypermedia system contains the following parts:

- *Content management* – maintains the domain model (learning objects with metadata, semantic concept networks / ontologies) and supports the authoring process (separation of content and layout, reusability, semi-automatic annotation)
- *Context management* – includes generic user modelling (preferences, learning styles), enabling reusability and sharing of the model by various applications
- *Adaptation management* – corresponds to presentation specification in the Dexter model; deals with adaptation specifications, including instruction management (learning strategies); adaptation specification is application independent and reusable, it can be specified without programming skills

In [10] we have proposed an adaptation strategy specification technique with the objective to separate the content of educational materials from the knowledge driving the adaptation process, which includes the instruction. In general, each of these parts can have a different author. Similarly, it is good to separate also the declarative and procedural knowledge, as the first one can be specified as attributes and metadata also by authors without the programming skills. From our point of view an adaptation strategy specifies how the individual objects (learning objects or content fragments) should be presented by the system based on their attributes and the current parameters of the learner (user) model, or more generally of the context model.

6 FOSP Method

Our WINDS experience has shown that authors without technical background can specify declarative instructional knowledge. There exist many repositories containing milions of learning objects with metadata (e.g. Cisco, Ariadne). This fact should be taken into account when designing authoring methods and tools. The *Learning Object Metadata* (LOM) standard defines a learning object as any entity, digital or non-digital, that may be used for learning, education or training [13]. Content models identify different kinds of learning objects and their components. A comparative analysis of six known content models [15] led to the creation of a general model that includes the existing standards and distinguishes between:

- *Content fragments* – learning content elements in their most basic form (text, video), representing individual resources uncombined with any other; instances
- *Content objects* – sets of content fragments; abstract types
- *Learning objects* – aggregate instantiated content objects, add a learning objective

To illustrate our method let us consider the following first. When a teacher wants to teach a learner certain new knowledge or skill, he usually first decides what types of learning resources are suitable for the particular user, e.g. for one learner it can be a definition and an example, for another a demonstration and an exercise. Then he should order the resources, i.e. decide whether to start with the definition or the example. Each learning resource can have alternative representations, so the teacher has to select the most suitable one – narrative explanation, image, animation, video, etc. This illustrates the basic reasoning behind our method, which takes into account also different presentation opportunities of various devices. Note that we are proposing a technique to specify an adaptation strategy, not an adaptation strategy itself. Specification of adaptation strategies is a task for instructional designers.

In our approach an adaptation strategy maps the domain model (learning objects with attributes and metadata) and the context model (including the learner model with learning styles and preferences) onto the course presentation for the learner. To be more concrete we define the following sets:

- *Role* – the pedagogical role of the object (e.g. definition, example, demonstration)
- *Style* – the learner's learning style (e.g. intuitive – sensitive, active – reflective)
- *Media* – the media type (e.g. text, image, audio, video, animation)
- *Context* – the usage context (e.g. multimedia desktop, mobile device)
  The proposed adaptive strategy is based on these functions:
- *Weight*: Role × Style → Integer
- *Sequence*: Role × Style → Integer
- *Alternative*: Media × Style → Integer
- *Threshold*: Style → Integer
- *Granularity*: Context → Integer

The *Weight* function represents the relevancy of the pedagogical role for the learning style. The *Sequence* function defines the order for the presentation of the role for the learning style. (Note the difference between these two: an introduction does not have to have the highest relevancy, but when selected it should be the first. The selected components do not have to be ordered according to their relevancy.) The *Alternative* function expresses the relevancy of the media type for the learning style. The *Threshold* function sets the threshold for the object display based on the learning style. The *Granularity* function specifies the maximal number of objects presented at once for the context. The proposed adaptation strategy consists of four operations:

- *Filter*: for the current object it selects just those components that have their *Weight* greater than *Threshold*

- *Order*: this sorts the selected components according to the *Sequence* value
- *Select*: from the alternative components it chooses that one with the highest *Alternative* value
- *Present*: it displays the componets taking into account the *Granularity* value

So to define a pedagogic strategy for a certain learning style the instruction designer needs to specify the functional values of *Weight, Sequence, Alternative, Threshold,* and *Granularity* for different types of learning objects (i.e. content objects). But it is not necessary to define all the values. If no value is specified a default one will be applied: 0 for *Weight*, the minimum value for *Threshold* and the maximum one for *Granularity*. The basic operations *Filter, Order, Select* and *Present* are interpreted by the system. According to their first letters we call this method *FOSP*. To implement this method in practice it is crucial to choose suitable visualization of the functional values and an intuitive user interface to control them.

7   Summary

In this paper, we have proposed a method how to specify adaptation strategies in adaptive hypermedia applications. The key idea of the method is to simplify the complex authoring process for teachers. Collaborative authoring is supported by sharing of partial results between various authors that participate in the development of adaptive hypermedia. This approach is compliant with the established standards and recommendations, including the AHAM reference model. Specification of adaptation strategies by separating the content, declarative and procedural knowledge in adaptive courses is quite natural and similar approaches have been applied in related areas.

References

1. Brusilovsky, P.: Developing Adaptive Educational Hypermedia Systems: from Design Models to Authoring Tools. In: Murray, T., Blessing, S., Ainsworth, S. (eds.): Authoring Tools for Advanced Technology Learning Environments. Kluwer (2003)
2. Carro, R.M., Pulido, E., Rodríguez. P.: TANGOW: a model for Internet Based Learning. IJCEELLL 1-2 (2001)
3. Cristea, A.: Authoring of adaptive and adaptable educational hypermedia: Where are we now and where are we going? Proceedings of the WBE 2004 Conference. IASTED (2004)
4. Cristea, A., Calvi, L.: The three Layers of Adaptation Granularity. Proc. of the International Conference on User Modelling. Springer (2003)
5. Cristea, A., de Mooij, A.: LAOS: Layered WWW AHS Authoring Model and their corresponding Algebraic Operators. Proc. of WWW 2003 Conference. ACM (2003)
6. De Bra, P., Houben, G. J., Wu, H. (1999). AHAM: A Dexter-based Reference Model for Adaptive Hypermedia. Proc. of the Hypertext and Hypermedia. ACM (1999) 147-156
7. De Bra, P., Ruiter, J.P.: AHA! Adaptive hyermedia for all. In: Fowler, W., Hasebrook, J. (eds.) Proc. of WebNet 2001 Conference. AACE (2001) 262-268

8. Jones, A. et al.: Grand Research Challenges in Information Systems. Computing Research Association (2002)
9. Halasz, F., Schwartz, M.: The Dexter hypertext reference model. Communications of the ACM 2 (1994) 30—39
10. Kravcik, M., Specht, M.: Authoring Adaptive Courses – ALE Approach. Proc. of the Web Based Education 2004 Conference. ACTA Press (2004)
11. Kravcik, M., Specht, M., Oppermann, R.: Evaluation of WINDS Authoring Environment. Proc. of the Adaptive Hypermedia 2004 Conference. Springer (2004)
12. Kravcik, M., Specht, M.: Flexible Navigation Support in the WINDS Learning Environment for Architecture and Design. Proc. of the Adaptive Hypermedia 2004 Conference. Springer (2004)
13. LOM: IEEE Standard for Learning Object Metadata. IEEE (2002)
14. Rada, R.: Hypertext: From Text to Expertext. McGraw-Hill (1991)
15. Verbert, K., Duval, E.: Towards a Global Component Architecture for Learning Objects: A Comparative Analysis of Learning Object Content Models. Proceedings of the ED-MEDIA 2004 Conference. AACE (2004)
16. Weber, G., Kuhl, H.-C., Weibelzahl, S.: Developing Adaptive Internet Based Courses with the Authoring System NetCoach. In: Reich, S., Tzagarakis, M.M., De Bra, P. (eds.) Hypermedia: Openness, Structural Awareness, and Adaptivity. Springer (2001) 226-238

Visualizing Adaptivity for Teachers: an Authoring Tool for Designing Educational Adaptive Websites

Jacopo Armani [1]

[1] Institute of Communication Technologies
Università della Svizzera italiana, Via G. Buffi 13, 6900 Lugano, Switzerland.
jacopo.armani@lu.unisi.ch
http://www.istituti.usilu.net/armanij

Abstract. So far educational adaptive technologies have proven their effectiveness only in small-scale lab courses, thus they still wait for being released to the large community of educators. Among the reasons, it is the difficult task of designing and authoring a highly interactive adaptive course, especially for non-technical group of educators. This paper presents the preliminary results of a research on the development of a user-friendly authoring environment for designing web-based adaptive courses. This work is part of a larger research effort, which is aimed at merging the most established adaptive techniques with the state of the art of the Learning Management Systems.

1   Introduction

Adaptive technologies in the field of education have proven so far their effectiveness only in small lab experiments, thus they are still waiting for being presented to the large community of educators. First of all, as pointed out by some recent studies [4], adaptive educational hypermedia systems are difficult to design, set-up, and implement, due to the high technical competencies they require to master them. In particular, all of the (few) existing general purpose adaptive educational systems have a steep learning curve, that forbids a non technical teacher to autonomously create a course.

More generally speaking, the main issues that hinder the spread of many of the available adaptive systems in community of educators are:

1. High technical competencies to set up an adaptive course (i.e. writing of XML descriptors, textual configuration files, ...);
2. Difficulty in specifying in the system language the interactions that must occur between the user and the system (i.e. definition of concept networks, condition statements, resource indexing, ...);
3. Lack of ready-to-use patterns that exploit frequent adaptive teaching strategies.

Despite this situation, different researchers point out the importance of adaptivity in the definition of effective learning scenarios. For example, studies from the Instructional Design field [13] show how much the adaptive instruction paradigm has

436

been, and still is, a common trait in every day instructional situation: a teacher in a classroom naturally adapts his/her learning goal, presentation style, instructional strategy, and language to match the needs of his/her class, thus, why this can not happen online too?

2   Literature Review

In the last decade, several domain-independent Educational Adaptive Hypermedia Systems (EAHS), with different degrees of authoring capabilities, have been proposed. Some important examples are Interbook [6], Net-Coach [14], and AHA! [7]. Yet, all of them have been used quite always within the research group who developed them (with very rare exceptions, actually the Author of this paper has experimented with AHA! to design a set of adaptive courses to assess the usability of the tool, cf. [1]).

Moreover, the task of building authoring interfaces for adaptive systems has been recognized as one of the main reason for the small diffusion of EAHS so far [4]. In this direction, some researchers [3] are trying to develop intelligent authoring interfaces that can help the instructors in their tasks of designing an AEHS, by providing them with adaptive and intelligent support. On the other hand, many EAHS rely on interfaces that are still textual or, in the best cases, form based.

The idea of design patterns for adaptivity is not new (cf. [15], [16]). For instance, the SCORM consortium suggests over twenty different kind of learning patterns that have, at different degrees, some kind of adaptivity: from simple personalized learning environment, to advanced trial-and-error environments. Surprisingly the practise of design pattern has not even began yet, even though it is doubtless that it would be extremely beneficial for educators and, in the end, for learners. The main reason is because, until now, educators lack of right tools to do that. By the way, according to past studies [9] this feature seems to be very relevant for supporting educators unleashing their creativity indeed.

3   Introduction to ADLEGO

ADLEGO is a low-level adaptive rule-based engine. In ADLEGO an educational website is organized in resources. Each resource provides access to content which can be pulled from an external site or a local directory on the server. Moreover a resource comes with a set of presentation and tracking rules. The former are inspected by ADLEGO to rendering the resource itself and the links from one to another resource. The latter are used for sending to the user model information about the user's behavior within the resource.

The system supports basic actions that can be performed on different properties of a resource. One can grant or deny access to the resource, or perform operations on the incoming or outgoing links of it. Those operations include: hiding, disabling, adding an icon or a text note, setting a color or a style. Despite this basic set of actions that are available, ADLEGO allows indeed to set up many of the established adaptive

techniques (for the full taxonomy refer to[5]), namely adaptive link annotation, adaptive link hiding, adaptation of modality, adaptive text and multimedia presentation, and map adaptation.

4 The Visual Authoring Environment

The Authoring Tool for ADLEGO is a visual multi-window interface that presents in a integrated view the different facets of an adaptive website: the hypertext structure, the content, the adaptive interaction model, the user model.

The left panel gives an overview of the resources. ADLEGO support a traditional tree-like structure as many commercial Learning Management Systems. Though, it is possible to develop a more complex hypertext structure of resources, by connecting them with hyperlinks. For this reason a complementary graph view of the course is provided. Within this interface the educator can add new resources and put them inside the tree with a simple drag & drop mechanism. Moreover some visual cues inform about the nature of content of the resource (internal /external content or content to be provided).

Clicking on a resource in the left panel will open the corresponding resource detail in the top right panel (see top right of Fig.1a). In this panel a preview of the current page is presented, displaying its title and content. Moreover, the rules that have been specified for that resource are listed on the left and right sides. As anticipated in the former chapter, they can be either presentation or tracking rules (respectively in the left and right column).

Each rule is displayed with an icon that represents the action that is performed when the rule condition applies. For link rules an additional cue informs whether the rule applies to incoming or outgoing links.

Clicking an icon brings up a contextual menu to sorting, editing, or deleting the corresponding rule. To edit a rule a visual Rule Editor is provided (see Figure 1b). The Rule Editor is split in two versions: a basic and an advanced one. The former interface has been designed to help the teacher in the task of writing simple rules, in this way reducing the likelihood of errors during the formulation of complex Boolean conditions. For this reason the basic interface allows to define an array of conditions which are connected by *and* clauses only. This approach stems from past studies on the difficulties encountered by non-programmers in the statement of Boolean conditions [11][12], and it aims to cope with the reported common misunderstanding of *not* and *or* Boolean clauses by non technical people. Moreover only a subset of actions is available, along several macro rules, thus fostering the instructor on reasoning on how to present the resource itself, without being distracted by technicalities.

Conversely, the advanced interface supports the full expressive power of the ADLEGO rule engine, yet providing a less error-prone environment for writing complex rules. This result is accomplished by a set of panels, which allow to quickly build a condition without knowing exactly the underlying syntax of each terms. The instructor simply clicks on a variable icon and the interface fills the condition window with the corresponding statement according to the right syntax.
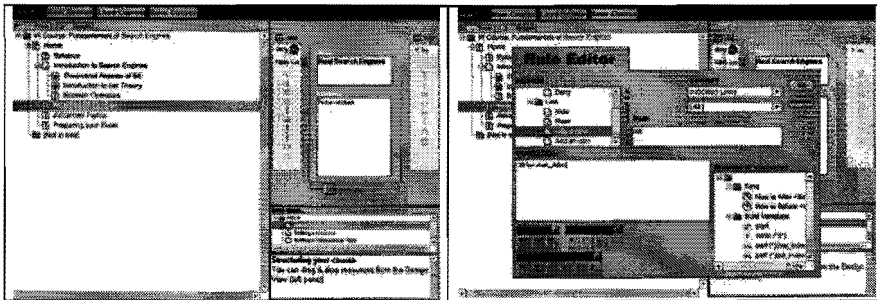
Fig. 1. (a) - Interface of the Visual Authoring Tool; (b) - Rule Editor: advanced panel

Finally, the expert user can also type a condition using the ADLEGO syntax and test it with the syntax checker.

A similar interface is provided for writing tracking rules, but with a different set of actions that can be performed: setting, incrementing, decrementing the value of a variable, etc.

Since the authoring tool is still under development, some features have not been implemented yet. In the near future, the tool will allow to store and retrieve sub-sets of resources, along with their rule sets, to foster reusability. This feature will pave the road to the development of design patterns, which an educator could easily store and reuse in his/her different projects.

5   Discussion

According to results from HCI field [10], four minimalism principles should be taken into account for the design of an authoring tool:

1. Choose an action-oriented approach;
2. Anchor the tool in the task domain
3. Support error recognition and recovery
4. Support ready to do, study, and locate

Taking them in account means basically asking ourselves a question: what should be the border between flexibility and usability of the interface? There is no an easy answer to that. In our project, we have narrowed down the spectrum of the targeted end users of our tool to be able to come to a conclusion. Our research framework is that the design process of an adaptive educational website is under the responsibility of an instructional designer with no programming background. This assumption leads to reduce as much as possible the richness of the interface, and therefore of the design blueprint that can be produced with it. On the other hand, it is evident that we can not impoverish over a certain threshold the set of tools which an educator should be able to use. This issue still requires more debate, and we suggest that interesting results

could be gained from the empirical evaluation of usability of both adaptive courses and their authoring tools as well.

Another insight we had is that making use of strong visual metaphors for helping the educator understanding all the aspects of an adaptive system, would improve the usability of the authoring tool in the end. Yet, what is the best metaphor to achieve this? The current project makes use of the well known "desktop" metaphor to build up on the existing conventions that we all share by the nature of modern window based operative systems. Other metaphors could suit the case as well.

Moreover, since the design of an user-system interaction requires a time consuming task for testing that all designed behaviors actually occur, some kind of simulation or debugging tools should be provided to asses it in a controlled and organized way.

The current implementation of the authoring tool has been designed to suit the needs of the specific adaptive engine, namely ADLEGO, however a more general approach could be explored as well. The next generation of authoring tools could be able to produce a more application-independent model, and could provide compiling tools to translate it into the major adaptive engines (i.e. the same authoring interface could compile the same model of adaptive course in either the Interbook , AHA, or ADLEGO syntax).

Finally a more complex scenario arises when we think in the perspective of web services. Imagine a network of: adaptive servers (executing a different adaptive engine each), user models, and content and service providers. In this context the authoring and design needs cannot be easily integrated in a holistic interface anymore. But still, the designer of the learner experience (our educator), needs to have access to all of them, and perhaps even modify parts of them.

6   Conclusions

A visual authoring tool to design an adaptive website seems to be the missing key to unfold the hidden potentiality of adaptive technologies for education. The importance of visualizing all of the different aspects of an educational adaptive systems is even more evident when we think at the community of instructional designers and teachers as our main target audience. Those members do not usually have the required technical skills to unleash the power from an adaptive engine, even though it has been designed with simple features (i.e. conditional fragments, adaptive link annotation only).

A prototype of a visual authoring tool for instructors has been discussed in this paper. The authoring tool allows a teacher to structure the website in a network or a tree of resources, connect them with the actual content (both locally stored or coming from an external website), and define the necessary rules to present it in an adaptive form to the learners, just using simple drag & drop mechanisms. Moreover every part of the adaptive course being developed is shown to the author in a visual form, in order to support them thinking and manipulating the usually abstract objects that constitute an adaptive website (concept networks, user model variables, etc.). We are

currently setting up an evaluation test for the presented authoring tool in order to assess its impact[2].

References

1. Armani J., Botturi L.: Adaptive Hypermedia System Design: a Method from Practice. Proceedings of ICWI 2003, Algarve, Portugal, (2003), 843–848.
2. Armani J.: Shaping Learning Adaptive Technologies for Teachers: a Proposal for an Adaptive Learning Management System. Submitted to ICALT '04, (to appear)
3. Aroyo L., Dicheva D., and Cristea A.: Ontological Support for Web Courseware Authoring. Proceedings of ICALT '02, Las Vegas, US, (2002).
4. Brusilovsky P.: Developing Adaptive Educational Hypermedia Systems: from Design Models to Authoring Tools. In: Murray T., Blessing S., & Ainsworth S. (eds.): Authoring Tools for Advanced Technology Learning Environment, Dordrecht: Kluwer Academic Publishers, (2003), 377–410.
5. Brusilovsky P.: Adaptive hypermedia. In: Kobsa A. (ed.): User Modeling and User Adapted Interaction, Ten Year Anniversary Issue 11 (1/2), (2001), 87–110.
6. Brusilovsky P., Eklund J., and Schwarz E.: Web-based education for all: A tool for developing adaptive courseware. Computer Networks and ISDN Systems, 30 (1-7), (1998), 291–300.
7. De Bra P., and Calvi L.: AHA! An Open Adaptive Hypermedia Architecture. The New Review of Hypermedia and Multimedia, 4, Taylor Graham Publishers, (1998), 115–139.
8. EduTools: Providing decision-making tools for the E-D-U community, Url: http://www.edutools.info/course/, (last visited on Feb 20th, 2004).
9. Finzer W. F., and Gould L.: Rehearsal World: Programming by Rehearsal. In Cypher A. (ed.): Watch What I Do – Programming by Demonstration. The MIT Press Cambridge, Massachusetts, London, England, (1993), 79–100.
10. Hackos, J.T.: An Application of the Principles of Minimalism to the Design of Human-Computer Interfaces. Common Ground 9, (1999), 17–22.
11. Pane J.F., Ratanamahatana C.A., and Myers B.A.: Studying the Language and Structure in Non-Programmers' Solutions to Programming Problems. International Journal of Human-Computer Studies, Vol. 54:2, (2001), 237–264.
12. Pane J.F., and Myers B.A.: Tabular and Textual Methods for Selecting Objects from a Group. Proceedings of VL 2000: IEEE International Symposium on Visual Languages, Seattle, WA: IEEE Computer Society, (2000), 157–164.
13. Park O., and Lee J.: Adaptive Instructional Systems. In: Jonassen, D.H. (ed.): Handbook of Research on Educational Communications and Technology, 2nd ed., AECT, (2004).
14. Weber G., Kuhl H.-C, and Weibelzahl S.: Developing adaptive internet based courses with the authoring system NetCoach. In: De Bra P., Brusilovsky P., and Kobsa A. (eds.): Proceedings of Third workshop on Adaptive Hypertext and Hypermedia, July 14, 2001. Sonthofen, Germany, Technical University Eindhoven, (2001), 35–48.
15. Avgeriou, D. Vogiatzis, A. Tzanavari, S. Retalis: Design Patterns In Adaptive Web-Based Educational Systems: An Overview. Proceedings of Web Education Conference 2004, 11-14 February 2004, Innsbruck, Austria, (2004).
16. SCORM. Best Practices Guide for Content Developers, 1st Edition, (2004). Available online at: http://www.lsal.cmu.edu/lsal/expertise/projects/developersguide/

---

[2] The present work has been carried on under the supervision of Prof. Brusilovsky (School of Information Sciences, University of Pittsburgh, PA, USA).

Authoring processes for Advanced Learning Strategies

Jana Trnková[1], Wolfgang Theilmann[2]

[1] Telecooperation Research Group, TU Darmstadt, Germany
jana@tk.informatik.tu-darmstadt.de

[2] SAP Research, CEC Karlsruhe, Germany
wolfgang.theilmann@sap.com

Abstract. The paper provides an overview on the authoring process in the adaptive learning environment with support of advanced leaning strategies. We explain the concept of the metadata model and adaptation process implemented in the L^3 learning environment. We provide a summary of experiences from different projects using L^3, point out the most common difficulties during the authoring process and describe our future plans to support authors.

1 Introduction

Authoring process in e-Learning is a complex problematic, which involves also specific didactical, design related and technological issues. Modern approaches as adaptability and reusability make this process even more complicated. A good e-Learning course is typically a result of team cooperation. Authoring environment has an important role to make this process smoother and help to bridge the gaps between the different areas of expertise. Therefore, recently many learning environments are coming up with integrated pedagogical concept. However, very often the authors seem to be only more confused and pushed to use a certain didactical approach. We believe that support of the authors should include these two aspects: the direct support of authoring process (e.g., improving of user interface and integration of templates) and adaptability of pedagogical concept to the specific requirements of the author.

In our paper we describe the authoring process based on the concept of advanced learning strategies. This concept had been implemented in L^3 learning environment (later adopted by SAP Learning Solution) and tested in few projects. We provide the overview on the experiences with this approach and identify the main challenges of authoring processes. Finally we introduce our ideas for improving the current authoring environment and the areas of our future research[3].

---

2 Basic Authoring Process

This section describes the underlying basic approach for structuring and authoring learning content. Starting with the course model we explain how the concepts of learning strategies influence the authoring process.

2.1 Course Model

One of the major goals in L^3 is to provide the methodology and the tools to structure learning material in a way that allows for both, reusability and adaptive delivery.

Content Aggregation Model. In L^3, content is aggregated in four distinct structural levels where each higher level may contain instances of all lower levels. The lowest level of granularity is formed by *knowledge items* which represent the smallest indivisible element in a course. Each knowledge item shall contain material that illustrates, explains, practices or tests a certain aspect in one thematic area and thus refers to actual learning content. Several related knowledge items are typically assembled into one *learning unit*, which is the logical representation of such a distinct, thematically coherent unit. Learning units are still considered small in terms of "size" (i.e. duration) and are further grouped into larger structural units, so-called *sub courses*. Sub courses may also be used to build an arbitrarily deep nested structure by including other sub courses. At the highest structural level sub courses, learning units and knowledge items are contained in a *course*.

Meta-data. Besides structural composition, course material in L^3 can be tagged with additional meta-data that further improves the support for adaptive delivery, reusability, and search and retrieval of existing material. The meta-data set used in L^3 can be divided into four categories:

1. *Instructional meta-data.* The L^3 authoring tool allows authors to attach the full Learning Object Meta-data (LOM) set to individual course elements.

2. *Knowledge types.* Receptive knowledge items can be categorized using a didactical ontology defined in [1]. At the topmost level, it distinguishes between orientation knowledge ("know what a topic is about"), action knowledge ("know how"), explanation knowledge ("know why something is the way it is") and reference knowledge ("know where to find additional information"). These four basic types are further sub-divided into a fine grained ontology. Furthermore, knowledge items can represent also a (performance) test which may have implications on the competencies a learner has mastered (see below).

3. *Relations.* While assembling the higher level building blocks of an L^3 course, an author may specify relations between elements. Matter of facts relations describe the dependencies strictly on a subject level (e.g., "part of"). Didactic relationships describe restrictions for the delivery to the learner (e.g. "prerequisite"). Again, both types of relationships are sub-divided into a fine grained ontology [1].

4. *Competencies.* Performance evaluation is an integral part of the L³ learning platform. Course authors can assign competencies (or skills) to learning material and can provide test procedures to evaluate the individual learner's performance.

Strategies and Navigation. Sequencing is deliberately omitted from our content aggregation model, thus allowing different sequencing rules to be applied to the same course material: One strategy might start at the bottom, i.e. the specifics, moving up to the more general concepts, which resembles an *inductive strategy.* At the opposite end, another strategy may lead the learner from the general concepts to the specifics, thus implementing a *deductive strategy.* The computation of a learner's path through the material is divided into two steps:

To navigate between higher-level elements (sub courses and learning units), a strategy used focuses on the matter of facts relations defined by the author. One can think of this strategy as moving along the different topic areas. In other words, it operates on a macro level, thus the term *macro strategy* is used in the rest of this paper.

Opposed to that, a different strategy is used when entering a specific topic enclosed in a learning unit. Here are no matter of facts relations between the knowledge items, but the items are tagged with different knowledge types. The strategy determines a didactical approach taken to present the topic specific knowledge to the learner. E.g., an "action oriented" strategy may present any action items, before it moves on to the other items, whereas an "overview only" will present orientation knowledge while ignoring all other items. This part is termed *micro strategy.*
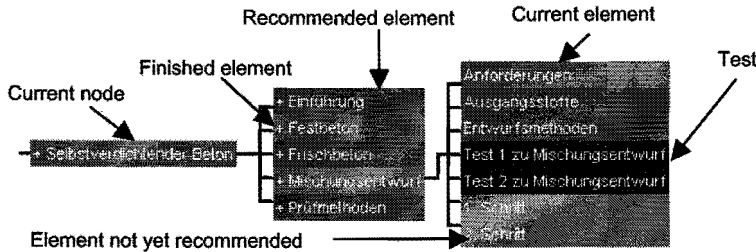

Fig. 1. Example of navigation path generated by L³

At the beginning of learning session learner chooses micro and macro strategy. Based on this choice and pedagogical metadata set by author, the recommended order of learning elements is suggested. This can be followed by clicking on the navigation button *Forward,* or it is possible to display a navigation path in the bottom part of the window and simply click on the desired element. Navigation path also gives an orientation about visited and recommended elements as it is shown in Fig. 1.

2.2 Authoring Process

For the author is a course represented as a set of graphs. A *node* represents a structural unit of a course and node attributes carry the meta-data attached to the corresponding unit. An *edge*, in turn, represents a relation between two structural components.
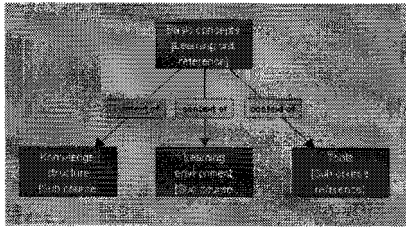

Fig. 2. Example course: "Authoring in L^3"

Fig. 3. Learning Unit "Relations"

The following example may illustrate this: The author has divided a course about "Course authoring in L^3" into three sub courses and one learning unit. She also decided that the concepts explained in the learning unit provide the context for the concepts covered in the three sub courses (see Fig. 2).

The learning unit "Relations" introduces the different relation types, gives examples, provides further explanations on "non-subject taxonomic" relations, and contains a "Test on relations". In this unit, the author has decided to declare the first example about "Associative relations" as a prerequisite of the second example (see Fig. 3).

3 Experiences within Pilot and Customer Projects

This section reports experiences made with the authoring and using learning strategies within various project contexts – from research pilots to a commercial product.

3.1 Research Pilot L^3

The approach of authoring learning content and applying learning strategies on that content at runtime was first used within the German lighthouse research project L^3. A consortium of 20 companies headed by the SAP Research was developing and establishing a national backbone for advanced education and training. L^3 aims to make lifelong learning possible by implementing an organizational and technical infrastructure that can be used by everyone, for professional and private education.

Within L^3 the authoring environment was used and evaluated by professional content developers. The experiences from the authors showed that the structuring and tagging of instructional units is a highly complex task and that content creators need support to introduce this to their organization and to deal with the methodology. A

445

two days introduction with hands-on sessions has been developed and results in a reasonable learning curve so authors have been able to create and/or reengineer first domain fragments. More specific they have to abandon the "traditional" way of "hard-wiring" courses, but design self-contained learning units to allow flexible assignment and reusability. The overhead introduced through the initial creating process has been measured to 5-10% depending on the experience of the author. Some authors still tend to create "hard-wired" courses by using many prerequisite relations. However, their content got lower ratings from the students because of the lack of redundancy. Self-contained learning units that cannot assume that other units have been already consumed automatically lead to a higher redundancy level.

3.2 WiBA-Net

WiBA-Net Project [3] was a German e-learning project for architects and civil engineers, supported by the German Ministry of Education and Research and SAP AG. It was a multi disciplinary multi-site project involving six Universities in Germany, headed by the domain expert group of Prof. Grübl (Civil Engineering Dept., Darmstadt University of Technology).

The project has a web-based interface for students and educators, a WiBA-Net Portal. In the background, the portal consists of few mostly independent components, which are even located on different computers. Since we were trying to create a compact and easy-to-use environment, this modularity remains hidden to the end-user.

Since Pedagogical Department of TU Darmstadt (Germany) has been one of the project partners, we had been receiving feedback right from the beginning of the project. First suggestion came up from the students, which were missing an overview of visited materials and materials which still need to be seen. Actually this information was available from the content overview but this has been shown not to be sufficient. Students want an overview of their progress continuously, without any clicking. Therefore we have implemented displaying a number of the visited pages and all the pages together (see Fig. 4).

Another requirement came from teachers, which were willing to receive a feedback on content from learners. In order to achieve a comment on a particular content page, the WiBA-Net ID number (from database of knowledge network) must be provided. Thus we extracted the ID number and displayed it in the course interface (see Fig. 4).
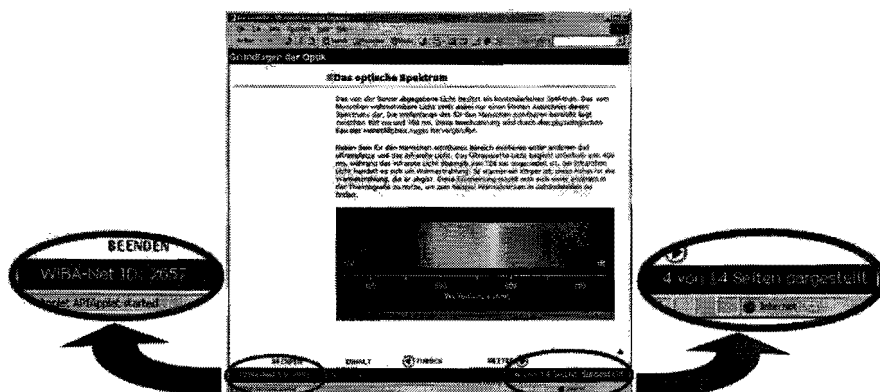
Fig. 4. WiBA Net Project: Extensions of original L^3 environment

3.3 Commercial Product SAP Learning Solution (SAP LSO)

The SAP LSO [5] is a commercial product build upon the concepts of L^3. It realizes a comprehensive solution for blended learning tightly integrated to an Enterprise Resource Planning (ERP) system. Learning activities and results can be correlated with the ERP module Human Resource (HR). The SAP LSO is primary targeting corporate learning scenarios. The content used by customers of the SAP LSO mainly stems from 2 sources. General purpose content (e.g., courses about office products) is typically bought from external professional content developers. Specific content about a company's core business is typically produced within the company. External content is mainly offered by using the SCORM packaging format [4]. Such content can be imported and converted into the internal format.

4 Evaluation and Future Research

Previous projects showed that adaptability and learning strategies are a very complex topic. The big advantage of flexibility for the learners is becoming a problem for the authors. We have recognized following topics as the main obstructions during the authoring process:

- Creating of self-contained reusable learning units
- Predicting the behaviour of the course under different learning strategies
- Understanding of different pedagogical concepts and creating a reasonable structure for the course – adaptive to the specific learning needs of student

Templates. The pedagogical power of L^3 allows the authors to create a very sophisticated courses based on modern didactical approaches. On the other hand, this

requires an experienced user with a strong pedagogical background. Less experienced users are advised to use the templates. We would like to improve current (relatively simple) template manager and implement an advanced tool, which will allow, besides creating a template of a course structure, also to define own learning strategy. The open question is how to keep the plurality of learning process and adaptability together with support of specific learning strategies defined by authors. We are considering incorporating into the template editor also the choice to allow certain strategies to use with the template. Another open issue is how to assist authors in enhancing their course material to be applicable for several strategies.

Strategy Visualization. One of the lacks of L^3 is insufficient transparency of the final design of the course under the different macro and micro strategies. The authors have difficulties to predict the behavior of the course under the different strategies. We plan to integrate an improved tool for the strategy visualization. It should:

- allow switching between the different strategies,
- provide an overall view on structure of the course,
- be able to simulate viewing the course (visibility of learning elements to student, whether is learning element recommended at certain stage).

Standard Conformance. The most relevant standard for e-Learning lately becomes SCORM [4]. Last version (SCORM 2004) introduced a new concept of Sequencing and Navigation. The Sequencing and Navigation is, of course, an important step for support of adaptability and learner-centred approach. Nevertheless, the implementation of sequencing rules is very closely connected to the structure of the particular course – it doesn't allow definition of general rules related to the metadata, but only the rules tightly connected to the concrete learning units. The sequencing means are very much on programming level instead of at pedagogical level. This approach is rather different from ours.

References

1. Meder, N. (1999) Didaktische Ontologien. In Proc. 6. Tagung der Deutschen Sektion der Internationalen Gesellschaft für Wissensorganisation (Hamburg, Germany, September 23-25, 1999), pp. 401-416. (in German)
2. Rößling, G., Trnková, J., Langendorf, U., Tillack, K., Mühlhäuser, M. (2002): Learner-Centric Online Teaching for Non-Computer Science Students. Proceedings of ED-MEDIA 2002. Denver, Colorado. AACE Press, Charlottesville, VA. pp. 1645-1650.
3. SCORM definition and resources. Online:
    http://www.adlnet.org/index.cfm?fuseaction=scormabt (seen May 12, 2004)
4. SAP Learning Solution. Online: http://service.sap.com/learningsolution (seen May 12, 2004)

Adaptive Hypermedia Authoring: From Adaptive Navigation to Adaptive Learning Support

Pythagoras Karampiperis[1,2] and Demetrios Sampson[1,2]

[1] Department of Technology Education and Digital Systems,
University of Piraeus,
150, Androutsou Street, Piraeus, GR-18534, Greece
[2] Advanced e-Services for the Knowledge Society Research Unit,
Informatics and Telematics Institute,
Centre for Research and Technology Hellas,
42, Arkadias Street, Athens, GR-15234 Greece
{pythk, sampson}@iti.gr

Abstract. Educational hypermedia systems seek to provide adaptive navigation, whereas intelligent web-based learning systems seek to provide adaptive courseware generation. The design of powerful authoring frameworks by merging the authoring approaches used in the above mentioned systems is recognized as one of the most interesting questions in adaptive web-based educational systems. In this paper we address adaptive hypermedia authoring proposing an authoring framework that combines the approach of automatic courseware generation with the paradigm of educational hypermedia systems based on the use of ontologies and learning object metadata.

1 Introduction

Educational hypermedia systems seek to provide adaptive navigation, whereas intelligent web-based learning systems seek to provide adaptive courseware generation. Adaptive navigation seeks to present the content associated with an on-line course in an optimized order, where the optimization criteria takes into consideration the learner's background and performance on related knowledge domain [1], whereas adaptive courseware generation is defined as the process that selects learning objects from a digital repository and sequence it in a way which is appropriate for the targeted learning community or individuals [2]. The need for gradual merge between the authoring approach of adaptive educational systems and the authoring approach of adaptive hypermedia systems has been already identified in literature [3].

In this paper we address adaptive hypermedia authoring proposing an authoring framework that combines the approach of automatic courseware generation with the paradigm of educational hypermedia systems. The paper is structured as follows. Initially, we survey the adaptive techniques used in educational hypermedia systems, classifying them in two main classes namely adaptive presentation and adaptive navigation techniques. The second part discusses the main steps in the adaptive educational hypermedia design process and presents the abstraction layers of adaptive

hypermedia authoring process proposing an authoring framework that enables the definition of learning objectives and automatic authoring of adaptive activities. This framework is based on the use of pedagogical templates which include the rules for adaptive navigation and can be processed by an adaptive content selection mechanism in order to serve adaptive web-based courses based on a diverse set of pedagogical strategies. The selection of learning path takes into consideration learner's cognitive characteristics and preferences.

2 Adaptivity in Educational Hypermedia Systems

In the literature there are several adaptive techniques employed in educational hypermedia systems that can be classified in two main classes, namely:

- Adaptive Presentation. The goal of the adaptive presentation techniques is to adapt the web-based content to the user's goals, knowledge and other information stored in the user model [3].
- Adaptive Navigation. Adaptive navigation seeks to present the learning objects associated with an on-line course in an optimized order, where the optimization criteria takes into consideration the learner's background and performance on related learning objects [4].

Adaptive Content Selection is the first step to adaptive navigation and adaptive presentation and is based on a set of teaching rules according to the cognitive style or learning preferences of the learners [5]. Adaptive Content Selection, Adaptive Navigation and Presentation are recognized as among the most interesting research questions in intelligent web-based education [6].

3 Adaptive Educational Hypermedia Authoring

The information structure of an adaptive hypermedia system can be considered as two interconnected networks or "spaces" [3]:

- a network of concepts (knowledge space) and
- a network of educational material (hyperspace or media space).

Accordingly, the design of an adaptive hypermedia system involves three key steps:

- structuring the knowledge
- structuring the media space
- connecting the knowledge space and the media space.

3.1 Authoring Abstraction Layers

The process of Adaptive Hypermedia Authoring can be represented by the use of five abstraction layers as shown in figure 1. In the literature several authoring frameworks have been proposed e.g. the LAOS [7], but those frameworks are focusing more on the concept and the adaptation logic layers. In our approach we propose an additional

layer called *Pedagogical Strategy Layer* that focuses more on the pedagogical characteristics rather than the concepts covered by the educational resources. At this layer a pedagogical template based on the IMS Learning Design specification is introduced that is responsible for filtering the learning paths according to the selected pedagogical strategy. The proposed authoring abstraction layers are the following:

- *Learning Objectives Layer.* In this layer the author (or the learner if the educational hypermedia system includes an automatic courseware generator) can define a "learning goal". The learning goal is a node in a concept hierarchy graph that corresponds to the desirable by the learner knowledge.

- *Conceptual Layer.* In this layer related to the learning goal concepts are selected based on the structure of the knowledge space. The use of educational ontologies can significantly assist the structuring of the knowledge space.
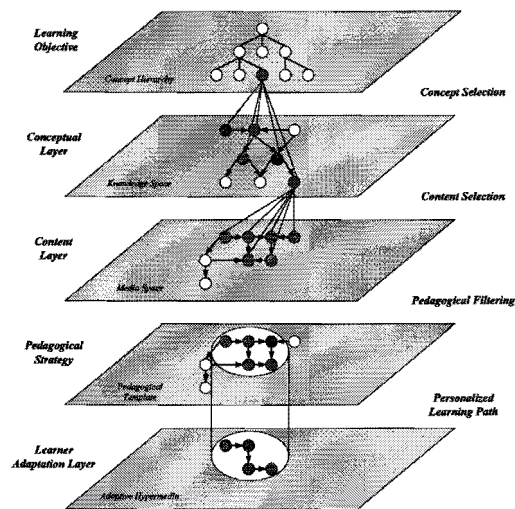

Figure 1. Abstraction Layers of Adaptive Hypermedia Authoring

- *Content Layer.* In this layer the learning resources that are related to the previously selected concepts are selected based on the connection of the knowledge space with the media space. The result of the selection is a directed acyclic graph (DAG) of learning objects inheriting relations from both spaces. This graph contains all possible learning paths in order for a learner to achieve the specified learning goal.

- *Pedagogical Strategy Layer.* This layer filters the media graph and produces a sub-graph which:
  1. is also a directed acyclic graph (DAG)
  2. includes all possible learning paths in order for a learner to achieve the specified learning goal, according to a specific pedagogical strategy.

The "pedagogical filtering" is based on the use of reusable templates allowing the definition of generic learning activities. These templates include the rules for adaptive navigation and can be processed by an adaptive content selection

mechanism (previous abstraction layer) in order to serve adaptive web-based courses based on a diverse set of pedagogical strategies.

Figure 2 presents examples of such templates following the "diagnose-and-remedy" pedagogical strategy and an alternative "behavioral" approach.
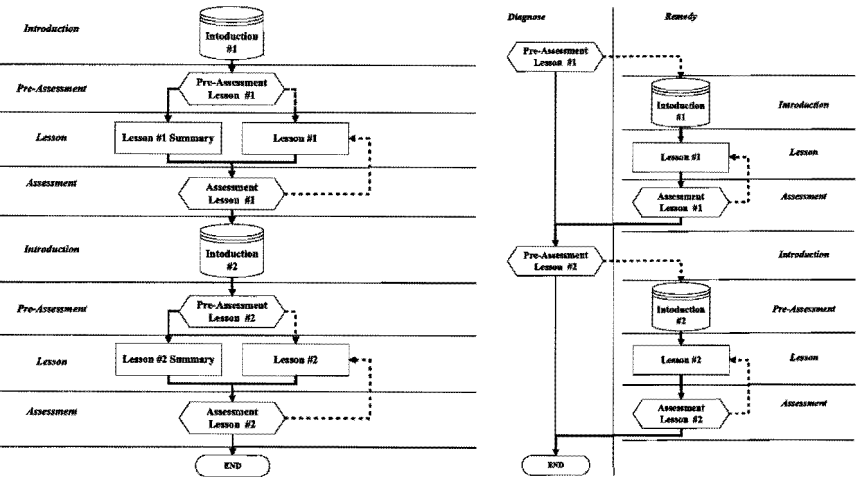

Figure 2. Example of Behavioral Template (a) and Diagnose-and-Remedy Template (b)

- *Learner Adaptation Layer*. This layer includes the process of adaptive learning path selection in order to produce a personalized learning path. The selection process takes into consideration educational characteristics of learning objects, learner cognitive characteristics as well as learner preference-related information stored in the learner profile. In our case, we use learning object characteristics derived from the IEEE Learning Object Metadata (LOM) standard [8] and learner characteristics derived from the IMS Learner Information Package (LIP) specification [9].

3.2 Discovering Optimum Learning Path

In order to extract from the resulting directed acyclic graph of learning resources the "optimum" learning path, we need to weight each connection of the DAG. The weighting process consists of two phases:

- *Selection of Criteria*. In Table 1 and 2 we have identified the LOM and LIP characteristics respectively, that can be used as criteria for the selection of the learning path.

452

Table 1. Learning Object characteristics for Learning Path Selection

Criteria	IEEE LOM	Explanation
General	General/Structure	Underlying organizational structure of a Learning Object
	General/Aggregation Level	The functional granularity (level of aggregation) of a Learning Object.
Educational	Educational/Interactivity Type	Predominant mode of learning supported by a Learning Object
	Educational/ Interactivity Level	The degree to which a learner can influence the aspect or behavior of a Learning Object.
	Educational/Semantic Density	The degree of conciseness of a Learning Object, estimated in terms of its size, span or duration.
	LOM/Educational/Typical Age Range	Age of the typical intended user. This element refers to developmental age and not chronological age.
	LOM/Educational/Difficulty	How hard it is to work with or through a Learning Object for the typical intended target audience.
	LOM/Educational/Intended End User Role	Principal user(s) for which a Learning Object was designed, most dominant first.
	LOM/Educational/Context	The principal environment within which the learning and use of a LO is intended to take place.
	LOM/Educational/Typical Learning Time	Typical time it takes to work with or through a LO for the typical intended target audience.
	LOM/Educational/Learning Resource Type	Specific kind of Learning Object. The most dominant kind shall be first.

Table 2. Learner characteristics for Learning Path Selection

Criteria	IMS LIP	Explanation
Accessibility	Accessibility/Preference/typename	The type of cognitive preference
	Accessibility/Preference/prefcode	The coding assigned to the preference
	Accessibility/Eligibility/typename	The type of eligibility being defined
	Accessibility/Disability/typename	The type of disability being defined
Qualifications Certifications Licences	QCL/Level	The level/grade of the QCL
Activity	Activity/Evaluation/noofattempts	The number of attempts made on the evaluation.
	Activity/Evaluation/result/score	The scoring data itself.

- *Weight Calculation.* After identifying the set of characteristics/criteria that will be used, we define a weighting function that corresponds to the inverse suitability of a learning resource based on the profile of the target learner or group of learners. Let us consider a set of learning objects which is valued by a set of criteria $g = (g_1, g_2, ..., g_n)$. The assessment model of the inverse suitability of each learning object for a specific learner, leads to the aggregation of all criteria into a unique criterion that we call a weighting function and is defined as an additive function of the form: $W(g) = \sum_{i=1}^{n} w_i \times g_i \in [0,1]$ with the following additional notation:

- g_i :the value of the ith selection criterion in the range [0,1] with 1 the less suitable value and 0 the most suitable value,

- w_i : the inverse suitability weight factor of the ith selection criterion

Higher weighting value, means that a learning resource is less suitable, thus the link in the DAG that leads to that resource has less possibility to be included in the learning path.

After weighting the DAG with the use of the weighting function, we need to find the optimum (shortest) path by the use of a shortest path algorithm.

4 Conclusions

In this paper we address adaptive hypermedia authoring proposing an authoring framework that combines the approach of automatic courseware generation with the paradigm of educational hypermedia systems based on the use of ontologies and learning object metadata. The main advantage of this framework is the use of pedagogical templates which can be processed by an adaptive content selection mechanism in order to create adaptive web-based courses based on a diverse set of pedagogical strategies.

Acknowledgements

References

1. Brusilovsky, P.: Adaptive and intelligent technologies for web-based education. Künstliche Intelligenz, Vol. 4 (1999) 19-25
2. Knolmayer, G.F.: Decision Support Models for composing and navigating through e-learning objects, In Proc. of the IEEE International Conference on System Sciences, (2003)
3. Brusilovsky, P.: Developing adaptive educational hypermedia systems: From design models to authoring tools. In: Murray, T., Blessing, S., Ainsworth, S. (eds.): Authoring Tools for Advanced Technology Learning Environment. Dordrecht: Kluwer (2003)
4. Brusilovsky, P., Eklund, J., and Schwarz, E.: Adaptive Navigation Support in Educational Hypermedia on the WWW In: Howard, S., Hammond J., Lindgaard, G. (eds.): Human-Computer Interaction. New York: Chapman & Hall (1997)
5. Brusilovsky, P., Vassileva, J.: Course sequencing techniques for large-scale Web-based education. IJCEELL, Vol.13 (2003)
6. Devedžić, V.B.: Key Issues in Next-Generation Web-Based Education. IEEE Transactions on Systems, Man and Cybernetics Part C, vol. 33(3) (2003) 339-349
7. Cristea, A.I.: Evaluating Adaptive Hypermedia Authoring while Teaching Adaptive Systems. In Proc. of the ACM Symposium on Applied Computing SAC'04 (2004)
8. IEEE Draft Standard for Learning Object Metadata, IEEE P1484.12.1/d6.4 (2002)
9. IMS Global Learning Consortium Inc., Learner Information Package (LIP) Final Specification v1.0 (2001)

Authoring Web Content in ActiveMath: From Developer Tools and Further

Paul Libbrecht

DFKI and Universität des Saarlandes, Saarbrücken, Germany
paul@activemath.org

Abstract: In the ActiveMath learning environment, authoring is currently based on source editing following a *build*-practice similar to software development cycles. In this article we explain the characteristics of a build-cycle that are important to the creation of content for an adaptive educational hypermedia such as ActiveMath. The trust of an author into the behaviour of the system is one of the important goals that is aimed at. We then describe what, we expect, would further help the author's trust, namely, usable tools to input and play simulations of the learning process.

1 ActiveMath as an adaptive educational hypermedia

ActiveMath is an intelligent web-based learning environment. It presents content and lets learners perform interactive exercises.

Content, in ActiveMath is organized in knowledge units called *items* which roughly correspond to paragraphs in a text-book. The content of items is made of text and mathematical formulæ encoded semantically using OPENMATH [2]. Items are given a type (for example, a *definition* or *exercise*), and are complemented with metadata, the latter is made of slot-values (e.g., the *difficulty* or *learning-context*) as well as relations (e.g., the statement that a proof *proves* a given assertion, or for a concept to *depends-on* another concept). A subset of items, named *concepts*, along with their metadata make the *domain-model*. Please see [6] for a more detailed coverage of ActiveMath knowledge handling.

The adaptivity in ActiveMath is based on an overlay user-model based on this domain-model. The user-model is permanently updated using information such as reading of items and exercise results. Based on this user-model the following adaptivity features are provided in ActiveMath:

1. Using preferences, the presentation is given an appearance or *theme*
2. In ActiveMath the learner mostly accesses content through the familiar metaphor of books which are presented as a sequence of pages with a table-of-contents. The latter is presented with visual hints (little red, yellow, or green bullets) indicating which page refers to concepts with low, medium, or high user-model values. This can be seen as an elementary link-annotation adaptivity.

3. Books can be dynamically generated in ActiveMath: they are generated according to the goals of a learner and to a pedagogical scenario. Course generation makes use of the items types, slot metadata, and relations as well as the user-model values so as to select the concepts that should be read as well as the supporting texts and exercises. This course generation can be viewed as a form of adaptive navigation support. While staying with the metaphor of a book, this course generation will be enhanced into a reactive component where the learner will be presented, in the usage of the book, with modifications to her book considered to be appropriate for her learning (see [7]).
4. Interactive exercises are currently mostly non-adaptive in ActiveMath: they are, for example, multiple-choice-questions. Exercises, within the LeActiveMath European project are planned to become adaptive using the same source of information as the course generation: it should make it possible for an interactive exercise to propose actions and provide feedback depending on the knowledge (and understanding or applications capabilities) of the learner for the given concept.

2   Authoring in ActiveMath: Tools Available

This section reviews briefly the authoring tools available in order to write content for ActiveMath.

2.1   Writing by Hand

Content in ActiveMath is encoded as XML documents in the OMDOC syntax [4]. As such, it can, in principle, be written by hand. This was done by some developers in our group while building the system. Experience has shown that doing so was a very confusing task especially with respect to OPENMATH formulæ which are encoded in very deep sub-trees.

An alternative was to write QMath documents, offering a compact syntax for both formulæ and content structure. The QMath processor then converts them to OMDOC. Results were disappointing as QMath was not complete enough for the needs of ActiveMath's OMDOCs. The treatment of mathematical formulæ in QMath was however kept: a wrapper was written, called OQMath, letting QMath process the formulæ. This allows the rest of the document be a valid XML document.

Experience has proven that the encoding for OQMath documents offers a reasonable readability while still allowing support of XML-based editing tools. An editor was chosen as reference tool to edit documents, the open-source editor jEdit. It offers, among others, templates, suggestion of possible children at insertion point and automated XML-validation (with a feedback similar to spell-checking).

The package is distributed under the name jEditOQMath and comes along with build-scripts to let authors reload content easily into a running ActiveMath, thus allowing them to cycle between content-preview and content-editing. The tool has

been used successfully by non-developers, even without prior knowledge of HTML or XML.

2.2 On the Importance of Validation and Error-Reporting

As we see, the developer-tools approach is still quite present. But developer-tools are not only present by the fact that a source is being edited, but also by the fact that a *build-script* is being used along with error-reporting presented in the source. We describe here the validation tasks and error-reporting performed in the current jEditOQMath and highlight why they are important:

- XML-validation: in jEditOQMath, it happens simply at each save and makes sure the content elements are appropriately nested. The lack of such validation has been observed several times to create awkward presentation problems which are hard to detect.
- reference checking: reference between items are both inside the items and in the metadata relations. For a long time, tools to report these errors were not present and the database storing the content was very tolerant. Reference errors were frequent and had such misbehaviors as the lack of content in course-generation, the crash of the latter, or wrong user-model updating.

Actually, the needs for error-reporting are independent of the fact that a source is being edited. A visual tool should, as well, provide such feedback, including an error-list taking the user to the place where the error is to be corrected.

2.3 Verifying the Content

The need to verify (or *test*) an installed content can also be deduced from authors observed thus far: they spend almost more time to proof-read the content presentation than actually writing content. They do so as a *demo-user* (sometimes several) using their local web-browser.

One reason for this fact is certainly that the current presentation is from an XML source with extensible presentation of mathematical symbols for which it is easy to loose the overview. Moreover, this presentation provides access to many possible interactions (e.g. the navigation along a path of relations in the dictionary). It has been observed that such aspects of the presentations are, indeed, manually checked by authors.

All the adaptive behaviors of ActiveMath are also verified manually: the appearance under different *themes*, the results of course-generation, and the user-model updates. Such tests are, however, very long to perform: currently, course-generation takes several minutes and relies on a user-model state, which the author should be clear with. Moreover, verifying the user-model update can only be done following a navigation path which takes a long sequence of clicks and may need much resources to be computed.

As a result, such verifications, although wished, are very rarely performed.

3 Scope of the Authoring Task

Before going further with the verifications task, allow us to try to answer the following question: *how much information should be affected by an authoring tool?*

The candid answer to this question would be that authoring tools should edit the *content*. Authors tend, however, to wish more than just providing content items, along with their metadata. Here are a few examples of possible modifications of the default ActiveMath behaviour that authors have wished thus far:

- the presentation of ActiveMath functions may be changed in order to make the system more accessible to target users (for example removing some links-generation for school pupils)
- adapting the pedagogical rules used in the course-generation scenarios to particular usages or particular content
- performing elementary changes in the appearance such as the introduction of the institution's logo or the change of some colour choices
- the base user-model that new registrants will be endowed with should be adapted to the expected newcomers (or their groups)

In order to be able to provide the freedom to perform and distribute such information, the scope of authoring should encompass the whole data of ActiveMath, including configuration, rules, and menu-templates. A notion of *project* should thus to be defined, extending the notion of content-collection. We shall try to satisfy these requirements: projects will be defined which will have *deployment* routines to install on a fresh ActiveMath. As much as possible, these projects will be encoded using ontology-based tools so as to allow a declarative knowledge representation of such modifications.

Offering a freedom as important as impacting the whole ActiveMath is, however, dangerous: it is easy to break a system by changing its configuration or changing a set of rules and a presentation can be made unusable because of wrong colour choices. The need to verify the *installation* of a project is thus made even more important. In the next section, we sketch how such verification could be helped by simulations which we propose to implement.

4 Simulations to Check the Learning Path

In [3], Hayashi, Ikeda, Seta, Kakusho, and Mizoguchi present an approach to author learning content using ontological engineering. They propose to model *conceptual simulations* which are high-level specifications of the expected behaviour of the content-playing-in-the-software. This approach seems to be the right path to take in the long term, where the systems' behaviour is sufficiently transparent, it seems not to provide an answer to nowadays verification wishes on existing adaptive systems and requires a very abstract representation for the simulations to be entered.

We claim that such a simulation can be made much more visual and concrete, in fact, close to the current practice of authors checking the content with his browser but

providing capability to input quickly such a simulation (including the time spent to read items), store it and replay it, with a summarized view (e.g. thumbnail) and, most probably, with automated tests on such values as the learner-model entries or the existence of a link.Making these simulations of the size of a thumbnail allows an author to have several simulations under the eyes, thereby being to envision several target users. Being able to replay these simulations often with the content evolving allows the author to use these as a form of integrated tests: a quick view on the sequence of screens obtained in such a simulation provides a glimpse at the expected views the target user will experience, the measure of success of the tests is a measure of achievement of the content, a practice similar to the practice of unit-testing in software development.

Such simulations are probably of more general applicability. In particular, they apply for both content that is re-used and content that is freshly authored.

5   Conclusion

We have been describing the authoring tools realized thus far for the ActiveMath learning environment. The experience gained has proven the importance of the validation tools and verification possibilities so that authors' trust in the presentation and adaptive features can be gained.

In order to raise the trust we propose to provide to authors efficient and usable tools to input and play simulations of the learning process using visual approaches but still allowing computable verifications.

It should be observed that the visual simulations we are proposing could be interpreted as an application of the WYSIWYG paradigm (*What You See Is What You Get*). This is misleading, however, as the simulations are intended to provide multiple views on the content whereas a WYSIWYG approach is based on a single view.

6   Related Work

The problem of putting the control of intelligent *agents*, such as adaptive systems, at work under the hands of a user is not new, see for example [5]. However, we have found little done towards offering control of an adaptive systems to a user. These simulations would like to provide ways to experiment with an adaptive systems more efficiently and in a comprehensive fashion.

Our investigation in the literature for finding related work has not been fruitful. The high-level simulation formulated in [3] seems to be the only such approach and is fundamentally different from ours. We anticipate, however, that the needs for such a concrete simulations will grow as the serving world evolves in adaptivity functions.

7 Future Work

The development of the source-editing facilities that we have presented will be stabilized and the authoring tools in ActiveMath will migrate to edition within visual tools. Following the *view to the future* of [1], we are currently evaluating considering graph-based input of the domain-model along with the items' content using the Protégé ontology editor. The wealth of the verification tools will be kept and be complemented with visual simulations and their associated tests.

Acknowledgements

References

1 Peter Brusilovsky. Developing adaptive educational hypermedia systems: From design models to authoring tools. In Tom Murray, Stephen Blessing, and Sharon Ainsworth, editors, *Authoring Tools for Advanced Technology Learning Environment*. Kluwer Academic Publishers, Dordrecht, 2003. See http://www2.sis.pitt.edu/~peterb/papers/KluwerAuthBook.pdf.

2 O. Caprotti and A. M. Cohen. Draft of the open math standard. Open Math Consortium, http://www.nag.co.uk/projects/OpenMath/omstd/, 1998.

3 Yusuke Hayashi, Mitsuru Ikeda, Kazuhisa Seta, Osamu Kakusho, and Riichiro Mizoguchi. Is what you write what you get?: An operational model of training scenario. In Gilles Gauthier, Claude Frasson, and Kurt VanLehn, editors, *Proceedings of the Fifth International Conference on Intelligent Tutoring Systems (ITS 2000)*, volume 1839 of *LNCS*, pages 192-201. Springer, June 19-23 2000. See also http://www.ei.sanken.osaka-u.ac.jp/pub/hayashi/hayashi-ITS2000.pdf.

4 Michael Kohlhase. OMDOC: Towards an internet standard for mathematical knowledge. In Eugenio Roanes Lozano, editor, *Proceedings of Artificial Intelligence and Symbolic Computation, AISC'2000*, LNAI. Springer Verlag, 2001. See also http://www.mathweb.org/omdoc.

5 Pattie Maes, Agents that reduce work and information overload. *Commun. ACM*, 37(7):30-40, 1994.

6 E. Melis, J. Büdenbender E. Andrès, A. Frischauf, G. Goguadze, P. Libbrecht, M. Pollet, and C. Ullrich. Knowledge representation and management in ACTIVEMATH. *Annals of Mathematics and Artificial Intelligence, Special Issue on Management of Mathematical Knowledge*, 38(1-3):47 - 64, 2003. Volume is accessible from http://monet.nag.co.uk/mkm/amai/index.html.

7 C. Ullrich., An instructional component for dynamic course generation and delivery. In R. Tolksdorf, R. Eckstein, eds, *Proceedings of Berliner XML Tage 2003*, 467-473, 2003.

Educational Adaptive Hypermedia meets Computer Assisted Assessment*

Enrique Alfonseca, Rosa M. Carro, Manuel Freire, Álvaro Ortigosa, Diana Pérez, and Pilar Rodríguez

Computer Science Department, Universidad Autonoma de Madrid,
Carretera de Colmenar Viejo, km. 14,5,
28043 Madrid, Spain
{Enrique.Alfonseca,Rosa.Carro,Manuel.Freire,Alvaro.Ortigosa,
Diana.Perez,Pilar.Rodriguez}@ii.uam.es

Abstract. In this paper we explore the many possibilities that arise when we combine adaptive web-based courses with computer-assisted assessment. We argue that this integration has several advantages, such as the feasibility of getting a better model of the student's progress, which will be used with adaptation purposes, and the possibility of proposing and evaluating open-ended questions in the way that is judged more suitable for each student.

1 Introduction

Adaptive hypermedia has been widely used for the development of adaptive Web-based courses, in which each student is individually guided during the learning process [1]. Most of these systems obtain feedback from the student from two sources: their behaviour browsing the course (e.g. pages visited, time spent in each or navigational path) and test questions (e.g. true-false, multiple-choice or fill-in-the-blank questions). Some authors have expressed their concern that this limited way of assessment may not be really measuring the depth of the student learning [2]. This fact has been the motivation of the field known as Computer-Assisted Assessment (CAA) of student essays. CAA of student essays is a long-standing problem that has received the attention of the Natural Language Processing research community. There are many possible ways to approach this problem, including a study of the organization, sentence structure and content of the student essay [3, E-rater], pattern-matching techniques [4, IEMS], or Latent Semantic Analysis [5, IEA]. Valenti et al. [6] describe the state-of-art of CAA systems.

In order to support adaptive distance teaching and learning, we have developed the TANGOW system, which supports the description of adaptive web-based courses and their dynamic generation, so that their components are tailored to each student at runtime [7,8]. We have also developed, independently, a CAA

---

system called Atenea [9] which is based on n-gram co-occurrence metrics [10]. In this paper we describe the ongoing integration of TANGOW and Atenea and the benefits of this integration.

The paper is structured as follows: in Section 2 we describe separately Atenea and TANGOW, next in Section 3 we describe their integration and finally Section 4 will highlight the conclusions and future work.

2 Atenea and TANGOW

Atenea [9,11] is a Computer-Assisted Assessment system for automatically scoring students' short answers. It relies on the combination of shallow natural language processing modules [12] and statistically-based evaluation procedures. The recall is calculated by studying the percentage of those references that is covered by the student's answer and the precision of the student's answer is obtained by calculating the BLEU score [10].

The BLEU algorithm relies on the idea that a text is better when it is closer to a model text written by an expert. It was originally devised for evaluating Machine Translation systems, with the core idea that a Machine Translation is better when it is closer to the human translation. Hence, it looks for coincident n-grams (usually from unigrams to trigrams) between the human translator and the machine translations. In past work [9] we proved that BLEU can also be applied for evaluating students' answers, since the core idea remains: *the more similar a student's answer is to the teacher's reference answer, the better it is.* BLEU has been implemented, with minor modifications, as a module called ERB (Evaluating Responses with BLEU).

The system has already been tested with ten short questions, which are grouped in three collections: Operating Systems, Advanced Operating Systems and Object-Oriented Programming.

The scores provided by ERB are values between 0 and 1, where the upper and the lower bounds depend on the particular question. Nonetheless, we can perform a linear regression to find a correspondence between the interval of possible Atenea's scores and a fixed rank of scores, for instance, between 0 and 10. As expected, the quality of the assessment is very influenced by the kind of question and the references written. When scoring definitions, the correlation between Atenea's scores and the marks assigned manually can reach 0.80 [9]. On the other hand, questions that ask the student to make a reasoned argument or to compare several topics are more difficult to evaluate since they require a deeper linguistics processing.

The feedback that the students get from the system is a numerical score and a copy of their answer where, with color codes, they can observe which were the coincident n-grams and which words did not appear in any reference. From that output they can easily know which are the portions of their answers that are correct and have contributed in incrementing their score. Figure 1 shows an example answer page. In the user profile, students may also indicate whether they just want the score and are not interested in receiving this feedback.
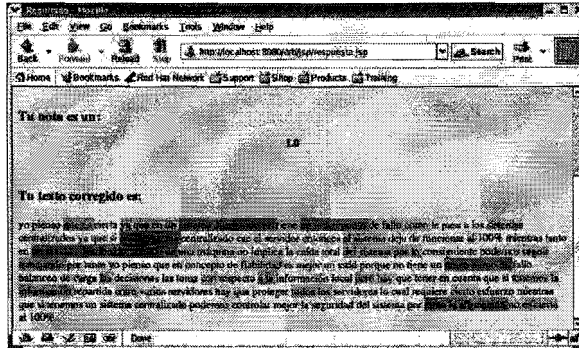
Fig. 1. Feedback that a student gets after answering the question *"Discuss whether distributed systems are more robust than monolithic systems"*, in Spanish. The darker the background, the longer the coincident n-gram.

Although Atenea is currently underpinned by ERB, it is not only limited to it. In fact, more NLP modules are currently being added to the already existing ones, including syntactic analyzers and word-sense disambiguation. A web-based wizard has also been developed to facilitate the task of introducing new data sets of questions and new questions.

The TANGOW system delivers adaptive web-based courses, and has evolved significantly since [7]. Courses delivered by TANGOW are composed of several tasks, that can be accomplished by the students. A task can correspond to either a theoretical explanation, an example, an exercise to be done individually or an activity to be performed collaboratively (problems to be solved, discussions, etc). The set of available tasks is constantly regenerated, tracking changes in the student's profile (static features and dynamic actions). Once a task is chosen, the system generates the corresponding web pages by selecting, among the content fragments and the set of available collaborative tools, those that provide the best possible fit to the current profile.

A rule-based formalism has been developed in order to facilitate the specification of alternative structures for the same course, and to support different teaching strategies, navigational guidance variations and collaboration workspaces for each type of student [8].

3 The integration of Atenea and TANGOW

The integration of Atenea and TANGOW will support the inclusion of CAA exercises inside adaptive courses, as a new type of TANGOW task. The process of integrating both systems was expected to be quite easy: Atenea would be launched from TANGOW and, after asking the students and automatically evaluating their answers, it would return the results to TANGOW so that this information could

be used to update the user model and continue with the adaptation process. Atenea is currently configured to show different questions depending on the student's language and experience. The assessment is adapted to the used model, e.g. by showing easier questions to novice students. The information stored in user model also affect the set of reference answers that is chosen. The integration is not complete yet, but our ongoing work on implementation indicates that it will be simple to finish the links between both systems.

An initial step in the integration process was to decide which features from the current TANGOW user model would be used in Atenea in this first experience. We chose to use the *student name* as the login input in order to address the student by his or her name; *age*, because questions should be formulated in a simpler fashion for children than for adults, and different writing styles are expected from them; *language*, because we plan to extend Atenea with multilingual capabilities; *experience*, because the assessing process should be different for advanced students than for novice ones; and *feedback type*, because when formative assessment is used, the feedback should be more detailed than for summative assessment (where the score is the most relevant result).

Concerning the order of the questions, it is possible to take into account the student experience so that advanced students are not asked questions that they have already solved or that are too easy for their level. Moreover, the higher the level of experience, the stricter the system should be when assessing student answers.

The protocol for connecting TANGOW and Atenea is the following:

- TANGOW gathers information about the student's profile and sends it to Atenea, along with the identification of the task the student is going to perform, as well as the type of feedback desired.
- Atenea randomly chooses a question from the dataset corresponding to this task, that has not already been solved by the student (that is, not yet graded or graded less than half of the maximum score). The question is chosen taking into consideration the student profile. The answers submitted by the students are then evaluated by Atenea, and the resulting score and feedback is presented to the student. This process is repeated until the student has answered the required number of exercises. Finally, once the stop condition is satisfied, Atenea returns a holistic student score for the task to TANGOW.

A first consequence of the integration will be a richer set of activities, which can contribute to a more engaging learning process. Secondly, the use of the TANGOW formalism allows course authors to specify different teaching strategies by incorporating CAA activities at different points of the course, depending on each student's evolution. It will be possible for authors to choose the types of users to whom CAA activities will be presented; the places in the course where these exercises will appear; the requirements for a CAA activity to be proposed; and the grading criteria to determine the degree of success of each activity. Each of these adaptations can be made in different ways depending on the user's model. Finally, the formalism also supports the adaptation of CAA activities
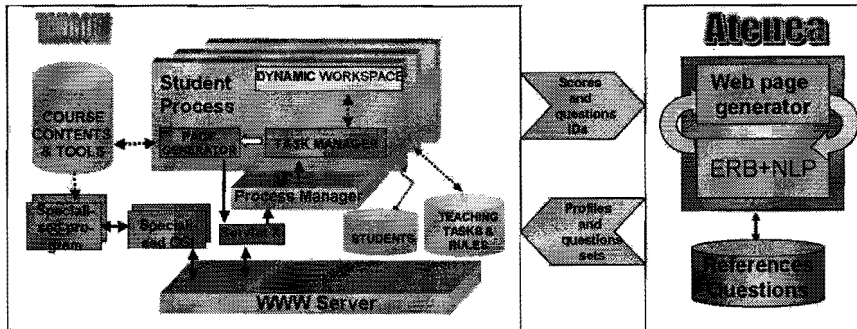
Fig. 2. Architecture of the integration between TANGOW and Atenea

themselves: the questions to be asked and the reference answers can be chosen according to each student's profile.

4 Conclusions and future work

We are implementing the integration of the adaptive hypermedia educational system TANGOW with Atenea, a program for automatic assessment of student answers. Atenea attains a good correlation with respect to teachers' marks, particularly when evaluating definitions and short descriptions [9]. The current implementation allows the students to try out their knowledge, and its complete integration with TANGOW, whose feasibility has been proved, will support the following:

- Atenea will use the description of the user profiles maintained by TANGOW, so it will accept variable profiles.
- The adaptation engine from TANGOW will decide at which time each student should be assessed, depending on his/her profile, knowledge, and actions, and Atenea will choose the most adequate set of questions for this student, resulting in a fairer evaluation.
- TANGOW will benefit not only from the possibility of automatically evaluating free-text answers, but also from the feedback from those questions, which can be used to guide the students during the rest of the course.
- It will be possible to obtain a dataset of student answers related to their profile and performance in the course, which we shall use in further studies to analyze how the adaptation can improve CAA activities.

The interaction protocol between Atenea and TANGOW has already been designed and is being currently implemented. Current work comprises a complete integration of Atenea and TANGOW in the direction described above and the evaluation of the integrated system with real students.

References

[1] Brusilovsky, P.: Adaptive hypermedia. User Modelling and User-Adaptive Interaction, Ten Year Anniversary Issue (Alfred Kobsa, ed.) 11 (2001) 87–110

[2] Whittington, D., Hunt, H.: Approaches to the computerized assessment of free text responses. In: M. Danson (Ed.), Proceedings of the Sixth International Computer Assisted Assessment Conference, Loughborough, UK (1999)

[3] Burstein, J., Leacock, C., Swartz, R.: Automated evaluation of essay and short answers. In: M. Danson (Ed.), Proceedings of the Sixth International Computer Assisted Assessment Conference, Loughborough, UK (2001)

[4] Ming, Y., Mikhailov, A., Kuan, T.L.: Intelligent essay marking system. In: C. Cheers (ed.), Learners Together, Singapore, NgeeANN Polytechnic (2000)

[5] Laham, D.: Automated content assessment of text using Latent Semantic Analysis to simulate human cognition. Ph.D. Dissertation, University of Colorado, Boulder (2000)

[6] Valenti, S., Neri, F., Cucchiarelli, A.: An overview of current research on automated essay grading. Journal of Information Technology Education 2 (2003) 319–330

[7] Carro, R., Pulido, E., Rodríguez, P.: Dynamic generation of adaptive internet-based courses. Journal of Network and Computer Applications (1999) 249–257

[8] Carro, R., Ortigosa, A., Schlichter, J.: A rule-based formalism for describing collaborative adaptive courses. In: Knowledge-Based Intelligent Information and Engineering Systems. LNAI 2774, Springer-Verlag (2003) 252–259

[9] Pérez, D., Alfonseca, E., Rodríguez, P.: Application of the BLEU method for evaluating free-text answers in an e-learning environment. In: Proceedings of the Language Resources and Evaluation Conference (LREC-2004). (2004)

[10] Papineni, K., Roukos, S., Ward, T., Zhu, W.: Bleu: a method for automatic evaluation of machine translation (2001)

[11] Pérez, D., Alfonseca, E., Rodríguez, P.: Upper bounds of the BLEU algorithm applied to assessing student essays. In: Proceedings of the 30th International Association for Educational Assessment (IAEA) Conference. (2004)

[12] Alfonseca, E., Perez, D.: Automatic assessment of short questions with a BLEU-inspired algorithm and a shallow semantic representation. Accepted in the 4th International Conference Spain for Natural Language Processing (ESTAL) (2004)

WORKSHOP 7:

Applying Adaptive Hypermedia Techniques to Service Oriented Environments

Pervasive Web Services and Context Aware Computing

Workshop Co-Chairs:

Vincent Wade
Owen Conlan
Wolfgang Nejdl

Preface

Traditional Adaptive Hypermedia Systems have tended to act as stand-alone applications that have attempted to fulfil a user's informational need, e.g. personalised content retrieval and delivery, as well as his/her infrastructural needs, e.g. content and media management. Adaptive Hypermedia techniques are proving effective in many application areas e.g. eLearning, Information Retrieval etc.

Today, Service Oriented computing environments offer sets of 'potentially collaborative' services capable of supporting user applications and context appropriate features to a user. In particular, research in the Semantic Web community is focusing on Semantic Web representation, discovery and more recently web service orchestration and choreography. Whether using an Ontological approach or other knowledge driven approaches, adaptive web services are now the subject of intense research. In the case of ubiquitous or pervasive computing environments, the features and services available to the user are offered through the many devices in their physical environment creating the possibility of multi-modal interactions. The adaptivity required by such services is obvious but not always well architected.

This workshop will explore Adaptive Hypermedia techniques in their integration and support of service oriented adaptivity. Areas which will be addressed include emergent service oriented environments such as Adaptive (Semantic) Web Services and Pervasive (Computing) Services as well as more traditional service oriented environments such as eCommerce, eLearning and eGovernment. A key focus of the workshop will be to explore the common problems of adaptive information composition and delivery in conjunction with that of adaptive service composition and integration. Through this workshop the connections between personalisation and (web) service paradigms will be investigated. This workshop also aims to identify and examine the strengths of AH techniques in supporting, and being the subject of, the semantic/ontology-driven composition of application services.

Integrating Adaptive Hypermedia Systems with service oriented computing environments and semantic/ontology-driven composition approaches presents researchers with a number of challenges. In examining the application of Adaptive Hypermedia Techniques to Service Oriented Environments integration may be considered at many levels:

- Service Architectures and Interfaces
- Semantic Representations of Services, (Information) Domains, and Context
- Knowledge Sharing and Information Model interoperability
- Reasoning techniques for adaptive planning, decision support or service choreography
- Semantic Interoperability within the adaptive system

Through this integration key research questions may be considered:

- What are the most appropriate mechanisms for achieving integration of these layers?
- Is the implementation dependent on the services involved or is there a best practice for integrating Adaptive Hypermedia Systems as part of integrated computing environments?
- Can or should the Adaptive Hypermedia functionality be seamlessly integrated with other services?
- Is it possible to utilise techniques employed in AH for the personalization of Web Service discovery, selection or composition?
- Are commonly understood ontologies required to achieve sharing of knowledge/information models such as service, content and user models?
- Can ontology/information mapping techniques be used to bridge semantic gaps between services (semantic interoperability)?

This workshop aims to address these research issues and provide a forum in which researchers may voice their opinions on the integration of Adaptive Hypermedia Systems and techniques with Service Oriented Computing.

August, 2004
Vincent Wade, Owen Conlan and Wolfgang Nejdl

Workshop Organization

Chair - Vincent Wade, *Trinity College, Dublin*
Co-Chair - Owen Conlan, *Trinity College, Dublin*
Co-Chair - Wolfgang Nejdl, *Learning Lab Lower Saxony [L3S]*

Program Committee

Wolf-Tilo Balke, *University of California, Berkeley*
Peter Dolog, *Learning Lab Lower Saxony [L3S]*
Nicola Henze, *Learning Lab Lower Saxony [L3S]*
Cord Hockemeyer, *Karl-Franzens Universität, Graz*
Dave Lewis, *Trinity College, Dublin*
David Millard, *University of Southampton*
Declan O'Sullivan, *Trinity College, Dublin*

Adaptive Hypermedia Services for Learning

Peter Brusilovsky, Sergey Sosnovsky, Michael Yudelson

School of Information Sciences
University of Pittsburgh, Pittsburgh PA 15260, USA
{peterb, sas15, mvy3}@pitt.edu

Abstract. This paper discusses the advantages of offering adaptive hypermedia functionality in the e-Learning context through *adaptive hypermedia services*. We think that this option bridges the gap between the complexity of authoring and the ease-of-use necessary for successful adaptive hypermedia. This paper presents an open architecture for adaptive e-Learning that would make these adaptive hypermedia services possible. It briefly describes two adaptive hypermedia services QuizGuide and NavEx that stands between E-Learning portal and re-usable interactive content providing additional value for teachers and students who want to use content through an e-Learning portal. The value added by QuizGuide and NavEx is the ability to provide navigation support for each student without causing overhead for the teacher. Teachers can bypass the time-consuming process of selecting relevant, reusable content for each course lecture while students receive better guidance when e-Learning is adapted to their learning goals and knowledge.

1 Introduction

A number of pioneer adaptive hypermedia systems such as ELM-ART [21], 2L670 [13], and KBS-HyperBook [15] have demonstrated the benefits of adaptively serving full-scale web-based courses. Several adaptive hypermedia authoring systems and platforms [7; 14; 22] have been developed to assist in the production of these specialized web-based courses. Nevertheless, nearly all web-based courses are now developed and served through so-called Learning Management Systems [8] such as Blackboard [3] or WebCT [20]. Learning Management Systems (LMS) are powerful integrated systems that support a number of activities performed by teachers and students during the e-Learning process.

A quick comparison may tell us why LMS rather than adaptive hypermedia (AH) authoring systems are chosen as the primary way to develop web-based courses. First, LMS support a whole range of teacher activities while AH authoring systems focus mostly on content organization and presentation. Secondly, adding a new content fragment to an LMS requires no overhead, while any fragment added to an AH course must be indexed with regards to the domain model's concepts [5].

In this context, how can we bring the power of AH to thousands of real users? How can the gap be bridged between AH and LMS? In our earlier paper [9] we argued that the current generation of LMS systems can't support full-scale adaptive hypermedia.

Should we now focus on developing a new generation of LMS which have an embedded AH functionality (as pioneered by ALE and a few similar systems [18])?

The authors present here another method: embed AH functionality into modern web-based courses using *adaptive hypermedia services*. The major bottleneck which prevents the use of full-scale adaptive hypermedia in the classroom appears to be the complexity a teacher faces when trying to create a complete AH course – even when being given the best authoring tools in existence. As demonstrated by current LMS use in universities, a typical teacher is able to locate useful resources and attach them to their course web site. However, teachers are rarely able to assemble a full-scale course from multiple instances of these small components, even if they skip the indexing step required of adaptive hypermedia. While we can expect that large course development teams and even some motivated and dedicated teachers will embrace and be able to use the adaptive LMS of the future, the real question is how we can help everyone else. Our answer to this question is simple – we suggest offering adaptive hypermedia services that can be chosen by the classroom teacher and attached to courses as a single reusable component.

AH Services allow one to organize the complexity of authoring while maintaining the ease-of-use necessary for adaptive hypermedia. In our model, AH Services can be designed and maintained by professional teams (which we call *service providers*) and should be able to be used by anyone teaching a web-based course. The idea of AH Services was pioneered in APeLS [10; 11; 12; 19]. In our work we want to expand the concept of AH services as well as to develop several practical services that anyone can use. We are also working on an open architecture for adaptive e-Learning that makes AH Services possible. This paper presents our architecture and briefly describes two AH Services that we have developed recently.

2   The KnowledgeTree Architecture

KnowledgeTree is a distributed architecture for adaptive e-learning based on the re-use of intelligent educational activities [6]. Capitalizing on the success of integrated LMS, KnowledgeTree aims to provide one-stop comprehensive support for the needs of teachers and students who are using e-Learning. In doing so, it attempts to replace the current monolithic LMS with a community of distributed communicating servers (or services). The architecture assumes the presence of at least four kinds of servers: learning portals, activity servers, value-added services, and student model servers (Figure 1). These kinds of servers represent the interests of three main stakeholders in the modern e-Learning process: content and service providers, course providers, and students.

A *learning portal* represents the needs of course providers - teachers (trainers) and their respective universities or corporate training companies. The portal plays a role similar to modern LMS in two aspects. First, it provides a centralized single-login point for enrolled students to work with all learning tools and content fragments that are provided in the context of their courses. Secondly, it allows the teacher responsible for a specific course to structure access to various distributed fragments according to the needs of his or her course. Thus, the portal is the component of the

architecture that is centered on supporting a *complete course*. Replicating the familiar functionality of an LMS, it provides a course-authoring interface for the teacher and maintains a runtime interface for the student. The difference between this and LMS is an architectural separation of the *unique course structure* created by the teacher or course author from *reusable course content and services*. In KnowledgeTree, both learning content and learning support services (together called *activities*) are provided through the portal by multiple distributed *activity servers* (Services). A portal has the ability to query activity servers for relevant activities and launch remote activities selected by students or by the portal itself.
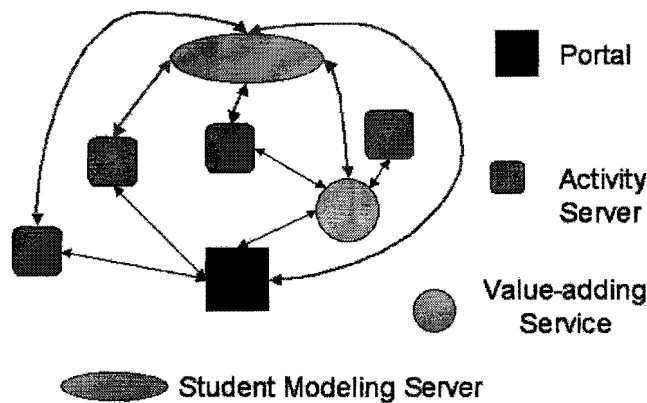

Fig.1. Main components of the KnowledgeTree distributed architecture.

An *activity server* is a component that focuses on the projected needs of the content and service providers. It is centered on *reusable content and services*. It plays a role similar to an educational repository in modern courseware reusability approaches, in the sense that it hosts reusable learning content. The difference between this and a traditional learning repository is twofold. First, unlike repositories that are pools for storing simple, mostly static, learning objects, an activity server can host highly interactive and adaptive learning content. It can also host interactive learning services such as discussion forums or shared annotations. Secondly, the activity server uses a different way to deliver its reusable "content": While simple learning objects are merely copied and inserted into new courses, an activity is re-used by referencing it and then delivered through the server.

These activities can't be merely copied as files, but have to be served from dedicated web servers maintained by the content providers. The duty of an activity server is to answer the portal's and value-added service's requests for specific activities and to provide complete support for a student working with any of the activities residing on the server. The concept of reusable activities encourages content providers to develop highly-advanced, interactive learning content and services. In particular, content and service activities delivered by a server can be intelligent and adaptive. Each activity can obtain up-to-date information about each student from the *student model server* and thus provide a highly personalized learning experience. It

472

also monitors student progress and changes that take place in student goals, knowledge, and interests; then sends updates to the student model server.

A value-added service combines features of a portal and an activity server. It is able to pipe through itself "raw" content while adding some valuable functionality to it - such as adaptive sequencing, navigation support, visualization, or content integration. Like a portal, it is able to query activity servers and access activities. Like an activity server, it can be queried and accessed by a portal. Value-added services are maintained by service providers. Since these services are course-neutral, they can be re-used in multiple courses. Thus they provide larger building blocks for a teachers assembling an E-Learning system with the help of a portal.

The *student model server* is a component that represents the needs and the prospects of students in the process of e-Learning. This kind of server allows distributed e-Learning to be highly personalized. Ideally, a student model server can support student learning for several courses. It can be maintained by a provider (i.e., a university) or by the students themselves. It collects data about student performance from each portal and each activity server and provides information about the student to adaptive portals and activity servers that are then able to adapt instructional materials to their students' unique personalities and present development.

We anticipate that in the context of pure web-based education, the student model server would reside on the student's own computer and support just one user. Using this method, the server can also serve as a tool for the user to monitor his or her own progress within various activities and courses. In the context of classroom education, the server can reside on a computer maintained by the educational establishment. Here it also supports the teacher's need to monitor the progress and the performance of the whole class. These arrangements can help to solve a number of privacy and security problems associated with student modeling.

With the KnowledgeTree architecture, a teacher develops a course using one portal and many activity servers and services. The student works through the portal serving this course, but interacts with many learning activities served directly by various activity servers. The student model server provides a basis for performance monitoring and adaptivity in this distributed context. The KnowledgeTree architecture is open and flexible. It allows the presence of multiple portals, activity servers, and student modeling servers. The open nature of it allows even small research groups or companies to be "players" in the new e-Learning market. It also encourages creative competition between developers of educational systems, i.e., competition based on offering better services, not by monopolizing the market and resisting innovation. An activity server that provides some specific innovative learning activities can be immediately used in multiple courses served by different portals. A newly created portal that offers better support for a teacher or answers better to the needs of a specific category of course providers can successfully compete with other portals since it has access to the same set of resources as other portals. A new kind of student model server that provides better precision in student modeling or offers a better support for student model maintenance can successfully compete with older servers. Overall the architecture reflects the move from a product-based to a service-based Web economy.

While working with KnowledgeTree over the last two years we have clearly realized the need for adaptive hypermedia services. A teacher developing a course

473

with a portal faces large volume of educational resources. For example, we have developed a large amount of interactive questions and examples for programming that are available through our activity servers QuizPACK [17] and WebEx [4]. Potentially, a teacher may be interested in allowing the student to use a large amount of resources. However, it's a duty of the teacher to provide at least some minimal *guidance* to make sure that the student is not getting lost in the long list of resources, but is able to access the right things in the right time. What teachers are typically doing to provide this guidance is structuring resources – adding each resource to a specific part of the course, such as a lecture or weekly topic. However, even this simple structuring grows overwhelming when the number of available resources is more than a hundred. At this point, an adaptive hypermedia service can help. Our model uses adaptive navigation support service as a layer between the course and the "raw content". The availability of this service will allow a teacher to simply to add a whole set of activities to the course. Instead of providing navigation support manually for each activity, the teacher can simply rely on automatic adaptive navigation support to advise the students about what is the right activity to try at any given time.

To explore this model we have created two adaptive hypermedia services. NavEx provides an adaptive access to interactive examples developed with WebEx [4] and QuizGuide provides an adaptive access to QuizPACK quizzes [17].

3   The NavEx Service

NavEx (Navigation to Examples) was designed to explore the idea of providing adaptive navigation support for accessing programming examples. NavEx is an adaptive interface to our older system WebEx [4]. WebEx can serve interactive examples, but it has no knowledge about the examples and can't decide when a specific example is appropriate to explore. NavEx analyzes the context of each example, identifies programming concepts behind it, and uses the traditional "traffic light" metaphor for adaptive navigation support [5] in order to guide students to the most relevant examples.

The interactive window of the NavEx system is divided into 3 frames (Figure 2). The leftmost frame contains a list of links to all examples/dissections available for a student in the current course. The links are annotated with colored bullets. The red bullet means that the student has not mastered enough prerequisite concepts to view the example. Thus the link annotated with the red bullet is disabled. The green bullet means that the student has enough knowledge to view the example. A green check mark denotes that the example has already been seen by the student. The green "play" bullet means that the example is currently being viewed. The order of links to examples is fixed, so students can find them at the same place no matter how far they progress through the course.

The upper frame displays the name of the current example. Underneath it are two links: one loads the source code of the example to the central frame (to be copied, compiled, and explored), the other – loads the interactive *dissection* of the example (served directly by the WebEx system that is now a component of NavEx). Dissection uses the same source code but adds comments. These comments address the meaning

and purpose of each line of code, thus helping the student to understand the example better. The existence of extended comments is shown by green bullets on the left side of the code and can be activated by clicking on the bullet next to each line of the code. If the comment is available the bullet is green, white otherwise.
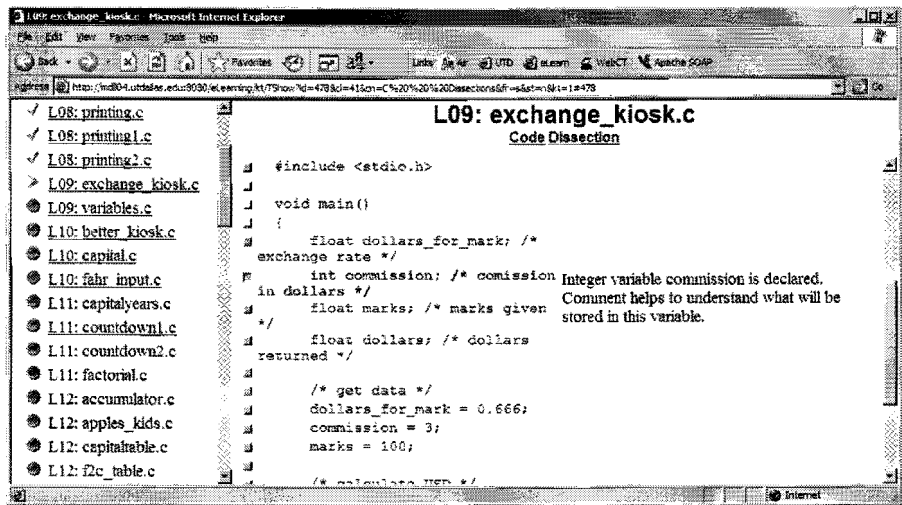

Fig.2. The interface of NavEx.

4 The QuizGuide Service

QuizGuide is an adaptive service that helps students select the most relevant quizzes that can be offered by the QuizPACK system [17]. Similar to WebEx, QuizPACK can deliver an activity, but has no knowledge of when this activity is appropriate to a student. QuizGuide adds a layer of navigation support between a learning portal and raw content. It uses another innovative kind of adaptive annotation in order to show every student which topics are currently most important and which ones require further work.

The student interface of the QuizGuide system consists of two main parts: the quiz navigation area and the quiz presentation area (Figure 3). In the quiz presentation area students answer the questions and receive feedback. There are two types of questions: *"What is the final value of the marked variable?"* and *"What will be printed?"* The feedback indicates whether the answer is correct or not. If it is not, the correct answer is also presented. After answering a question, students are provided with two options to continue. They can move to the next question in the quiz or repeat the previous one (with a different value parameter randomly generated). The student work with the quiz area of QuizGuide is supported by the original QuizPACK [17].

The quiz navigation area (left in Figure 3) provides hyperlinks to quizzes grouped by topics. When a student clicks on the topic name, the links to quizzes available for this topic pops out. The student can open one or several topics. Clicking on an opened

475

topic collapses the list back. Clicking on a quiz link loads the first question of this quiz in the quiz presentation area. Altogether, QuizGuide provides access to more then 40 quizzes organized in 20 topics. In this context, our use of stretchtext technology decreases the information load on the student by removing links to the unrelated quizzes while allowing students to see "the whole picture".
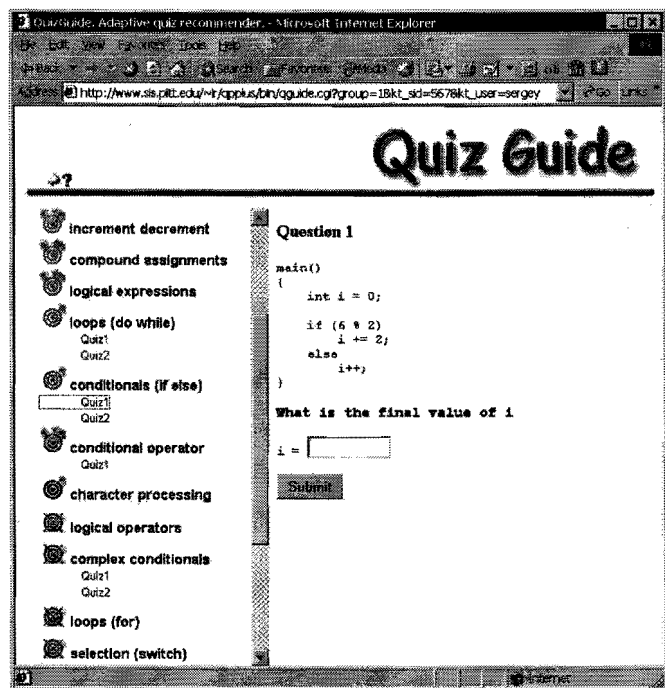

Fig.3. Student interface of QuizGuide.

Adaptive navigation support is provided in the navigation area by adaptive icons shown to the left of each topic. QuizGuide adapts to two of the most crucial characteristics of the user: knowledge level and learning goal. To reflect both the goal and knowledge relevance of each topic in one icon, QuizGuide uses the "target-arrow" abstraction (Figure 3). The number of arrows in the target reflects the level of knowledge the student has for that topic: the more arrows the target has, the higher the level is. The target color shows the relevance of the topic to the current learning goal: the more saturated the color is, the more relevant the topic is. Topics which the student is not yet prepared to study are annotated with a crossed-out target. Hence we have four levels of knowledge (from zero to three arrows) and four levels of goal relevance (not-ready, important, less-important and non-important).

QuizGuide system is implemented as a value-added service that resides between the original QuizPACK system and a learning portal. QuizGuide generates the list of annotated hyperlinks to quizzes and uses QuizPACK to deliver the quizzes through the quiz presentation frame. When generating adaptive quiz navigation, QuizGuide

476

sends a request to the central User Modeling server CUMULATE [6] and gets the current values for the knowledge level of all course topics.

5 Summary

We have developed two adaptive hypermedia services QuizGuide and NavEx that reside between E-Learning portal and re-usable interactive content providing additional value for teachers and students who use this content through the portal. The value added by QuizGuide and NavEx is the ability to provide navigation support for each student without causing overhead for the teacher. With our services, teachers can bypass the time-consuming process of selecting reusable content for each course lecture by determining which ones are relevant to goals and prerequisite restrictions. Instead, they can add a whole set of content as one package and rely on the navigation support provided by the AH Services. At the same time, the students receive better guidance in selecting content than when they are given the traditional list of resources for a specific lecture because the list is now limited and adapted to their learning goals and knowledge.

An adaptive service like QuizGuide and NavEx is a relatively advanced product. However, a team with good expertise in adaptive hypermedia and knowledge of the subject to be taught (domain knowledge) should be able to develop this kind of service relatively quickly. Once developed, such a service should be able to be used in many real courses, thus bringing the power of adaptive hypermedia to thousands of students.

An AH Service like QuizGuide and NavEx is a new entity in e-Learning technology. So far, almost all researchers and practitioners in e-Learning have only considered two major kind of entities – LMS and reusable content (residing in content repositories). Some projects have also considered non-adaptive services. Can we fit these adaptive services into modern e-Learning? If we recognize that reusable content can also be an interactive and adaptive content delivered from a content server, then an adaptive service is a natural add-on to e-Learning. For an LMS, it looks like any other adaptive content (as we have explained, the teacher can connect the whole service just like a single fragment of interactive content). At the same time, from the content side, the service looks like an LMS that can call and serve the content. Thus, AH Services can simply use established protocols that exist between LMS and content. This is exactly the method we have used to integrate our services into the KnowledgeTree architecture. Any portal and any content server that understands KnowledgeTree protocols can also be used with adaptive services. AH Services can be developed for any other distributed architecture that has a communication protocol between LMS and its adaptive interactive content. In particular, SCORM [1; 2] and CMI [16] standards come very close to this requirement. They allow an LMS to communicate with advanced interactive content. However, due to the rather primitive treatment of student modeling in these standards [6], the development of an adaptive service based on CMI and SCORM is difficult, as has been shown by [10]. We hope that our work with KnowledgeTree and adaptive services will contribute to developing more powerful standards for the future.

477

References

[1] ADLI: Sharable Content Object Reference Model (SCORM), Advanced Distributed Learning Initiative (2003) available online at http://www.adlnet.org/

[2] ADLI: Overview of SCORM 2004, Advanced Distributed Learning Initiative (2004) available online at http://www.adlnet.org/screens/shares/dsp_displayfile.cfm?fileid=992

[3] Blackboard Inc.: Blackboard Course Management System, Blackboard Inc. (2002) available online at http://www.blackboard.com/

[4] Brusilovsky, P.: WebEx: Learning from examples in a programming course. In: Fowler, W. and Hasebrook, J. (eds.) Proc. of WebNet'2001, World Conference of the WWW and Internet, Orlando, FL, AACE (2001) 124-129

[5] Brusilovsky, P.: Developing Adaptive Educational Hypermedia Systems: From Design Models to Authoring Tools. In: Murray, T., Blessing, S. and Ainsworth, S. (eds.): Authoring Tools for Advanced Technology Learning Environments: Toward cost-effective adaptive, interactive, and intelligent educational software. Ablex, Norwood (2003) 377-409

[6] Brusilovsky, P.: KnowledgeTree: A Distributed Architecture for Adaptive E-Learning. In: Proc. of The Thirteenth International World Wide Web Conference, WWW 2004 (Alternate track papers and posters), New York, NY, ACM Press (2004) 104-113

[7] Brusilovsky, P., Eklund, J., and Schwarz, E.:Web-based education for all: A tool for developing adaptive courseware. Computer Networks and ISDN Systems. 3Ɵ 1-7 (1998) 291-300

[8] Brusilovsky, P. and Miller, P.: Course Delivery Systems for the Virtual University. In: Tschang, T. and Della Senta, T. (eds.): Access to Knowledge: New Information Technologies and the Emergence of the Virtual University. Elsevier Science, Amsterdam (2001) 167-206.

[9] Brusilovsky, P. and Vassileva, J.: Course sequencing techniques for large-scale web-based education. International Journal of Continuing Engineering Education and Lifelong Learning 13, 1/2 (2003) 75-94

[10] Conlan, O., Wade, V., Bruen, C., and Gargan, M.: Multi-model, metadata-driven approach to adaptive hypermedia services for personalized eLearning. In: De Bra, P., Brusilovsky, P. and Conejo, R. (eds.) Proc. of Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'2002), Málaga, Spain (2002) 100-111

[11] Conlan, O., Wade, V., Gargan, M., Hockemeyer, C., and Albert, D.: An architecture for integrating adaptive hypermedia services with open learning environments. In: Barker, P. and Rebelsky, S. (eds.) Proc. of ED-MEDIA'2002 - World Conference on Educational Multimedia, Hypermedia and Telecommunications, Denver, CO, AACE (2002) 344-350

[12] Dagger, D., Conlan, O., and Wade, V. P.: An architecture for candidacy in adaptive eLearning systems to facilitate the reuse of learning Resources. In: Rossett, A. (ed.) Proc. of World Conference on E-Learning, E-Learn 2003, Phoenix, AZ, USA, AACE (2003) 49-56

[13] De Bra, P.: Teaching Through Adaptive Hypertext on the WWW. International Journal of Educational Telecommunications 3, 2/3 (1997) 163-180

[14] De Bra, P. and Calvi, L.: AHA! An open Adaptive Hypermedia Architecture. The New Review of Hypermedia and Multimedia 4 (1998) 115-139

[15] Henze, N. and Nejdl, W.: Extendible adaptive hypermedia courseware: Integrating
      different courses and Web material. In: Brusilovsky, P., Stock, O. and Strapparava, C.
      (eds.) Adaptive Hypermedia and Adaptive Web-Based Systems. Lecture Notes in
      Computer Science, Springer-Verlag, Berlin (2000) 109-120

[16] IEEE LTCS WG11: The Semantic Document v3.4, Computer Managed Instruction
      Working Group of the IEEE Learning Technology Standards Committee (2001)
      available online at http://ltsc.ieee.org/wg11/index.html

[17] Sosnovsky, S., Shcherbinina, O., and Brusilovsky, P.: Web-based parameterized
      questions as a tool for learning. In: Rossett, A. (ed.) Proc. of World Conference on E-
      Learning, E-Learn 2003, Phoenix, AZ, USA, AACE (2003) 309-316

[18] Specht, M., Kravcik, M., Klemke, R., Pesin, L., and Hüttenhain, R.: Adaptive Learning
      Environment (ALE) for Teaching and Learning in WINDS. In: Lecture Notes in
      Computer Science, Vol. 2347. Springer-Verlag, Berlin (2002) 572-581

[19] Wade, V.: Dynamic adaptive composition of adaptible Web services. Eindhoven
      University of Technology, Budapest, Hungary (2003) 53-62

[20] WebCT: WebCT Course Management System, Lynnfield, MA, WebCT, Inc. (2002)
      available online at http://www.webct.com

[21] Weber, G. and Brusilovsky, P.: ELM-ART: An adaptive versatile system for Web-based
      instruction. International Journal of Artificial Intelligence in Education 12, 4 (2001)
      351-384, available online at http://cbl.leeds.ac.uk/ijaied/abstracts/Vol_12/weber.html

[22] Weber, G., Kuhl, H.-C., and Weibelzahl, S.: Developing adaptive internet based courses
      with the authoring system NetCoach. In: Bra, P. D., Brusilovsky, P. and Kobsa, A.
      (eds.) Proc. of Third workshop on Adaptive Hypertext and Hypermedia, Sonthofen,
      Germany, Technical University Eindhoven (2001) 35-48, available online at
      http://wwwis.win.tue.nl/ah2001/papers/GWeber-UM01.pdf

479

Ontology-driven composition of service-oriented ubiquitous computing applications

Eleni Christopoulou and Achilles Kameas

Research Academic Computer Technology Institute, Research Unit 3, Design of Ambient
Intelligent Systems Group, 61 Riga Feraiou str. 26221, Patras, Greece
{hristope, kameas}@cti.gr

Abstract. The vision of Ambient Intelligence (AmI) implies a seamless
environment of computing, advanced networking technology and specific
interfaces. Technology becomes embedded in everyday objects and
environments such as furniture, clothes, vehicles, roads and smart materials,
and people are provided with the tools and the processes that are necessary in
order to achieve relaxing interactions with this environment. The AmI
environment can be considered to host several Ubiquitous Computing
(UbiComp) applications; a UbiComp application can be considered as a result
of the dynamic, ad-hoc composition of the services offered by the AmI
environment and the objects therein. Key features of such applications are
context-aware operation and emergent collective functionality. To achieve
these, among others, one has to deal with heterogeneity and support adaptive
composition and use. To do this, we propose to employ knowledge
management and decision making techniques. As a first step, we present in this
paper a service ontology and the management mechanisms we have developed
in order to enable AmI artifacts to apply a common world model and a set of
procedures that implement the composition of service-oriented UbiComp
applications.

1 Introduction

The vision of Ambient Intelligence (AmI) implies a seamless environment of
computing, advanced networking technology and specific interfaces [5] [8].
Technology becomes embedded in everyday objects and environments such as
furniture, clothes, vehicles, roads and smart materials, and people are provided with
the tools and the processes that are necessary in order to achieve relaxing interactions
with this environment. The AmI environment can be considered to host several
Ubiquitous Computing (UbiComp) applications; a UbiComp application can be
considered as a result of the dynamic, ad-hoc composition of the services offered by
the AmI environment and the objects therein.

Every new technology is manifested with objects that realize it; these objects may
be new or improved versions of existing ones, which by using the new technology,
allow people to carry out new tasks or old tasks in new and better ways. An important
characteristic of AmI environments is the merging of physical and digital space (i.e.
tangible objects and physical environments are acquiring a digital representation). The

term "artifacts" is used for the objects in AmI environments that are augmented by adding to them sensing, computation and communication abilities.

The AmI artifacts differ from traditional objects in a number of properties and abilities. Specifically artifacts can communicate with other artifacts and can interact with the environment. Of special interest is the information that artifacts process, which can be descriptions of the context of use, data to be used for a task, guidelines on how to perform a task, messages to be sent or that have been received from other artifacts. The result of information processing is a set of services, that is, a set of abilities that appear in the digital space and relate to information.

Traditional objects have physical characteristics; mechanical ones also have capabilities, which describe the tasks they can do. The concept "affordance" describes the relationship between objects and the tasks that can be performed with them [7]. The artifacts possess two new affordances with respect to objects. The first one is the composeability; artifacts can be used as building blocks of larger and more complex systems. This is a consequence of them possessing a communication unit and requires universal descriptions of tasks and services. The second one is the changeability; artifacts that possess or have access to digital storage can change the digital services they offer. This means that the tangible object can be partially disassociated from the artifact's digital services, as they are based on the manipulation of information. Both these affordances are result of the ability to produce descriptions of abilities, services and properties, which carry information about the artifact in the digital space. This ability improves object - service independence, as an artifact that acts as a service consumer may seek a service producer based on a service and not artifact description.

According to our approach the artifacts are treated as components of the UbiComp applications and offer a set of services. The composition of UbiComp applications can be based on the artifacts' services. The target of this paper is to show that an ontology can accommodate the issues that emerge during the composition of service-oriented UbiComp applications and present the ontology that we developed for this reason.

The rest of the paper is organised as follows. Section 2 describes the composition of service-oriented UbiComp applications, the key issues that arise during this procedure and how an ontology can be used to accommodate them. In section 3 is presented the ontology that was developed accentuating on the representation of services offered by the artifacts. Section 4 through examples depicts the ontology-driven composition and deployment of service-oriented UbiComp applications. Section 5 targets to present how adaptive hypermedia techniques can be applied to UbiComp applications. In section 6 related approaches are presented. The paper closes with the conclusion and an outlook on future work in section 7.

2 Key issues in service-oriented UbiComp applications

In UbiComp environments artifacts have properties, like physical characteristics and sensors/actuators, which take values. These values determine an artifact's state at a moment in time. The properties' values can change because of an event; so events cause the change of an artifact's state. In proportion to the state of an artifact a set of services is activated. The services that an artifact offers support the artifact's usage,

on the other hand the artifact' usages utilize the artifact's services. The services that an artifact can offer are determined by its physical and digital properties. A service can be seen as the publication of the state and properties' values of an artifact.

The Gadgetware Architectural Style (GAS) is a framework that supports the composition of UbiComp applications by treating the artifacts as components that offer services. The UbiComp applications are dynamic, distinguishable, functional and adaptive (re)configurations of associated artifacts, which communicate and/or collaborate in order to realize a collective behavior. Each artifact makes visible its properties, capabilities and services through specific interfaces (we'll sometimes use the term "Plugs"); an association between two compatible interfaces is called a "Synapse". The associations among the artifacts that users set depend on the services that artifacts offer and request and their compatibility. The (re)configuration of associations among the artifacts will enable users to set up their living spaces in a way that will serve them best. During the composition of UbiComp applications by associating the artifacts' services, a number of key issues that must be addressed arise. The descriptions of these issues follow.

2.1 Semantic interoperability

The composition of service-oriented UbiComp applications is based on the interaction and collaboration of both artifacts and services. A key issue of the artifacts and the services that they offer is their heterogeneity. So the challenge that we have to handle is the semantic interoperability among heterogeneous artifacts and heterogeneous services. In order to address the heterogeneity of artifacts we chose to base the interaction among artifacts on well-defined and commonly understood concepts, so as to enable a consistent and unambiguous communication. The common language that the artifacts have to use for their communication is represented by an ontology. The ontology that we developed is the GAS Ontology and its first goal was the description of the semantics of the basic terms of the UbiComp applications, such as eGadget (our term for artifact), Plug, Synapse, eGadgetWorld (our term for UbiComp application), and the definition of their interrelations. On the other hand in order to address the heterogeneity of services we first defined a semantic representation of the concept Service and then we designed a classification of a set of services based on common properties and characteristics.

2.2 Dynamic nature of UbiComp applications

One of the most important features of UbiComp applications is that they are created in a dynamic way. Users in order to create UbiComp applications have to select the necessary services and compose them consistently. Through plugs users perceive the services offered by the artifacts and can create and delete synapses between two compatible plugs. The compatibility of two plugs is determined by several factors e.g. the type of their input/output and the service that they offer/request, that must be represented into a formal form. Note that the synapses provide to users the necessary abstraction for service composition.

The dynamic nature of UbiComp applications depends also on artifacts mobility and failure that can cause the disestablishment of a synapse. In order to address artifacts' failures the UbiComp applications must be adaptive. A form of adaptivity is the automatic artifacts replacement. We selected to replace an artifact with another one that offers the same services. As this may be not feasible we decided to introduce the notion of "identicalness degree" between two artifacts. This degree depends on the services offered by two artifacts, their properties and their position into the proposed classification.

2.3 Context-awareness

An important issue of UbiComp applications is the context-awareness, as these applications must be able to perceive the current context and adapt their behavior to different situations. In UbiComp applications the term context is used to describe physical information, e.g. location and time, environmental information, e.g. weather and temperature, personal information, e.g. mood and activity. In our case, the term context refers to the physical properties of artifacts including their sensors/actuators and to their plugs that present services. Having described a service as the publication of an artifact's state and properties' values, the plugs provide context information. The user, by establishing synapses between plugs, both denotes his preferences and needs and defines the emerging behavior of the UbiComp application. Thus the UbiComp applications can demonstrate different behaviors even with the same context information depending on user preferences.

2.4 Adaptive services

In UbiComp applications the services provided to the users by the artifacts need to be adaptive to the changing requirements and needs of the users. Also they must be adaptive to changes of context information and fault tolerant. The possibility of adaptive service composition in a meaningful way is of special interest. The plug-synapse model that we use for the composition of service-oriented UbiComp applications supports service adaptivity. Initially this model captures users' needs, as users denote their preferences by establishing synapses. The plugs publicize context information, whereas the synapses represent artifacts' behavior dependent on context. One of the most important features of the plug-synapse model is that it provides users with an abstraction for service composition. Users have only to select the services that they want and combine them setting a synapse. The check for plugs compatibility secures the consistent service composition.

2.5 Semantic service discovery

The concept of service is fundamental, as the composition of UbiComp application depends on services. Users select the services that they want and form synapses seeking to achieve certain service configurations. Furthermore the services determine

both artifacts' replaceability and plugs' compatibility. Thus the need for a service discovery mechanism is evident. A semantic service discovery mechanism is preferable in order to discovery the semantically similar services. This mechanism can be supported by the service classification that we designed and represented into an ontology.

3 An ontology for service-oriented UbiComp applications

The ontology that we developed in order to address the aforementioned issues in service-oriented UbiComp applications is the GAS Ontology [3] and is written in DAML+OIL. The basic goal of this ontology is to provide the necessary common language for the artifacts and services collaboration.

The artifacts' ontology contains the description of the basic concepts of UbiComp applications and their inter-relations; for the feasible collaboration of artifacts this knowledge must be common. On the other hand an artifact's ontology should both describe the way that the artifact is used and represent its acquired knowledge; this knowledge cannot be the same for all artifacts. So artifacts may end up having different ontologies. Since artifacts' collaboration is designed to be ontology-driven, the existence of different ontologies could result to inefficient interoperability. The solution that we propose allows each artifact to have a different ontology with the condition that all ontologies will be based on a common vocabulary. Specifically the GAS Ontology is divided into two layers: the GAS Core Ontology (GAS-CO); that contains the common vocabulary, and the GAS Higher Ontology (GAS-HO); that represents artifact's specific knowledge. Thus, all artifacts represent their different knowledge with common concepts.

3.1 The GAS Core Ontology (GAS-CO)

The GAS-CO represents the common language that artifacts use to communicate, so it must describe the semantics of the basic terms of UbiComp applications and define their inter-relations. It must also contain the service classification necessary for the service discovery mechanism. Note that it contains only the necessary information for the interoperability of artifacts in order to be very small and even artifacts with limited memory capacity may store it. The GAS-CO is static and it cannot be changed either from the manufacturer of an artifact or from a user. The graphical representation of the GAS-CO is on Figure 1.

The core term of GAS is the eGadget (eGt). In GAS-CO the eGt is represented as a class, which has a number of properties, like name etc. The notion of plug is represented in the GAS-CO as another class, which is divided into two disjoint subclasses; the TPlug and the SPlug. The TPlug describes the physical properties of the object that is used as an artifact like its shape; note that there is a cardinality restriction that an artifact must have exactly one TPlug. On the other hand an SPlug represents the artifact capabilities and services; artifacts have an arbitrary number of SPlugs. Another GAS-CO class is the synapse that represents a synapse among two plugs; a synapse may only appear among two SPlugs. Using the class of eGW the

GAS-CO can describe the UbiComp applications that are created by the users; an eGW is represented by the artifacts that contains and the synapses that compose it. The class of eGW has two cardinality constraints; an eGW must contain at least two artifacts and a synapse must exist between their SPlugs.
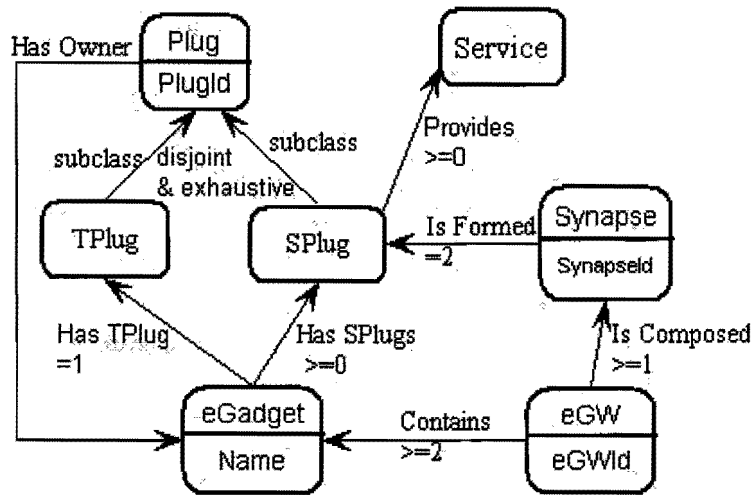

Fig. 1. A graphical representation of GAS-CO

3.2   The service classification

In order to define a service classification we first identified some services that various artifacts may offer; some results of this work are presented in Table 1. From these results it is clear that the services offered by artifacts depend on artifacts' physical characteristics and their sensors/actuators. The quality of services depends heavily on the placement of sensors/actuators at the artifact, e.g. if a weight sensor is placed on the left upper corner of an eCarpet and the user puts an eBook on the right down corner then the eCarpet will not perceive it.

Table 1. Services offered by artifacts

Artifact	Offered services
eLamp	switch on/off, light, heat
eBook	open/close, number of pages, current page
eDrawer	contains objects yes/no, number of objects, open/close, locked/unlocked
eMusicPlayer	sound, sound volume,, kind of music, play/pause/stop, next/previous track
eCarpet	object on it yes/no, objects' position, pressure, weight, frequency

485

Next we had to decide how we should classify the services. The classification proposals that we elaborated are the following: by object category, by human senses and based on the signals that artifacts' sensors/actuators can perceive/transmit. We decided to combine these proposals so that to describe a more complete classification.

So we initially defined the following elementary forms of signals that are used: sonic, optic, thermal, electromagnetic, gravity and kinetic. These concepts are divided into lower level services (subclasses); e.g. the sonic service may be music, speech, environmental sound, and noise. Additionally services may have a set of properties; e.g. sonic can have as properties the volume, the balance, the duration, the tone, etc.

Finally we enriched this classification by adding services relevant to environmental information, like humidity and temperature, and the concepts of time, position and movement.

3.3 The GAS Higher Ontology (GAS-HO)

The GAS-HO represents both the description of an artifact and its acquired knowledge; these descriptions follow the concepts defined in the GAS-CO. This means that the knowledge stored into the GAS-HO is represented as instances of the classes defined into the GAS-CO. Note that the GAS-HO is not a stand-alone ontology, as it does not contain the definition of the concepts that it uses, and its size doesn't need to be very small and depends only on artifact's memory capacity.

The information into GAS-HO is not static and it can be changed over time without causing problems to artifacts collaboration. As the GAS-HO contains both static information about the artifact and dynamic information emerged from its knowledge and use, we decided to divide it into the GAS-HO-static and the GAS-HO-volatile. The GAS-HO-static represents the description of an artifact containing information about artifact's plugs, the services that are provided through these plugs, its sensors and actuators, as well as its physical characteristics. On the other hand the GAS-HO-volatile contains information derived from the artifact's acquired knowledge and its use, such as the description of the synapses which the artifact's plugs are connected to and information about the services that other artifacts offer.

4 Ontology-driven composition of UbiComp applications

In this section we present an example of how we can use the GAS Ontology for the composition of service-oriented UbiComp applications. For the composition such applications artifacts must be GAS-compatible (use the GAS-Operating System [9]). The module that is responsible for the management of the GAS Ontology and supports the service discovery mechanism is the GAS Ontology manager [3]. The following example is based on the scenario, where a user creates its own "study" UbiComp application using two artifacts, an eBook and an eLamp.

The collaboration of these artifacts is feasible because both have stored the same GAS-CO. On the other hand the artifacts' GAS-HO ontologies are different. So eLamp's GAS-HO-static contains information about eLamp's plug "switch on/off" that offers a service type "light" and the eBook's GAS-HO-static contains the

description of plug "open/close" that reflects the book's state. The services that the artifacts offer can collaborate so these plugs are compatible allowing the user to establish a synapse between them. So when the user opens the eBook, the eLamp switches on, adjusting the light conditions to a specified luminosity level in order to satisfy the user's profile. The knowledge emerged from this synapse is stored in both artifacts' GAS-HO-volatiles. So the eBook "knows" that its plug "open/close" participates to a synapse with a plug that provides the service "light" with specific attributes e.g. luminosity.

If this synapse is broken e.g. because of a failure at the eLamp, a new artifact that offers a service type "light" must be found. The eBook's GAS-OS in order to find such an artifact sends a message for service discovery to the other artifacts that participate to the same UbiComp application. This type of message is predefined and contains the type of the requested service and the service's attributes. So an artifact may query just for a specific type of service or for a service with specific attributes. The GAS Ontology manager uses the service classification represented into the common GAS-CO of artifacts in order to find the artifacts that offer a similar semantically service with the one requested.

As the context information that is used in the UbiComp applications describes the physical and digital properties of artifacts, it is represented into both the GAS-CO and each artifact's GAS-HO-static. The GAS-HO-volatile of artifacts contains mainly knowledge emerged from the synapses that compose an UbiComp application. So this information represents the artifacts' behavior when they get context information through their synapses; these behaviors are defined by the user of the UbiComp application. As the GAS Ontology contains both context information and the description of the behaviors in proportion to context, provides the UbiComp applications with context-awareness.

5 Applying adaptive hypermedia techniques to UbiComp applications

Before presenting how adaptive hypermedia techniques can be applied to UbiComp application, we give an answer to the question: what can be adapted in UbiComp applications? Considering the UbiComp applications as dynamic (re)configurations of associated artifacts, few things can be adapted into these applications. First of all, the artifacts that take part in a UbiComp application can be adapted based on the user's profile and his preferences. Additionally, the properties, capabilities and services that each artifact makes visible through specific interfaces can be adapted to the user's needs and experience. The associations among artifacts can also be adapted based on the services that the artifacts offer and their similarity.

For the composition and deployment of an adaptive UbiComp application a critical issue is the user modeling; the representation and storage of the user profile. One significant difference between UbiComp and web-based applications is that the former are developed by the end-user. So at UbiComp applications it is not desirable to ask the user to provide to the system knowledge about its preferences, experience and goals. Though, this knowledge is necessary in order to provide an environment

487

adaptive to users' needs. In our approach users (dis)establish synapses between plugs and combine services in order to compose a UbiComp application. So a user denotes his preferences through the plug-synapse model. Also our system using a "fuzzy-logic agent" [6] tries to "learn" a user's profile so that to adapt the environment to his needs.

In hypermedia adaptation content-level and link-level adaptation is distinguished as two different classes, the adaptive presentation and the adaptive navigation [1]. For the composition of UbiComp application we have taken into account some methods of content adaptation. In the AmI environment various artifacts exist that offer numerous services. When a user composes a UbiComp application, selects a set of artifacts and sets specific service combinations. So during the deployment of this application the user gets information relevant only to this application. Specifically since the user selects the artifacts that he wants to use, he can view the services' and capabilities' descriptions of only these artifacts. Additionally, our framework can support the presentation to the user of a text-based explanation of the artifacts' usage and the functionality of their associations with other artifacts. Also, when users search for artifacts that offer a specific service, the system presents artifacts that offer semantically similar services.

The adaptive navigation in web-based systems attempts to guide the user through the system by customizing the link structure according to a user model. In UbiComp systems, the user needs an adaptive "mechanism" to guide him to compose a meaningful UbiComp application suitable to his profile. A kind of global guidance method that we use in our framework targets to inform the user about the artifacts that are available to him and their services as well as the service classification. A method of local guidance is the proposition to the user of semantically similar services that is supported by the service discovery mechanism and the service classification. The plug-synapse model provides a method of local orientation support; using this model our framework can show to the user the artifacts that he selected and the associations among them that he made.

6   Related work

Ontologies have been used in various infrastructures that support the composition of UbiComp systems. The UbiDev [10] is a homogeneous middleware that allows definition and coordination of services in interactive environment scenarios. In this middleware resource classification relies on a set of abstract concepts collected in an ontology and the meaning of these concepts is implicitly given by classifiers [14]. This approach is different than ours, because whereas they use an ontology for each application that includes several devices, our goal is to provide an ontology that drives the composition of various ad hoc UbiComp applications. Ontologies have also been used in the Smart Spaces framework GAIA [13] in order to address issues, such as the interoperability between different entities, the discovery and matching and the context-awareness [12]. The approach that the GAIA framework follows is fairly different to the one that we have proposed for the eGadgets project; an ontology server is used that maintains various ontologies. Another approach is the COBRA-

ONT [2], an ontology for context-aware pervasive computing environments. The Task Computing Environment [11] was implemented in order to support the task computing that fills the gap between what users really want to do and the capabilities of devices and/or services that might be available in their environments. This approach is fairly different to ours, since they use the OWL-S so that to describe the Web services and the services offered by the devices. An approach for applying adaptive hypermedia techniques to the composition of semantic web services is presented in [4]. Finally a very interesting work is the one made by the Semantic Web in UbiComp Special Interest Group [15]. The basic goal of this group is to define an ontology to support knowledge representation and communication interoperability in building pervasive computing applications. This project's goal is to construct a set of generic ontologies that allow developers to define vocabularies for their individual applications.

7 Conclusions and Future work

In this paper we presented how the composition of UbiComp applications can be based on artifacts' services, described the ontology that supports this composition and gave examples of deploying such applications. We described a service classification that assists a service discovery mechanism and presented how adaptive hypermedia techniques can be applied to UbiComp applications. The research presented in this paper has been carried out during the eGadgets project, a research project funded in the context of EU IST/FET proactive initiative "Disappearing Computer".

One of our imminent goals is to eliminate the limitation of the current version of the GAS Ontology that all artifacts have the same service classification, by adding to GAS Ontology manager the capability to map a service description to another one. Also we intent to use a set of methods in order to represent, acquire and refine the user model. Finally one of our targets is to develop the necessary mechanism in order to handle the existence of various users' profiles into the same UbiComp application.

References

1. Brusilovsky, P., 1996. "Methods and techniques of adaptive hypermedia", In P. Brusilovsky and J. Vassileva (eds.), Special Issue on Adaptive Hypertext and Hypermedia, User Modeling and User Adapted Interaction v. 6 n. 2-3, pp 87-129.
2. Chen, H., Finin, T., Joshi, A., 2004. An ontology for context aware pervasive computing environments, To appear, Knowledge Engineering Review - Special Issue on Ontologies for Distributed Systems, Cambridge University Press.
3. Christopoulou, E., Kameas, A., 2004. GAS Ontology: an ontology for collaboration among ubiquitous computing devices, To appear in Protégé special issue of the International Journal of Human – Computer Studies.
4. Conlan, O., Power, R., Barrett, K., Higel, S., O'Sullivan, D., 2003. "Next Generation Context Aware Adaptive Services", International Symposium on Information and Communication Technologies (ISICT 2003), Dublin.
5. Disappearing Computer initiative website http://www.disappearing-computer.net/

6. extrovert-Gadgets project website http://www.extrovert-gadgets.net
7. Gibson, J. J., 1979. "The Mifflin".
8. ISTAG website http://www.cordis.lu/ist/istag.htm
9. Kameas, A., Bellis, S., Mavrommati, I., Delaney, K., Colley, M., Pounds-Cornish, A., 2003. An Architecture that Treats Everyday Objects as Communicating Tangible Components. In Proceedings of the 1st IEEE International conference on Pervasive Computing and Communications (PerCom03). Forth Worth, USA
10. Maffioletti, S., Hirsbrunner, B., 2002. UbiDev: A Homogeneous Environment for Ubiquitous Interactive Devices. Short paper in Pervasive 2002 - International Conference on Pervasive Computing. pp. 28-40. Zurich, Switzerland.
11. Masuoka, R., Labrou, Y., Parsia, B., Sirin, E., Ontology-Enables Pervasive Computing Applications, IEEE Intelligent Systems, Sept/Oct 2003, pp 68-72.
12. Ranganathan, A., Campbell, R., 2003. A Middleware for Context-Aware Agents in Ubiquitous Computing Environments. In ACM/IFIP/USENIX International Middleware Conference, Rio de Janeiro, Brazil.
13. Ranganathan, A., McGrath, R., Campbell, R., Mickunas, D., 2003. Ontologies in a Pervasive Computing Environment. Workshop on Ontologies in Distributed Systems at IJCAI, Acapulco, Mexico.
14. Schubiger, S., Maffioletti, S., Tafat-Bouzid, A., Hirsbrunner, B., 2000. Providing Service in a Changing Ubiquitous Computing Environment. Proceedings of the Workshop on Infrastructure for Smart Devices - How to Make Ubiquity an Actuality, HUC.
15. Semantic Web in UbiComp Special Interest Group. http://pervasive.semanticweb.org

Adaptive Knowledge Services Based on Grid Architecture

Cord Hockemeyer[1], Dietrich Albert[1], Luca Stefanutti[2], David Lewis[3], and
Owen Conlan[3]

[1] University of Graz, Austria
[2] University of Padova, Italy
[3] Trinity College, Dublin

Abstract. Grid Technology has proven to be a suitable means for the
efficient sharing of various resources within a well–defined community.
The EC–funded projects LeGE–WG and e–LeGI have set out to apply
this technology for technology enhanced learning services. Previously, the
applicability of distributed skill maps for adaptive e–Learning within a
grid network has been discussed. In this paper, we propose a further ex-
tension of that idea to be applied for personalised knowledge and skill
management and human resource selection and development. This exten-
sion combines the flexibility of GRID as a service oriented environment,
capable of delivering both adaptive services, and a content distribution
network, suitable for delivering learning content.

1 Introduction

Over the recent years, grid technology has evolved as a powerful infrastructure
for application service provision. While the original aim was to share computing
resources for high performance computing tasks, the focus has shifted towards
more general application provision and data sharing in the meantime (see, e. g.
[1]). This is also reflected in the development of respective specifications, e. g.
the Open Grid Services Architecture (OGSA) specifications[4].

The e–LeGI and LeGE–WG R & D projects[5] aim at Progressing from the
original applying grid technology for e–Learning in a human–centered manner.
This includes especially an adaptation of the services to the individual learners
and their needs.

One way to achieve adaptivity in e–Learning is the use of prerequisite struc-
tures in order to adapt navigation in respective hypertexts to the learner's cur-
rent knowledge [2]. Distinguishing between concrete learning objects and the
rather abstract concepts or competencies taught therein supports adaptivity in
dynamic courses [3, 4]. Ideas for realising these concepts in a grid context have
been discussed [5, 6].

---

[4] See https://forge.gridforum.org/projects/arch.
[5] See http://www.lege-we.org.

The distinction between concrete objects and latent competencies also opens a door to other applications, namely in the area of knowledge management and human resource (HR) management. In the sequel, we will focus on how these applications might be used in a grid environment.

2 The Grid as an Application Service Environment

Progressing from the provision of computing power to the provision of general application services, new and more open standards for the interoperability of Grids are currently developed. The basic idea is that of a *virtual organisation* (VO) consisting of several persons or institutions who share the access to services provided by some member of the VO, e.g. data, programs and services, or physical resources.

Increasingly there is a movement to adopt such a virtual organisation approach to the delivery of higher education. Within Europe the EU Bologna objectives [19] has spurred studies into virtual campuses, where European universities collaborate in developing content, delivering eLearning services and collaboratively offering courses. In such a virtual campus a student at one institute may take a course that consists of modules offered by different institutes reflecting their respective local expertise in the module content. Technology enhanced learning in a virtual campus required making eLearning service available over the web to suitably registered students at other institutes. These services will offer access to eLearning content, opportunities to interact with tutors in remote institutes who are experts in this content area and even interacting with students studying the same content in other institutes, e. g. for attempting group exercises. Such a virtual campus must support interaction between organisations at three levels:

1. Exchange of services, where lecturers or students form one institute have authorised and accounted access to web services at another
2. Exchange of content, where courses offered at one institute reuse conceptual learning concepts originating from another, but adapted to a different course structure and to pedagogical, cultural, institutional and linguistic norms.
3. Exchange of knowledge, where the human capital on one institute is made available in others, for instance tutors who are expert in particular conceptual content or researchers expert in a specific experimental technique needed in a dissertation project.

This paper outlines how GRID technology can form the backbone for such virtual campus interactions.

The basis of Grid services then consists of two essential elements, (i) the technological Grid infrastructure and (ii) mechanisms for offering, discovering, and using the services within this infrastructure. While there exist also other, more proprietary approaches, we will in the sequel restrict to the case of a web service based Grid.

2.1 The Technological Grid Infrastructure

By *technological Grid infrastructure* we denote the rather general Grid concept of providing access to other Grid members' resources:

- Users need a seamless access to Grid services, i.e. once they are authorised to use the Grid their user/institution information has to be passed on to any other host in the Grid where they want to use resources without any further re–authentication requests.
- The technological infrastructure also has to take care of the members' rights, i.e. based on the information specified by each provider for each of their resources, usage costs have to be billed automatically to the using member. This may, of course, include that a user is informed about and asked for confirmation for taking over such costs.

As a result, we obtain an architecture as sketched in Fig. 1. This architecture reflects an interpretation of all resources available in the Grid as services [7]. On the network side, the architecture is based on the TCP/IP protocol family
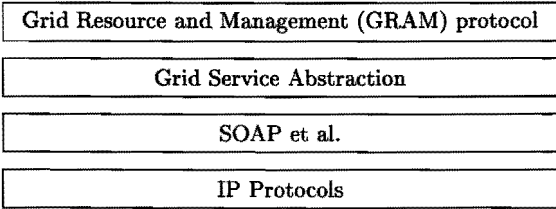
Grid Resource and Management (GRAM) protocol
Grid Service Abstraction
SOAP et al.
IP Protocols

Fig. 1. Simplified architecture for the technological Grid infrastructure

including the HTTP protocol. Based on this fundamental network infrastructure, all Grid related communication is done through the SOAP protocol (in case of a non–proprietary solution). The Grid service abstraction then provides the interpretation of all different types of resources as a service. Finally, the GRAM protocol (Grid resource and management) provides the request of and access to the services.

2.2 Mechanisms for Offering and Discovering Grid Services

Besides the technical infrastructure, there is another fundamental issue in Grid service provision, i.-e. offering, discovering, and using the services. While originally Grid specific functionalities had been planned (OGSI: Open Grid Services Infrastructure), more recent developments go towards applying open standards for web services. We will refer to three central standards which are all XML based:

1. The SOAP protocol provides mechanisms for the communication between machines, e. g. for sending data to be processed to the requested service and for sending back the results [8].
2. The web service description language (WSDL) allows for the description of web services, i. e. while SOAP defines how to exchange the data, WSDL describes what type of data are requested and/or delivered by a certain web service [9].
3. The web services inspection language (WSIL) supports the discovery and the construction of new services from existing services. WSIL records contain basically references to one or more WSIL and/or WSDL records [10]. Although this language is not part of the W3C web services protocol suite it may be very helpful in deploying web services.

3 Knowledge Management Based on Grid Technology and Knowledge Prerequisite Structures

Some current EC–funded R&D projects[6] investigate the application of Grid technology to technology enhanced learning (TeLearning). Our own work in this area focuses on integrating adaptive TeLearning based on knowledge prerequisite structure with the Grid approach [5].

On the other side, these knowledge prerequisite structures can well be used beyond TeLearning, e. g. in knowledge and skill management [11]. After a brief introduction into knowledge prerequisite structures and their use in TeLearning, we will discuss the broader application in knowledge management.

3.1 Knowledge Prerequisite Structures

Doignon and Falmagne have developed the theory of *knowledge spaces* originally aiming at the adaptive assessment of people's knowledge [12, 13]. They structure a set Q of test items by a *surmise relation* in the sense that, from a person being able to solve an item a correctly, it can be surmised that this person will also be able to solve another item b correctly. If we define the *knowledge state* of a person as the subset of items this person can solve, the set of possible knowledge states (called *knowledge space*) is restricted by the surmise relation. In fact, in most domains of knowledge, the knowledge space will be much smaller than the power set of Q, i. e. the set of all subsets of items. Such a structure allows for an adaptive assessment of knowledge by inferring, after a correct solution, that all prerequisites are also mastered or, after a wrong solution, that all those items are not mastered which have the current item as a prerequisite.

More recently, this model has been applied for adaptive TeLearning. Albert and Hockemeyer [2] have built the adaptive tutoring hypertext system RATH that limits the learners' navigation within a TeLearning hypertext by offering links only to those documents for which all necessary prerequisites are fulfilled by the individual learner.

---

[6] See, e. g., http://www.legewg.org/.

494

Albert et al. [14] have extended this theory by regarding not only the concrete test items but also the latent, underlying skills (or competencies) needed for finding the correct solution. This resembles the fact that we are normally less interested in the items a person can solve than in the competencies and skills this person has.

This extension has been applied by Conlan [3, 4] in the APeLS system. On the practical side, this separation of concrete learning objects and abstract competencies facilitates the system's adaption to changes in the course: While in the RATH system, changing or adding one document might well result in the necessity to change prerequisite links in many other documents, the APeLS system links the documents to the abstract competencies and, therefore, changes in one document do not require such changes in other places.

In addition to that, the APeLS system also marks the step forward from an adaptive server to an adaptive service. The user's learning environment can pass the user data directly to the APeLS service without any visible login request and, vice versa, results are passed back automatically to the learning environment. All communication with and about the APeLS service [15, 16] are done through standardised means like IEEE LOM [17] and ADL SCORM [18].

3.2   Adaptive TeLearning in the Grid

Proceeding from adaptive TeLearning to Grid–based knowledge services basically involves two steps, (i) going from adaptive services to Grid–based services. and (ii) going from TeLearning to knowledge management.

First ideas of using the Grid approach for adaptive TeLearning based on prerequisite structures have been given by Hockemeyer, Albert, and Stefanutti [5, 6]. If contents and their competence assignments are distributed over several servers, the system providing the adaptive service to the user and his environment cannot use a rather static map of these assignments any more but it has to work with and merge *distributed skill structures*. This means that the Grid has to provide the infrastructure to pull together quickly the distributed structure information which are then merged "on the fly" by the adaptive server. Please note, that such a distributed context makes the separation between concrete objects and abstract competencies or skill absolutely inevitable looking at the strongly increasing probability that some documents may be changed or added at some of the co–operating servers in the Grid.

3.3   Adaptive Knowledge Management in the Grid

There exist some close relationships between TeLearning and knowledge management within an organisation [7]. Talking about knowledge management, this contains, e. g.

---

[7] An adaptive TeLearning system may well be integrated with knowledge management by passing information about a learner's current knowledge at the beginning of a further education measure and, vice versa, by updating the database of the knowledge management system after an employee has finished an education activity.

- Intellectual capital reports of the organisation or sections thereof
- Composition of project groups based on the participants' knowledge and the project's needs
- Selection of new employees based on their knowledge and possible gaps in the organisation
- Selecting needs and appropriate measures for further education including the selection of suitable employees for such measures.
- Evaluation of employees

Applying the Grid technology for knowledge management would then be useful especially in the case of distributed organisations (the virtual organisations in Grid terminology may well coincide with real organisations distributed over many places). A Grid–based knowledge management system might then, e.g., support finding specialists from remote subsidiaries who can fill a gap in a local team with their competencies. Thus, it may become unnecessary to have local employees acquire that knowledge themselves if it is needed only rarely. Or, if an employee moves from one subsidiary to another, the information about their knowledge would immediately and seamlessly be available at the new place.

Applications of Grid–based knowledge management, however, are not limited within organisations. Job agencies (or companies offering casual employees) could share their data about specialists between each other and also with seeking companies.

4 Scenario

Section 2, The Grid as an Application Service Environment, indroduced the *virtual campus* scenario. Elaborating this scenario it is possible to envisage the formation of a new Masters Programme that is being developed jointly by a number of institutions that are geographically remote. The goal of this distributed development is to produce a highly focused, and possibly niche, Masters Programme that will leverage both the facilities and expertise of each of the institutions involved. In this scenario, or any that entails the formation of a *virtual organisation*, the principles of utilising GRID technologies described in this paper may be used. For example, an adaptive information service, accessed through GRID infrastructure, may provide a personalised course outline for an aspect of the Masters Programme. As described in Section 3.1, Knowledge Prerequisite Structures, this personlaised course may only be described conceptually, i. e. the actual learning content to teach the course has not been selected. Here, again, GRID can for the basis for delivering appropriate content. In this example GRID has been used as both a service delivery environment and a content distribution network.

With respect to Knowledge Management in GRID it is feasible to envisage a specialised Masters Programme involving tutor-tutee relationships, where the capacity to match tutors and tutees based on KM techniques provides a distintive added value. This is especially true in the case where the tutor and tutee

496

reside in geographically different areas. GRID could also be leveraged to provide appropriate collaboration services to support the relationship.

5 Conclusion

In this paper, we have discussed the applicability of Grid technology for adaptive services in general and especially for knowledge management and TeLearning. Through the scenario presented in Section 4 we presented a possible use case to illustrate how these adaptive services could utilise GRID as both a service oriented environment and a content distribution framework, thus facilitating the dissemination distributed knowledge. Through employing adaptive hypermedia mechanisms such as conceptual abstraction, as in APeLS, and prerequisite knowledge structures, as in RATH, as services available in a GRID environment rich adaptive experiences may be delivered to end users. The scenario also presents a model of learning that empowers the learner towards an *anytime–anywhere* learning paradigm.

Currently, however, many basic issues are still under discussion. For example, the open grid service architecture is still under development. Experiences from the e–LeGI project will be a useful source to evaluate the appropriateness of the Grid approach for adaptive hypermedia services in general.

Acknowledgements

References

1. Walker, D.W.: Emerging distributed computing technologies. Online available at http://www.cs.cf.ac.uk/User/David.W.Walker/IGDS/GridCourse.htm (2002) Downloaded May 30, 2004.
2. Hockemeyer, C., Held, T., Albert, D.: RATH — a relational adaptive tutoring hypertext WWW–environment based on knowledge space theory. In Alvegård, C., ed.: CALISCE'98: Proceedings of the Fourth International Conference on Computer Aided Learning in Science and Engineering, Göteborg, Sweden, Chalmers University of Technology (1998) 417–423
3. Conlan, O., Hockemeyer, C., Wade, V., Albert, D.: Metadata driven approaches to facilitate adaptivity in personalized eLearning systems. The Journal of Information and Systems in Education 1 (2002) 38–44
4. Hockemeyer, C., Conlan, O., Wade, V., Albert, D.: Applying competence prerequisite structures for eLearning and skill management. Journal of Universal Computer Science 9 (2003) 1428–1436
5. Hockemeyer, C., Albert, D.: Adaptive eLearning and the learning GRID. In Ritrovato, P., Salerno, S., Gaeta, M., eds.: 1st LEGE–WG International Workshop on Educational Models for GRID Based Services, Lausanne, Switzerland,

16 September 2002. Electronic Workshops in Computing (eWIC), Wiltshire, UK, British Computer Society (BCS) (2003)

6. Stefanutti, L., Albert, D., Hockemeyer, C.: Structuring and merging distributed content. In: 4th LeGE–WG International Workshop: Progressing with a European Learning Grid, Stuttgart, Germany, April 27–28, 2004. Electronic Workshops in Computing (eWIC), Wiltshire, UK, British Computer Society (BCS) (in press)

7. Foster, I., Kesselman, C., Nick, J.M., Tuecke, S.: The physiology of the grid: An open grid services architecture for distributed systems integration. Published online at http://www.globus.org/research/papers/ogsa.pdf (2002)

8. Gudgin, M., Hadley, M., Mendelsohn, N., Moreau, J.J., Nielsen, H.F.: SOAP: Simple object access protocol. W3C Technical Reports on SOAP, published online at http://www.w3.org/TR/soap/ (2004)

9. Christensen, E., Curbera, F., Meredith, G., Weerawarana, S.: WSDL: Web services definition language. W3C Technical Reports on WSDL, published online at http://www.w3.org/TR/wsdl/ (2004)

10. Brittenham, P.: An overview of the web services inspection language. Published online at http://www-106.ibm.com/developerworks/webservices/library/ws-wsilover/ (2002)

11. Ley, T., Albert, D.: Quality criteria for competency assignments: Examples from a project management case study. In: Proceedings of Informatik 2004, Gesellschaft für Informatik, Ulm, 2004. (to appear)

12. Doignon, J.P., Falmagne, J.C.: Spaces for the assessment of knowledge. International Journal of Man-Machine Studies **23** (1985) 175–196

13. Doignon, J.P., Falmagne, J.C.: Knowledge Spaces. Springer–Verlag, Berlin (1999)

14. Albert, D., Lukas, J., eds.: Knowledge Spaces: Theories, Empirical Research, Applications. Lawrence Erlbaum Associates, Mahwah, NJ (1999)

15. Conlan, O., Hockemeyer, C., Wade, V., Albert, D., Gargan, M.: An architecture for integrating adaptive hypermedia service with open learning environments. In: Proceedings of ED–MEDIA 2002. Volume 1 of World Conference on Educational Multimedia, Hypermedia, & Telecommunications. (2002) 344–350

16. Albert, D., Hockemeyer, C., Conlan, O., Wade, V.: Reusing adaptive learning resources. In et al., C.H.L., ed.: Proceedings of the International Conference on Computers in Education ICCE/SchoolNet2001. Volume 1. (2001) 205–210

17. IEEE Learning Technology Standards Committee (LTSC): Learning object metadata (LOM). Online available at http://ltsc.ieee.org/wg12/index.html (2003)

18. ADL Technical Team: Scorm: Sharable content object reference model. Published online at http://www.adlnet.org/index.cfm?fuseaction=scormabt (2004)

19. Bologna Declaration: The Bologna Declaration on the European space for higher education: an explanation. Published online at http://www.bologna-berlin2003.de/pdf/bologna_declaration.pdf

Utilizing Context in Adaptive Information Services for Pervasive Computing Environments

Ruaidhri Power, Declan O'Sullivan, Owen Conlan, Dave Lewis, Vincent Wade

Knowledge and Data Engineering Group
Trinity College, Dublin, Ireland
{Ruaidhri.Power, Declan.OSullivan, Owen.Conlan, Dave.Lewis,
Vincent.Wade}@cs.tcd.ie
http://kdeg.cs.tcd.ie

Abstract. Ubiquitous and pervasive computing environments have the potential to provide rich sources of information about a user and their surroundings. Such context information may form a basis upon which Adaptive Information Services may be adapted. However, the nature of context information means that it is usually gathered in an ad-hoc and distributed manner with many devices and sensors storing potentially relevant data. The reconciliation and reasoning across this information presents a research challenge, but has the possibility of yielding valuable insights about users. In an ad-hoc pervasive computing environment, determining context information cannot rely on a fixed meta-data schema. This work shows how an ontology driven context service architecture will perform distributed open schema queries over heterogeneous context sources in order to provide information service adaptation.

1 Introduction

The vision of pervasive computing is that computers will be integrated seamlessly into our daily lives. We already make much use of computers, however we can gain the most value from them when they are no longer things we interact with explicitly, but rather are blended into the background and assist us when needed [1]. In order to do this, pervasive computing environments must be able to collect a wide range of information and use this information to work with the user in order to achieve the user's goals. This information is termed context information, and its collection and management is termed context management.

Traditionally, Adaptive Information Services, such as Adaptive Hypermedia Systems [2] and personalized eLearning Services [3,4,5], have used a centrally stored and managed user/learner model as the basis for adaptation. These models tend to store pre-defined types of information and are built using explicit techniques, such as direct user querying, and implicit techniques, such as monitoring user interactions [6]. Context-based systems, however, provide a different approach to acquiring and storing modeling information. This approach, and more precisely the information model used, is more ad-hoc and potentially richer than the modeling techniques applied in most Adaptive Information Systems. The precise syntax and semantic descriptions of context information may not be known beforehand.

Our context management architecture uses an ontology-driven approach to bridge the heterogeneity of context information sources in pervasive computing systems. Ontologies are a technique for formally representing domain knowledge in an application independent way. Ontologies feature heavily in the Semantic Web initiative [7], which aims to provide ways of defining information so that it can be understood and processed by computers more easily. Examples of ontology languages are W3C's OWL[1], the Web ontology language and DARPA's DAML[2].

This paper describes the potential of context information when applied to Adaptive Information Services. Section 2 introduces context and the challenges that are involved in context management. Section 3 explores the potential for context to support Adaptive Systems and section 4 provides an overview of the context service architecture that we propose to support adaptive information services. Section 5 illustrates the architecture through exploration of an example scenario. Finally Section 6 presents conclusions and highlights future work.

2 Context in Pervasive Computing Environments

One of the realities that must be faced in context management is that there will not be a globally standard model for representing context information. Many current approaches [8] to context management advocate predefined models for context information, which applications interact with using middleware platforms for querying and manipulation. However, context data will come in many different forms, from many different sources. Any attempt to formally structure all potential context information would be difficult at best in a controlled situation, within one organization for example, but almost impossible in an inter-organizational scenario.

Context information for pervasive computing environments has particular characteristics, which provide challenges in undertaking context management. Firstly, the information that can compose the context of these environments is very broad, and can come from a variety of heterogeneous sources. A user's name, age, address, native language, current location and learning style could compose part of his context. Similarly, the people sharing a room with him or working in his office could be considered to be part of this context information, as could the current temperature and lighting conditions. Any system for context management must therefore be able to cope with information from a large variety of heterogeneous sources that will provide this information. Because almost any information could be considered context information from the point of view of some entity in a pervasive computing environment, there is very little information that we can discard as being irrelevant. Perhaps the most important characteristic of context information is that we cannot be entirely certain what information will be relevant in advance of constructing a system to manage this information. A useful solution to the problem of context management will therefore have a low impact on existing infrastructure, and cope well with heterogeneity. Such a system should also cope well with new forms of context information.

1 http://www.w3.org/TR/owl-guide/
2 http://www.daml.org/

500

The second challenging characteristic of context information in pervasive computing environments arises from the fact that the environment will consist of a highly dynamic collection of users and computing devices. These devices must seamlessly integrate with whatever computing environment they are presented with, so that their users can make most efficient use of them. In this environment a roaming user or device is the norm, rather than the exception. These environments frequently make use of temporary, ad hoc connections between devices to accomplish tasks. Therefore, context information systems must be able to dynamically discover and connect to information sources in order to extract data and manipulate it into relevant context knowledge. This frequently changing environment can lead to uncertainty: where gathered information can quickly become stale; services and devices can also suddenly become available or unavailable due to changes in connectivity.

Finally, these environments should present context information in terms that the user can relate to, in other words the information should be user centric. Context information will almost certainly be managed by the entity to whom that context information relates (for example a business or an ordinary individual), rather than being managed globally. This is due to a few factors: the sheer volume of data that will compose context will make a global view of all context information impossible. Privacy and security concerns will also prompt people to manage their own context information. Perhaps most importantly, the set of information that will compose this context is so dynamic that it will never be standardized, so mechanisms will have to be developed to promote interoperability between context systems. These mechanisms will translate context into a form where it can be understood by each organization's context system. This is particularly the case for roaming applications, where context information must be supplied and received for a roaming user or device to avail of services within another environment. A characteristic of a good solution will be that this information will be merged into each user's own view of the world, and redefined in terms that the user can understand.

3 The potential for Context in Adaptive Systems

This section outlines three important mechanisms for delivering service adaptivity for pervasive computing environments, namely service composition, policy-based management and adaptive hypermedia, and outlines how these might make use of context.

3.1 Service Composition

Pervasive computing environments will exhibit a large amount of heterogeneity in the components from which they are constructed. Any adaptive system supporting pervasive computing will therefore face major interoperability and integration challenges in combining the adaptivity of user services with adaptive resource management. There is increasing interest in automating the service composition process, so that the service offered to users appears to be adaptive [9]. In a pervasive computing environment, the automatic composition of service needs to be driven by both the task re-

501

quired by the user and the context in which the task is to be performed [10]. Ontological representations of context [11] can be used in automating the selection of existing services in a service composition using an ontological representation of the service. For instance, when composing wireless multimedia presentation services for wireless PDAs in particular location the video compression capabilities of candidate constituent video streaming services need to be compared to context information on the decoding capabilities of the PDA and the current capacity of the wireless link. Equally, context information may be used in accepting or rejecting plans for sub compositions during the planning process, by comparing it to the planned composite service properties.

3.2 Policy-based Management

Another adaptive technique, which is seeing increased deployment in managing the adaptive behavior of network and services, is policy-based management [12]. It uses expressive rule languages to determine behavioral rules for how a system should respond to predetermined events and system conditions. In pervasive computing environments, anyone entering the space may possess or use resources that may be shared. Policies provide a way of managing such ad hoc collections of resources, but need to employ flexible means of binding resources and policy subjects to rules at runtime [13]. As this requires matching terms in policy rules to ad hoc information, there is increasing interest in using ontologies for policy definitions [14], which in turn allows us to enforce of policy rules a run-time with ontology-based context information used for resolving events and conditions in a policy to equivalent event and condition in the pervasive computing environment.

3.3 Adaptive Hypermedia

Presentation-centric adaptive systems use explicit user models to tailor information to different users. Data is collected for the user model from various sources, e.g. contact lists, schedules, terminal capabilities, application usage histories, security, cost, navigational and presentational preferences. The user model is the basis of the adaptation effects, and thus in a pervasive computing environment it needs to be resolved against current contextual information. One area of strong research into personalized adaptive systems is Adaptive Hypermedia systems, which are typically applied to areas of learning, such as museum guides or eLearning. These offer an alternative to the traditional "one-size-fits-all" approach by employing user models that allow personalization in hypermedia systems. The benefits of such personalization include relevancy, reduced time to learn and improved retention and recall. We have already developed a sophisticated generic adaptive engine that has been applied successfully to personalized eLearning hypermedia [3], which we are now extending to support dynamic context information acquisition to populate the user model.

4 Proposed Architecture for Context Services

One of the driving forces behind the design for a context system proposed in this paper is to minimise the effort required to make a piece of software context aware. These software components will come in many forms, from the e-mail clients and office tools that are prevalent today, to tiny embedded operating systems with minimal processing power, to massive mainframe or cluster computers running large databases. For the purpose of this paper, any of these software components are referred to as applications. While this term may bring to mind today's software which is not context aware, throughout this paper it refers to any software component which wishes to make use of context information. These applications need to have easy access to more information about the environment in which they are operating, rather than being limited to the explicit input or information from hardwired data sources provided to current applications.

In our architecture, a 'context service' is the service provided to applications to make context information available to them. One role of a context service is to take queries from a context-aware client and to resolve those queries by acting as a mediator between the client and other information sources that the service has access to. As well as acting as consumers of context information (by executing queries), applications can also act as producers of context information by providing their context service with a description of the information they have available. If an application produces context information, a context service can advertise that information available to it to other context services.

An application can be designed as context-aware by defining an ontology that describes the domain of context information that the application is interested in querying, and also that it wants to make available to other applications. This ontology may be written from scratch, or it may be possible to reuse an existing ontology such as CoBrA-ONT [15]. This ontology is registered with the context service as belonging to the application, and is stored in the ontology repository.

The application developer has the option of providing mappings between concepts in the application's ontology and equivalent concepts in other ontologies used within the system. This is however not a requirement, as this step may be done at a later stage. If mappings are provided, they will be stored in the ontology mapping repository.

The internal architecture of a context-aware device is shown in Figure 1. Each box within the device represents an autonomous piece of software, with their interactions described by arrows. Starting from the bottom of the diagram, applications present queries to the context service. Each of these query messages contains the content of the query Q, a reference to the query language used L, and a reference to the ontology O that the query refers to. This query is taken by the context service which examines the query and ontology used. Combining these with mappings from the ontology mapping repository, the context service can then compose a new query that can be routed to other context services, which will attempt to return a corresponding result.

Any results that are returned are translated back from the ontology of the remote context service into the application's ontology before they are returned as a query response, **R**.
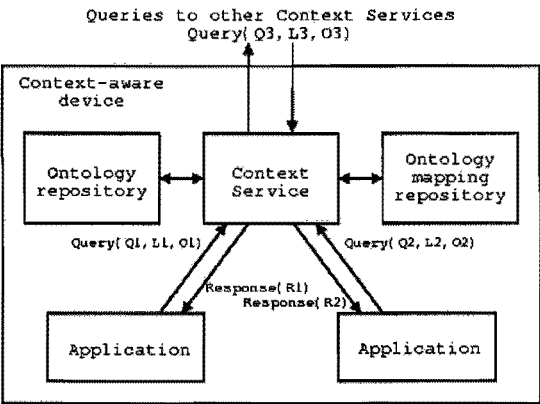

Fig.1. Context-Aware Device Architecture

The internal structure of a context service is shown in Figure 2. The first major functional section of a context service are its query interface/query analysis modules. The query analysis module also handles query decomposition. The decomposed queries are then passed to the query routing module.
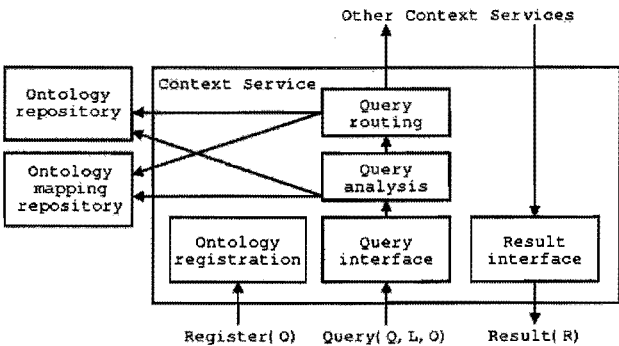

Fig. 2. Context Service Internal Design

Queries are routed to the query interface of the appropriate context service by the query routing module. Results are returned to and combined appropriately by the Result Interface.

5 Using Context in Adaptive Information Services

In this section we present a scenario in which information delivery to a user is adapted, based on available context information. The scenario considered is that of college students who take part in an arranged lecture and subsequently wish to review the lecture material at home. In this scenario, the many students taking part in the lecture all have separately constructed user models describing their competencies, preferred learning styles, and so on.

We consider the case of a particular student who is attending the lecture. Her user model has been exposed through a context service running on her PDA, and this model has been constructed using terms from a well-known user modeling ontology. Because this ontology is well-known, mappings exist between it and the ontology being used by the college's information services, which may be highly tailored to the college's specific needs.

When an information service needs access to these models it poses a query based on terms within its ontology to its local context service that then distributes the queries to the relevant remote context services in terms of their ontologies. The responses to these queries are then translated into the terms that the information service that posed the query has in its ontology. This mechanism allows the information services in the lecture theatre to present adapted content to the student based on preferences in her user model. For example, we could imagine an information service that provides lecture notes that would adapt the notes delivered based on the learning style of the user, or provide them in a different natural language if the user's context indicated that their native language was not English. A key feature of this approach is that any information that the students make available as part of their context does not need to be captured through either explicit or implicit techniques for user modeling, as it is automatically retrieved from context services as needed.

In addition to a user model, relevant information such as the characteristics of the student's display device (a PDA) is available as part of her context. This allows the lecture theatre software to deliver a set of notes that is text-based, rather than one that uses large diagrams, for display on the PDA. Once our student has returned home, she wishes to review the material covered in the lecture on her laptop. After she transfers the notes she downloaded during the lecture to her laptop, her laptop software can then use the stored reference to the context of the lecture to file the notes appropriately, and also contact the college information service to retrieve a set of notes that are better suited to its larger display. Because of concepts mastered during the course of the lecture, software on the laptop can now adapt the notes presented based on the updated user model as part of the student's context. This is true despite the internal model in the laptop's software being independently authored, as the context service will again, based on ontology mappings, translate responses to queries into terms that the laptop software will understand.

While this scenario relies on some aspects of pervasive computing such as location awareness, it demonstrates how information services in general can be given access to context information - user models and any other information - that can be used to perform adaptation.

6 Conclusion and Future Work

This paper has described context information and highlighted its use in Adaptive Information Services through a detailed scenario. It has also presented an ontology-based architecture for a distributed context management system. A state of the art in ontology based integration (e.g. KRAFT), content based routing, and distributed querying using P2P (e.g. Edutella) has been completed. An initial implementation of the context management system to verify the design presented in this paper is already underway.

Context information has the potential to *fill in the gap* left with traditional modeling techniques. However, the challenge arises in successfully leveraging this information as part of Adaptive Information Services. Context information will not necessarily conform to a pre-defined schema – the Adaptive Information Service may have to discover, and understand, the schema. In addition, the semantics of the information described may not be fully understood by the Adaptive Information Service – again this may need to be discovered, possibly with the aid of concept ontologies. For these reasons it is our belief that the integration of an adaptive system with a context management system which is ontology based potentially provides a powerful solution. Thus it is planned to integrate the ontology driven context management system outlined in this paper with such an adaptive system (APeLS [3]) to explore the potential of using context as a rich source of adaptation of information services.

References

1. Weiser M., "Some computer science problems in ubiquitous computing," Communications of the ACM, July 1993.
2. Brusilovsky, P. (2000) Adaptive hypermedia: From intelligent tutoring systems to Web-based education (Invited talk). In: G. Gauthier, C. Frasson and K. VanLehn (eds.) Intelligent Tutoring Systems. Lecture Notes in Com-puter Science, Vol. 1839, (Proceedings of 5th International Conference on Intelligent Tutoring Systems, ITS 2000, Montreal, Canada, June 19-23, 2000) Berlin: Springer Verlag, pp. 1-7.
3. Conlan, O., Wade, V., Bruen, C., Gargan, M. (2002) Multi-Model, Metadata Driven Approach to Adaptive Hypermedia Ser-vices for Personalized eLearning. In the Proceedings of Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems, AH 2002, 100-111.
4. De Bra, P., Santic, T., and Brusilovsky, P. (2003) AHA! meets Interbook, and more... In: A. Rossett (ed.) Pro-ceedings of World Conference on E-Learning, E-Learn 2003, Phoenix, AZ, USA, November 7-11, 2003, AACE, pp. 57-64.
5. De Bra, P. (2001) "AHA! Adaptive Hypermedia for All", project proposal. http://www.nlnet.nl/project/aha/200106-aha-proposal.html
6. Kobsa, A. (1993). User modeling: Recent Work, Prospects and Hazards. In Adaptive User Interfaces: Principles and Practice, M. Schneider-Hufschmidt, T. Kühme, and U. Malinowski, (eds.). 1993, North-Holland: Amster-dam.
7. Berners-Lee T., Hendler, J. Lassila, O. "The semantic web." Scientific American, May 2001.
8. Mitchell K., A Survey of Context-Awareness, Available: http://www.comp.lancs.ac.uk/~km/papers/ContextAwarenessSurvey.pdf [2002, Nov. 27]

9. Ponnekanti, S.R., Fox, A. (2002), "SWORD: A Developer Toolkit for Web Service Composition", To appear in The Eleventh World Wide Web Conference (Web Engineering Track), Honolulu, Hawaii, May 7-11, 2002

10. Masuoka, R., Labrou, Y., Parsia, B., Sirin, E., "Ontology-Enables Pervasive Computing Applications", IEEE Intelligent Systems, Sept/Oct 2003, pp 68-72

11. Chen H. and Finin T "An Ontology for Context-Aware Pervasive Computing Environments", Workshop on Ontologies and Distributed Systems at 18th International Conference on Artificial Intelligence, August 2003, Acapulco, Mexico.

12. Kagal, L., Finin, T., Anupam J.,"A Policy Language for Pervasive Systems", Fourth IEEE International Work-shop on Policies for Distributed Systems and Networks, Lake Como, 4-6 June, 2003

13. Sloman, M., Lupu, E. "Security and Management Policy Specification", IEEE Network, Vol. 16, no. 2, 2002, p 10-19

14. Tonti, G., Bradshaw, J.M., Jeffers, R., Montanari, R., Suri1, N., Uszok, A., "Semantic Web Languages for Policy Representation and Reasoning: A Comparison of KAoS, Rei, and Ponder" Proceedings of 2nd Interna-tional Semantic Web Conference (ISWC2003), October 20-23, 2003, Sanibel Island, Florida, USA

15. Chen H, Finin T, and Joshi A, "An ontology for context-aware pervasive computing environments," Special Issue on Ontologies for Distributed Systems, Knowledge Engineering Review, 200