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Workshop on Social Information Retrieval for Technology-Enhanced Learning SIRTEL09

Riina Vuorikari, Hendrik Drachsler, Nikos Manouselis and Rob Koper (Eds.)

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Rational

Learning and teaching resource are available on the Web - both in terms of digital learning content and people resources (e.g. other learners, experts, tutors). They can be used to facilitate teaching and learning tasks. The remaining challenge is to develop, deploy and evaluate Social information retrieval (SIR) methods, techniques and systems that provide learners and teachers with guidance in potentially overwhelming variety of choices.

The aim of the SIRTEL'09 workshop is to look onward beyond recent achievements to discuss specific topics, emerging research issues, new trends and endeavors in SIR for TEL. The workshop will bring together researchers and practitioners to present, and more importantly, to discuss the current status of research in SIR and TEL and its implications for science and teaching.

Topics of Interest

- Recommender systems and collaborative filtering in educational settings
- Defining the scope, purpose and objects of social information retrieval in TEL
- Novel ways of generating input for recommenders (explicit and implicit methods)
- Ranking of search results to support individualised learning needs
- Integrating SIR services in existing educational platforms
- Folksonomies, tagging and other collaboration-based information retrieval systems
- Social navigation processes and metaphors for searching information related to teaching
 and learning
- Social networks and interactions in learning communities to facilitate information sharing and retrieval
- Approaches to TEL metadata reflecting social ties and collaborative experiences in the field of education
- Pedagogic decisions, recommender systems and how to contextualise recommender system to support learning processes.
- Interoperability of SIR systems for TEL
- Visualisation techniques in learning and teaching
- Semantic annotation and tagging for social information retrieval purposes
- Evaluating the performance of SIR systems in educational applications
- Measuring the effectiveness of SIR systems in supporting learning and teaching
- Evaluation the user satisfaction with SIR systems in supporting learning and teaching

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Riina Vuorikari Hendrik Drachsler Nikos Manouselis Rob Koper

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LearnWeb2.0: Resource Sharing in Social Media

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1 Introduction

Today's popular resource sharing systems such as YouTube, Flickr, or Delicious provide diverse types of content and do not focus on a particular domain such as education. Petrides et al. point out that there is a need for platforms, which allow for sharing of educational resources [1]. These platforms should permit the storage of resources of different formats [2]. Typically, though, different Web 2.0 infrastructures focus only on particular media types, e.g. videos in YouTube, pictures in Flickr, and bookmarks in Delicious, even if these resources belong to one and the same learning context. In this paper, we close this gap and present *LearnWeb2.0*, an elearning and competence development environment for sharing educational multimedia-based resources which are spread across the Web.

2 LearnWeb2.0 – System Description

LearnWeb2.0 is fully embedded into the network of existing popular Web 2.0 systems. Therewith, we are able to seamlessly integrate LearnWeb2.0 into the users' every day interactions with these systems [3]. Currently, LearnWeb2.0 integrates ten different Web 2.0 services such as YouTube, SlideShare, and Bloggers and provides various innovative features: (i) A personal learning space offering a rich set of functions and a seamless overview of the entire set of learning resources distributed across the various Web 2.0 repositories, (ii) sharing through *standing queries*, where users are notified whenever a new learning resources via an intuitive drag-and-drop interface, (iv) integration of the user's social networks from different Web 2.0 services (Facebook, Delicious, Last.fm, and Flickr), and (v) provision of a (controlled) natural language interface, which enables users to control access to shared resources.

The LearnWeb2.0 Web platform provides a uniform interface to search for resources that are distributed across the ten integrated Web 2.0 services. Users can bookmark resources and collaboratively organize these bookmarks in groups as depicted in Fig. 1.a, which shows a group of educational resources about "MS Access". Further, via the LearnWeb2.0 browser plug-in (Fig. 1.b) users can simply drag-and-drop images, videos, text snippets, etc. from their desktop or from some Web site on the plug-in's icon to upload the resource to their favorite, appropriate Web 2.0 service and add it to LearnWeb2.0. Results of a questionnaire [3] and a user study that is currently conducted at Leibniz University Hannover confirm the ability of LearnWeb2.0 to support learners and educators in sharing, discovering, and managing Web 2.0 learning resources.



Fig. 1. (a) LearnWeb2.0 Web platform and (b) the LearnWeb2.0 browser plug-in, which allows resource upload via drag-and-drop.

3 Demonstration Overview

In this demonstration we will primarily show how LearnWeb2.0 works and how a user can employ it to efficiently develop her competences on the topic of interest. First, we demonstrate the personal learning space which integrates all Web 2.0 resources accessible to the user and enables retrieval, sharing and management of these resources. Next, we show how the aggregation of the user's social network can be exploited for collaborative competence development. Further, we demonstrate how educational resources already available at user's desktop can be uploaded using the drag-and-drop functionality of the LearnWeb2.0 browser plug-in. Finally, we demonstrate collaborative aggregation, annotation, rating and commenting resources to support efficient resource finding.

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Collaborative and Semantic Information Retrieval for Technology-Enhanced Learning Antonella Carbonaro

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Abstract. The paper presents an ontological approach for enabling personalized searching framework facilitating the user access to desired contents. Through the ontologies the system will express key entities and relationships describing resources in a formal machine-processable representation. An ontology-based knowledge representation could be used for content analysis and concept recognition, for reasoning processes and for enabling user-friendly and intelligent content retrieval.

Keywords: Ontology, Semantic Web Applications, collaboration in information searching, personalized searching framework.

1 Introduction

Technological advances in information and communication systems have challenged educational institutions to adopt the opportunities of distributed knowledge acquisition and delivery. Among the most recent trends, the availability of wireless communication standards and of mobile devices gives rise for a new landscape of learning as a networked, situated, contextual and life-long activities. In this scenario, new perspectives on learning and teaching processes must be developed and supported, relating learning models, learning methods, didactics, team organization and situational behavior models.

In a distributed learning environment, we usually have a large number of educational resources (web pages, lectures, journal papers, learning objects, social networks, ...) stored in many distributed and different repositories on the Internet. Without guidance, students will probably have great difficulties in finding the reading material relevant for a particular learning task. This problem is becoming particularly important in Web-based education where the variety of learners taking the same course is much greater. Vice versa, the courses produced using adaptive hypermedia or intelligent tutoring system technologies are able to dynamically select the most relevant learning material from their knowledge bases for each individual student. Nevertheless, generally, these systems can't directly benefit from existing repositories of learning material.

The Web is increasingly becoming important than ever, moving toward a social place and producing new applications with surprising regularity: there has been a shift from just existing on the Web to participating on the Web. Community applications and online social networks have become very popular recently, both in personal/social and professional/organizational domains [1]. Most of these collaborative applications provide common features such as content creation and sharing, content-based tools for discussions, user-to-user connections and networks of users sharing common

interest, reflecting today's Web 2.0 rich Internet application-development methodologies.

The Semantic Web offers a generic infrastructure for interchange, integration and creative reuse of structured data, which can help to cross some of the boundaries that Web 2.0 is facing. Currently, Web 2.0 offers poor query possibilities apart from searching by keywords or tags. There has been a great deal of interest in the development of semantic-based systems to facilitate knowledge representation and extraction and content integration [2], [3]. Semantic-based approach to retrieving relevant material can be useful to address issues like trying to determine the type or the quality of the information suggested from a personalized environment. In this context, standard keyword search has a very limited effectiveness. For example, it cannot filter for the type of information, the level of information or the quality of information.

By exploiting each other's achievements the Semantic Web and Web 2.0 together have a better opportunity to realize the full potential of the web [4].

Potentially, one of the biggest application areas of social networks might be personalized searching framework (e.g., [5],[6]). Whereas today's search engines provide largely anonymous information, new framework might highlight or recommend web pages created by recognized or familiar individuals. The integration of search engines and social networks can lead to more effective information seeking [7]. In fact, the system we want to propose can find application in any context in which the group collaboration is a requisite, and we believe that a Web-based learning system is an ideal application domain.

Additionally, we can consider semantic information representation as an important step towards a wide efficient manipulation and retrieval of information [8], [9], [10]. In the digital library community a flat list of attribute/value pairs is often assumed to be available. In the Semantic Web community, annotations are often assumed to be an instance of an ontology. Through the ontologies the system will express key entities and relationships describing resources in a formal machine-processable representation. An ontology-based knowledge representation could be used for content analysis and object recognition, for reasoning processes and for enabling userfriendly and intelligent multimedia content search and retrieval.

In this work we explore the possibilities of synchronous, semantic-based collaboration for search tasks. We describe a search system wherein searchers collaborate intentionally with each other in small, focused search groups. Developed framework (SWS2 – Semantic Web Search 2.0 - project) goes beyond implementation of ad hoc user interface. It also identifies information that one group member searches and uses it in realtime to improve the effectiveness of all group members while allowing semantic coverage of the involved domain. The semantic approach is exploited introducing an ontology space covering domain knowledge and resource models based on word sense representation.

There are many scenarios in which small groups of users collaborate on Web search tasks to find information, such as school students or colleagues jointly writing a report or a research, or arranging joint travel. Although most search tools are designed for individual use, some collaborative search tools have recently been developed to support such collaborative search task [11]. These tools tend to offer two classes of support: i) awareness features (e.g., sharing and browsing of group members' query histories, and/or comments on results and on web pages rating), ii) division of labor features (e.g., to manually split result lists among group members, and/or algorithmic techniques for modifying group members' search results based on others' actions) [12]. Collaborative search tools are relatively novel and thus not widely available.

2 Personalized Searching Framework

One of the areas in which information retrieval is likely to see great interest in the future is synchronous collaborative search. This concerns the common scenario where two or more people working together on some shared task, initiate a search activity to satisfy some shared information need. Conventionally, this need is satisfied by independent and uncoordinated searching on one or more search engines, leading to inefficiency, redundancy and repetition as searchers separately encounter, access and possibly re-examine the same documents. Information searching can be more effective as a collaboration than as a solitary activity taking advantage of breadth of experience to improve the quality of results obtained by the users [13]. Community-based recommendation systems [14], [15] or user interfaces that allow multiple people to compose queries [12] or examine search results [16] represent various forms of collaboration in search.

Traditional approaches to personalization include both content-based and userbased techniques. If, on one hand, a content-based approach allows to define and maintain an accurate user profile (for example, the user may provides the system with a list of keywords reflecting him/her initial interests and the profiles could be stored in form of weighted keyword vectors and updated on the basis of explicit relevance feedback), which is particularly valuable whenever a user encounters new content, on the other hand it has the limitation of concerning only the significant features describing the content of an item. Differently, in a user-based approach, resources are processed according to the rating of other users of the system with similar interests. Since there is no analysis of the item content, these information management techniques can deal with any kind of item, being not just limited to textual content. In such a way, users can receive items with content that is different from that one received in the past. On the other hand, since a user-based technique works well if several users evaluate each one of them, new items cannot be handled until some users have taken the time to evaluate them and new users cannot receive references until the system has acquired some information about the new user in order to make personalized predictions. These limitations often refer to as the sparsity and start-up problems. By adopting a hybrid approach, a personalization system is able to effectively filter relevant resources from a wide heterogeneous environment like the Web, taking advantage of common interests of the users and also maintaining the benefits provided by content analysis. A hybrid approach maintains another drawback: the difficulty to capture semantic knowledge of the application domain, i.e. concepts, relationships among different concepts, inherent properties associated with the concepts, axioms or other rules, etc [17].

In this context, standard keyword search is of very limited effectiveness. For example, it does not allow users and the system to search, handle or read concepts of interest, and it doesn't consider synonymy and hyponymy that could reveal hidden similarities potentially leading to better retrieval. The advantages of a concept-based document and user representations can be summarized as follows: (i) ambiguous terms inside a resource are disambiguated, allowing their correct interpretation and, consequently, a better precision in the user model construction (e.g., if a user is interested in computer science resources, a document containing the word 'bank' as it is meant in the financial context could not be relevant); (ii) synonymous words belonging to the same meaning can contribute to the resource model definition (for example, both 'mouse' and 'display' brings evidences for computer science documents, improving the coverage of the document retrieval); (iii) synonymous words belonging to the same meaning can contribute to the user model matching, which is required in recommendation process (for example, if two users have the same interests, but these are expressed using different terms, they will considered overlapping); (iv) finally, classification, recommendation and sharing phases take advantage of the word senses in order to classify, retrieve and suggest documents with high semantic relevance with respect to the user and resource models.

For example, the system could support Computer Science last-year students during their activities in courseware like Bio Computing, Internet Programming or Machine Learning. In fact, for these kinds of courses it is necessary an active involvement of the student in the acquisition of the didactical material that should integrate the lecture notes specified and released by the teacher. Basically, the level of integration depends both on the student's prior knowledge in that particular subject and on the comprehension level he wants to acquire. Furthermore, for the mentioned courses, it is necessary to continuously update the acquired knowledge by integrating recent information available from any remote digital library.

2.1 Use case analysis

A first level of system analysis can be achieved through its functional requirements. Such functional requirements are described by the interaction between users and the systems itself. Therefore, users may be interested in semantic-based search or collaborative semantic-based search.

We define an interaction between users as a collaborative search session managed by the system using specialized components: in particular, the system should cover both user manager and sessions between users manager roles.

2.2 System modules

In the following we list the components able to handle user data:

- i) User Interface Controller: it coordinates the information flow between interface control and other system components and allows to perform data presentation for the GUI visualization.
- ii) Semantic searcher: it implements semantic-based searches extracting concepts related to introduced keywords using a thesaurus and searching in the underling ontology corresponding documents.
- iii) Interest coupler: it performs intersection between user interest matching relevant terms extracted from semantic searcher.
- iv) User Manager: it deals with user. For example through the User Manager, it is possible to register new users or to search for their information. Moreover, it is able to associate mail boxes to user to enhance communication.
- v) Session Manager: it manages collaborative search sessions allowing user insertion and search terms shared between users. It allows to maintain consistency between session views and creates message boxes for the specific session whose content is available to all the participants.

2.3 Data analysis

i) OWL

The ontology developed to test implemented framework maintains relation between courses, lessons, teachers and course material. Ontology is a representation model in a given domain that can be used for the purposes of information integration, retrieval and exchange. The ontology usage is widely spread in not only the artificial intelligent and knowledge representation communities, but most of information technology areas. In particular, ontology has become common in the Semantic Web community in order to share, reuse and process domain information between humane and machine. Most importantly, it enables formal analysis of domain knowledge, for example, context reasoning becomes possible by explicitly defining context ontology.

There are several possible approaches in developing a concept hierarchy. For example, a top-down development process starts with the definition of the most general concepts in the domain and subsequent specialization of the concepts, while a bottom-up development process starts with the definition of the most specific classes, the leaves of the hierarchy, with subsequent grouping of these classes into more general concepts. The hybrid development consists in a combination of the top-down and bottom-up processes. Due to our personal view of the domain we took the combination approach. Once we have defined the classes and the class hierarchy we described the internal structure of concepts defining the properties of classes. Over the evolving ontology we perform diagnostics to determine the conformance to common ontology-modeling practices and to check for logical correctness of the ontology. User Data

ii) User

It maintains data of the users handled by the system.

Session Data

It maintains data corresponding to collaborative search sessions.

2.4 Developed system interaction

The developed system proposes three different interaction between the users. Search interaction

This interaction starts when a user performs a search proposing one or more keywords. The Semantic searcher module returns a list containing relevant documents and recommends terms for the possible following searches. Therefore, the User Interface Controller is able to find similar user with similar interest in performed searches using Interest Coupler module.

Collaborative search session interaction

A user can decide to contact another user, proposed by the system similar to his interests, to start collaborative search session. The request produces an Invitation message in the message box of the target user. Concurrently, a listening permanent loop allows to User Interface Controller to advise target user. In the case of positive response, the User Interface Controller creates a new collaborative search session and a Session Join request is sent.

iii) Interaction during a collaborative search session

The user could modify the list of search terms adding or removing some keyword. The request, managed by the User Interface Controller, is forwarded to Session Manager that updates search terms, replacing term list and requiring GUI updates. The same interaction can be used to implement a session chat, allowing more collaboration value to the system.

iii)

i)

ii)

2.5 System GUI

The search home page is showed in Figure 1. Box A allows to the user to insert his nickname to use during SIG sessions dynamically showed in box B.

SIG is now activel You are: Fable	THIS .	b service Search	r Fabio
		You have searched for web service Number of results found: 3 is	1 0.042 secon
	Relevant terms for the search		
	• <u>web</u>	Material Date	Lesson
Welcome to the SemWebSearch(2) Application	 <u>ws</u> <u>wsb_service</u> <u>servicio_wsb</u> 	A Dispensa side sul'introduzione del corso con argomenti e modalità d'esame 12-03-200	3 Chapter_1
This service allows you to search through the available resources for the Semantic Web e Web Services: Nuove Tecnologie per la Rete course.	web_service_description_language sementice_ebs	A Dispensa Un Web Service è un sistema software progetato per supportare l'interoperabilità tra diversi elaboratori di	3 Chapter_9
You can search a term or a phrase in both English and Italian, and obtain, as results, all the course materials that are semantically related to that.	<u>web_ontology_language</u>	A Dispense Web Ontology Language: linguaggio di markup semantico 04-04-200	3 Chapter_4
web service Search		Ъ	
This version of SWS supports the SIG system that allows two users to search in a collaborative way. Click the button below and enter a nickname.	SIG buddy SIG buddy to the senth Pape - Invite his user to a SIG session		

Fig. 1. SWS2 home page

Fig. 2. Collaborative search session

If a user participate to collaborative search sessions, the system proposes in his search result page a new box containing similar users (Figure 2, box A). This button also allows to send Invitation message to target user; a background function verify the presence of new Invitation messages and, eventually, notify them to the user.

Figure 3 box A shows communication facilities offered to system users, while Figure 3 box B shows terms actually used to search session. Using components showed in box B1 the user may add search terms, while using the component showed in box B2 the user may remove session search terms. The button showed in box B3 is twofold: on one hand, it allows users to accept the lists of terms created by the system. On the other, through such button, it is possible to perform the described semantic searches.

3. Considerations

Golovchinsky et al. [7] distinguish among the various forms of computer-supported collaboration for information seeking, classifying such systems along four dimensions: intent, depth of mediation, concurrency, and location.

The intent could be explicit or implicit. In our framework two or more people set out to find information on a topic based on a declared understanding of the information need, which might evolve over time. So, our framework implements explicit information seeking scenarios.



Fig. 3. Collaborative search terms specification

The depth of mediation is the level at which collaboration occurs in the system. Our system implements algorithm mediation at the search engine level explicitly consider ongoing collaboration and coordinate users activities during the search session.

People can collaborate synchronously or asynchronously. In our system the collaboration is synchronous involving the ability of people to influence each other in real time.

Finally, collaboration may be co-located (same place at the same time) or, as in our framework, distributed, increasing opportunities for collaboration but decreasing the fidelity of possible communications.

An important step in the searching process is the examination of the results retrieved. In order to test developed framework we have collected over 50 different documents concerning actual domain. We have extracted several concepts used during the annotation phase and performed tests to verify searching functionalities. It is currently difficult to replicate or make objective comparisons in personalized retrieval researches, so to evaluate search results we have considered the order used by the framework to present retrieved results. During this step, the searcher browses through the results to make judgments about their relevance and to extract information from those found to be relevant. Because information is costly (in terms of time) to download, displays of result lists should be optimized to make the process of browsing more effective. We have also evaluated the effect that the proposed framework has on collaboration and exploration effectiveness. Using implemented tools, searchers found relevant documents more efficiently and effectively than when working individually and they found relevant documents that otherwise went undiscovered.

The work described in this paper represents some initial steps in exploring semantic-based search retrieval collaboration within a focused team of searchers. It could be considered as one possible instance of a more general concept. While the initial results are encouraging, much remains to be explored. For example, most of the current research on sensemaking has been at the individual level, with little understanding of how sensemaking occurs in collaborative search tools.

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Tags and self-organisation in a multilingual educational context

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Abstract. Social tags offer a novel aspect to study learning resources, its metadata and how users interact with them. This paper investigates the impact of social tagging on the discovery of digital learning resources in a multilingual context. The main hypothesis is that the self-organisation aspect of a social tagging system helps users discover learning resources more efficiently and that the user-generated tags make the system, which operates in a multilingual context, more flexible and robust.

Keywords: Learning resource metadata, tags, self-organisation, discovery, social information retrieval.

1 Introduction

Since the late 1990's, digital repositories for learning purposes have gained ground. Such repositories with metadata and/or educational content have been set up on regional, national and international levels to offer digital learning resources for teachers and learners from K-12 to tertiary and vocational education [1, 2]. Sharing, using and reusing the content are the main drivers of the learning object economy [3]. Participants of this economy are educational institutions, digital libraries & learning object repositories (LOR) and their diverse stake-holders such as managers, content providers, policy makers, educators and learners, each with their own needs, requirements and agendas. Users and the usage in the field of learning resource repositories and digital libraries have been studied by different means, such as using Web metrics [4, 5, 6], attention metadata [7], data mining techniques [8] and mixed and qualitative methods [9, 10, 11].

Social tags offer an interesting aspect to study learning resources, its metadata and how users interact with them. Tags, as opposed to conventional metadata description such as Learning Object Metadata (LOM) [12], are free, non-hierarchical keywords that end users associate with a digital artefact, for example a learning resource. Tags are formed by a triple of (user,item,tag). Tags and the resulting networks,

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folksonomies, are commonly modelled as tri-partite hypergraphs [13, 14]. This ternary relational structure gives rise to the (item,user) relationship, which can be regarded as a parameter of the interaction between a user and a learning resource in question. By looking at the (user,tag) relation, tags can be regarded as part of user models that reflects user's interests and intentions. The full relational structure emphasises also the (item,tag) relations that allow tags to be part of describing the item that they are related to, in this case the learning resource. Additionally, the (item,tag) relation can also be extended to the whole metadata (e.g. LOM) that is used to describe the item, creating an additional relationship (tag,LOM). Figure 1 represents these relationships between a user, a learning resource, its metadata (LOM) and tags. The main interest in this study is to understand these relationships and their ramifications in Technology Enhanced Learning (TEL) and more specifically, for digital learning resources. In [15] a review of related work is given.



Fig. 1. Relational structures that emerge when a social tagging tool is introduced as a feature to a conventional Learning Object Repository (LOR).

2. Self-organisation and social tagging

Learning Object Repositories (LOR) and digital libraries can be regarded as sociotechnological systems with complex combinations of people, content artefacts and technologies. A social tagging and bookmarking tool as a feature on a conventional LOR potentially adds a number of dynamical mechanisms in such system. The act of a user adding a tag to a resource, for example, can be regarded as a lower-level interaction on the portal that is executed on the basis of purely local information, e.g. the user has discovered a resource that is relevant to his information seeking task. This individual behaviour, however, also modifies its environment. The tag(s) added by the user now appear in the resource-related tagclouds and on the global tagcloud

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creating patterns on the system level. This, in turn, has potent to modify the behaviour of other individuals, as they might be inclined to use the tag as a navigational aid or prompt for their own resource discovery process. Such phenomena is explained as stigmergy, it provides a general mechanism that relates individual and colony-level behaviours in the literature of social insects, first introduced by P. Grassé in 1959 [16], and for example, in Swarm Intelligence [17]. Swarm Intelligence is based on the idea that the design of adaptive, decentralised and robust artificial systems could be inspired by social insects (for self-organising applications in general, see [18]). Implementations of these ideas in technology enhanced learning exist, e.g. a collaborative filtering [19, 20], designing lifelong learners [22], sequencing recommendations [23], and self-organising navigational support [24]. The grounding of these works relies in complexity theory [25, 26].

By studying the behaviour of social insects such as ants, termites or certain wasps, the scientists have elicited three characteristics behind their success in carrying out complex tasks such as building a nest or finding a shortest route to a food source [27]. These are:

- Self-organisation (activities are neither centrally controlled nor locally supervised);
- Flexibility (the colony can adapt to a changing environment);
- Robustness (even when one or more individuals fail, the group can still perform its tasks).

Self-organisation represents the idea that even if individuals follow simple rules, the resulting group behaviour can be surprising complex and effective. Self-organisagtion is explained as "a set of dynamical mechanisms whereby structures appear at the global level of a system from interactions among its lower-level components. The rules specifying these interactions are executed on the basis of purely local information, without reference to the global pattern, which is an emergent property of the system rather than a property imposed upon the system by an external ordering influence." [17, p.9]. According to the authors, the four basic ingredients of self-organisation are the following:

- 1. Positive feedback: simple behavioural "rules of thumb" that promote the creation of structures. An example of this is "recruitment" is by ants, i.e. when other ants start following a trail to a food source thanks to indirect interactions among insects.
- 2. Negative feedback counterbalances positive feedback and helps to stabilise the collective pattern. In the example of wayfinding among ants, this can be food source exhaustion, or competition between food sources.
- 3. Self-organisation (SO) relies on the amplification of fluctuations (e.g. random walks, errors). Randomness is often crucial since it enables the discovery of new solutions. An example of this is an ant that gets lost and finds a new, unexploited food sources.
- 4. Multiple interactions. SO generally requires a minimal density of mutually tolerant individuals who are able to make use of the results of their own activities as well as of others' activities. E.g. trail networks can self-organise and be used

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collectively if individuals use others' pheromone (a chemical substance that can be sensed by other ants).

3 Studies on self-organisation in the context of multilingual educational resource discovery

A series of studies [28, 29, 30, 31] has been conducted on a learning resource portal currently known as the Learning Resource Exchange, hereafter referred to as *portal*. The portal was developed by European Schoolnet and its partners in the MELT and Calibrate projects. A version of the LRE federation of repositories [32] was made available to a restricted number of schools with more than 30 000 open educational resources and nearly 90 000 assets from 19 content providers in Europe and elsewhere. These resources exist in different languages and conform to different national and local curricula. A common Learning Resource Exchange Application Profile [33] is used by content providers which make the use of classification keywords from the LRE Thesaurus mandatory [34]. This Thesaurus currently exists in 17 languages. The portal offers a social tagging tool, which allows users to add tags to resources so that they can easily find them later and share them with other users.



Fig. 2. The Learning Resource Exchange portal is available in different languages.

Figure 2 shows the front page of the portal. It offers different categories of searches: "Explicit search" (text based and advanced search) and "Browse by category" that take advantage of multilingual metadata. "Community browsing", on the other hand, takes advantage of the other users' behaviour.

In the following part, first a study on self-organisation aspects of a social tagging system is introduced. Then, the other two important aspects behind the success of social insects are studies, namely how the user-generated tags make the system more flexible and robust. This part of the paper presents a trilogy of studies using empirical, behavioural data captured from log-files and users' attention metadata trails.

3.1 Self-organisation

Attention metadata (e.g. how do users search, what do users click on, what do they bookmark) was collected from users on the portal and a model on users' search-playannotation behaviour was created, the logging schema is explained in details in [30].

The following observations were gathered:

- Users follow a simple rule: "Search resources using your preferred search method. When a resource is relevant, bookmark it with tag(s)". When a user discovers resources and provides annotations at the individual level, they are regarded as lower-level interactions that are executed on the basis of purely local information. These comprise 16% of all the actions on the portal (Figure 3).
- This individual behaviour modifies the environment and creates spatiotemporal structures such as the Community browsing features, which are global patterns on the system level. These are tagclouds (e.g. global, resource-specific and personal ones) and lists of "most bookmarked resources". On average, 21% of users' search actions take advantage of these spatiotemporal structures.
- Tagclouds are an example of the spatiotemporal structures which emerge as a result of self-organisation. When a tagcloud, for example, influences the behaviour of other individuals in discovering new resources and further tagging and rating them, this is considered as a sign of stigmergy. Bookmarks and ratings indicated in green boxes in Figure 3 show how 33% of all annotations were initiated through these structures creating an ongoing feedback loop in a self-organised system.
- When other users start using these spatiotemporal structures as a social navigation aid, it can be understood as positive feedback to the system. This prompts convergence in the behaviour: it increases the frequency of use of the same resources and tags, and creates the emergence of patterns (e.g. "most bookmarked resources" and "top-used tags"). On average 29% of the all plays and 33% of annotations are generated through these structures.
- Negative feedback is given to the system when a user, for example, does not find a relevant resource using a tag and thus chooses to use some other retrieval method. This is a control mechanism that counterbalances positive feedback in the system.
- Amplification of fluctuations is a counter-measure against too much positive feedback, which can lead to 'suboptimal convergence' and kill innovation, result of which could be no new emerging behaviours. Discovery and annotations of new resources that have no previous annotations through "Explicit search" and "Browse by category" introduce new items to spatiotemporal structures, 67% of all annotations were produced this way. These annotations act as seeds from which new structures can nucleate and grow.
- Multiple interactions (e.g. on search behaviour, clicks, annotations) from users, both authenticated and non-authenticated, are recorded on the back-end of the LOR using attention metadata schema designed for social discovery processes.

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Individuals are able to make use of the results of their own activities (e.g. 2% of plays are generated by authenticated users as they replay the resources that they bookmarked), however, these emerging structures are also made available collectively to all the users which increases their use manifold (on average 28% of plays are generated through these structures).



Fig. 3. The search-play-annotate model of user behaviour on a learning resource portal depicting the characteristics of self-organisation.

Lastly, we studied whether Social Information Retrieval strategies made users more efficient when discovering relevant learning resources. By Social Information Retrieval strategies we mean all the Community browsing features, and it also comprises the retrieved resources that contain user-generated Interest indicators. These are Interest indicators such as a rating on a scale 1 to 5 (1="of no use" to 5="very useful") or a bookmark with tags (called Favourites).

According the ideas of self-organisation, ants, for example, are attracted to the shorter path to a food source because of its higher concentration of "pheromone", a chemical that ants use to mark the path. Following the same logic, the users who are attracted by the annotations of other users should find the relevant resources with less effort. In [30] a measure for user's efficiency in finding relevant resources was defined. We showed that by taking advantage of the given SIR methods on the portal, the users spent less effort in finding relevant resources. The average efficiency ratio went down from 4.4:1 to 2.8:1, meaning that with SIR methods, 2.8 searches were needed to find one relevant resource. However, we were not able to show that by using Community browsing methods users were to discover more relevant crossboundary resources. By cross-boundary discovery we mean that the user and the learning resource discovered come from different countries, and/or that the content is in a language other than the user's mother tongue.

Following the idea of self-organisation and stigmergy, learning resources and their metadata on the one hand, and social tagging and its products, tags on the other hand, do not only create new ways to discover learning resources, but also create a learning resource metadata ecology. The term "metadata ecology" is used to mean the interrelation of conventional metadata and social tags, and their interaction with the

environment, which can be understood as the repository in the large sense (resources, their metadata, interfaces and underlying technology) and its community of users. In the following Section, the other two important factors in social insects success are studies, namely flexibility and robustness.

3.2 More flexible and robust system

[27] describe flexibility of social insects as the capacity of a colony to adapt to a changing environment, and robustness meaning that even when one or more individuals fail, the group can still perform its task. Similarly, we are interested in these properties for the users of the learning resource portal on the one hand, and for the learning resource metadata ecology on the other hand, i.e. how tags can make the system of a learning resource portal more flexible and robust.

Flexibility and robustness regarding users

Studying the same portal we documented different user behaviour while interacting with the self-organised model such as ours. In this study [29], over a period of six months, empirical data from more than 200 users was gathered. We found that 33% of the users contributed tags, whereas 32% of users never contributed tags themselves, but used them for retrieval. Moreover, 35% of users did not interact with tags at all (Figure 3). Chi-Square test for these differences is significant (p< 0.001). We thus have seen that 59% users used the new emerging structures to discover resources, indicating that due to self-organisation on the portal, more flexible ways to access resources have been created. We can also argue that it is a robust system, as even if only 33% of users contribute tags, they are used by 59% of users for retrieval purposes.

For the resource discovery, we were interested whether all the tags were used in a similar way. Out of more than 3800 distinct tags, our logging analyses show that only 11% of the tags were clicked on and that they generated 2631 clicks. On average, each tag received 6.9 clicks; however, in reality, 20% of the top clicked tags generated 79.6% of the clickstream.

This led to study how the supply of tags in the system matches with the demand, i.e. how flexibly can the portal's offer to *adapt to a chancing environment*. A measure for "attractive tags" was introduced which compares the amount of clickstream on a tag against how many times it had been added to the system by teachers (i.e. supply). If the number is above one (1), it means that the tag has generated more clickstream than supply. This means that the tag is "attractive". If the number equals to one, it means that there is an equal amount of demand and supply, and below one indicates that there is supply, but no demand. We found that 21% of tags were "attractive" and 24% had an equal demand and supply. 55% of tags received less clicks than there were supply. Language-wise, within the "attractive" and "equal" tags, 28% are in another language than English. The flexibility of the tags to *adapt to a chancing*

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environment by accommodating users' demand was demonstrated in showing that 45% of tags attracted more or equal amount of demand than there was supply.



Fig. 4. Different users interact differently with the social tagging system (n=234).

Flexibility and robustness regarding metadata ecology

Moreover, we also studied the flexibility and robustness of the system from the point of view of interplay between social tags and conventional metadata, i.e. relationship (tag,LOM) [31]. Flexibility in this case can be regarded as the capacity of the metadata to adapt to a changing environment, and robustness can be interpreted meaning that even if one or more metadata elements of LOM fail, thanks to tags, the system can still perform its task, i.e. support teachers in discovering learning resources.

As the portal is made available to teachers from European countries and its interface is made available in multiple languages, it is normal that users tag in multiple languages. The tagging behaviour in a multilingual context is studied in [28]. Similarly to the previous study, we also found that users tag in multiple languages. In this study we found that 29% of the tags were in English, although a very few users had English as mother tongue. A medium correlation (r=0.57) was found between the language of the content and language of tags.

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Fig. 5. Attractive tags, i.e. the tags that proportionally received more clicks from users as opposed to tags that were added by users. The "wish list" of the users of an international learning resource portal.

We ran a database query against all the tags and the multilingual Thesaurus terms. We found that 11.3% of distinct user-generated tags exist in the LRE multilingual Thesaurus. We call these "Thesaurus tags", as they are end-user generated, but they also exist in the Thesaurus. The number of times "Thesaurus tags" were applied rises to 30.6% of all tags (i.e. the same tag added to many resources). On average, these tags were reused 11.8 times compared to other tags which were reused on average 2.4 times. It is interesting that, especially in a multilingual context, such a high percentage of overlap exists between natural language and controlled vocabularies. In [35] authors report that the folksonomy set overlapped with the indexer set on average 19.5%.

These "Thesaurus tags" by users can be used to improve the semantic interoperability of tags. First, they have a potential to be used as a "bridge" between existing descriptors and tags, and thus enhance the semantic interoperability within and across languages.

*****	Changes of State [en]
73	Tags: chemistry of phases experiment koolielu lämpeeppi change of state thermodynamics change melt selection kemia אמדע
	Classification: sciences, physical sciences (NT)
	Age: 14-16 Resource type: experiment, simulation, exploration

Fig. 5. Learning resource "Change of State" with tags (e.g. "kemia") and indexing terms "sciences" and "physical sciences" from the multilingual Thesaurus.

One example is the resource "Change of State" in Figure 5, which has tags by endusers as well as the classification terms by the expert indexer. Table 1, on the other hand, shows the Thesaurus "descriptor 195" representing the concept of "chemistry" with its language equivalences. As we can now observe, the tag "*kemia*" is actually a "Thesaurus tag". Thanks to the multilingual Thesaurus, we can first of all recognise the similarity between a "Thesaurus tag" and the descriptor, and then assign

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properties to these tags from the Thesaurus, e.g. the tag "kemia" is related to the concept of "descriptor 195" and its language is Finnish. A similar idea of connecting tags to existing ontologies has been presented in [36], although the difference is that in our case, we use the resource and its existing descriptors as a proxy for the semantic link between the descriptor and tag, and that this process can be automated to take place at the back-end without being intrusive to the user.

The information gained from the link between the "Thesaurus tag" and descriptor can be used in various ways. It can be used, for example, in the tagcloud to show different translations of the tag "*kemia*". As for the retrieval purposes, the system could infer that other resources indexed with the "descriptor 195" are also relevant. Here, the user will get a chance to retrieve learning resources in multiple languages, thanks to the inter-language connection that the multilingual Thesaurus offers. Moreover, "Thesaurus tags" open up new options to navigate across multilingual resources, for example, a thematic multilingual tagcloud could be created by displaying all the tags that are added to resources which contain a given Thesaurus descriptor (e.g. tagcloud on physical sciences).

 Table 1. Language equivalences for the Thesaurus "descriptor 195", including also one usergenerated "Thesaurus tag" kemia.

Descriptor ID	Language equivalences	
195	Chemie	fr
	chemistry	en
	kemi	SV
	kemia (Thesaurus tag)	fi
	kémia	hu

Secondly, the "Thesaurus tags" can be suitable descriptors to be added to the original LOM description of the learning resource, particularly in cases where the original indexing has been poor or limited. In our example of "Change of State", we know from the Thesaurus hierarchies that the "descriptor 195" is a narrower term of the existing indexing term "physical sciences". As the "Thesaurus tag" narrows down the current classification of the learning resource in question, we can automatically add it as a new classification term for the resource.

Thirdly, the area of intra-language equivalence within the multilingual Thesaurus could be improved with tags, as in our evaluations they have been identified as a good source for non-descriptors [37]. A non-descriptor provides the intra-language equivalence that facilitates access to resources that are indexed by using the thesaurus terms that do not translate well to the language that the end-user uses. For example, the tag "efl" (= "English as foreign language") could be expressed in thesauri terms as "English language" + "foreign language". When the user types a text search "efl", not only tagged resources would be retrieved, but also the ones with the above descriptors. In this way the gap between natural language and controlled language could be reduced. The same could apply also for gathering better scope-notes, which deal with the meaning of terms and help the user to understand the term better. Especially in a multilingual context, where some differences occur from one language/culture to another, this feature is useful to understand cultural differences.

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Flexibility and robustness regarding crossing contexts

Previous studies have shown that the reuse of learning resources is low [e.g. 6]. Barriers to reuse have been studied in [11], where the authors argue that a "repository-centric perspective" of learning resource repositories create a barrier for the use and reuse of learning resources, as repositories are often introduced as a stand-alone tool to users. To improve the reuse, [6] show that improving even one of the steps in the reuse chain would improve the probability of reuse and therefore, the amount of reuse within the platform. The interplay between learning resource repositories is considered as a step in the reuse chain, and this study focuses on the mechanisms that could create such interplay.

We studied the relationship of (tag, item) and how it can be used to create interplay between different contexts [31]. The research challenge was to demonstrate whether the end user generated tags can create cross-references between separate pieces of content that reside in heterogeneous content platforms in a multilingual context. We focused on tag-based interest structure on learning resources that teachers have tagged on a number of different educational platforms or tools. [38] argue that tag-based interest structures in social tagging systems are less segmented than item-based interest structures, which are typically used for social recommendation purposes.

To study the possibility of interplay more than 20 000 tag applications between five different educational resource platforms were collected (Calibrate, LeMill, OER Commons, LRE and *delicious.com*). We then analysed all the tag-item pairs from the datasets to find the overlap between tags in different services. The entire dataset comprises 21269 tag applications (Table 2). We found that 666 of the distinct tags (7.4% of all distinct tags) overlap at least in two out of five different tagging systems. They result in 6452 tag applications, which covers 30% of all the posts in our dataset. Using this tag-based interest structure, we can create an aggregated "cross-platform tagcloud". It filters 7.4% of all distinct tags and creates man-made bridges across two or more platforms taking advantage of the tag-based interest structure in an educational context.

Tags appear	Distinct tags	Applications	% tag applications
Total in 2 or more			
platforms	666	6452	30.3%
All tags 5 services	9036	21269	

Table 2. Tags shared among five different tagging tools in an educational context.

The idea of allowing users to access resources originating from different platforms through tags is complimentary to other forms of sharing learning resources and their metadata between repositories [32, 39]. Our proposal of a "cross-platform tagcloud", though, introduces three new aspects. First, it builds on the social interactions among users in terms of co-construction of knowledge as tags, and secondly, it uses them as a way to offer interplay between learning resources platforms. Lastly, it introduces the idea of accessing both institutional resources (usually subject to some quality control within a closed information retrieval system) and private collections of resources from

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various sources. Such ideas are novel in the area of learning object repositories, where the *de facto* way of sharing resources is based on federating and harvesting metadata. Instead of accessing the entire set of "conventional" metadata, which can amount to thousands of resources (e.g. the LRE alone makes more than 35 000 resources available), "man-made" filters, i.e. tags, bridge between platforms and guide the user's choice of resources.

4 Conclusion and future work

In this study we have focused on three different aspects of self-organisation and stigmergy on a learning resource platform with a social tagging feature. We have been able to show that the self-organisation aspect of a social tagging system helps users discover learning resources more efficiently. We also showed that both users and the metadata ecology benefited from the flexibility and robustness of such system.

Thanks to the triple (user, item, tag) when represented in a "cross-platform tagcloud", we have been able to show that content which comes from heterogeneous repositories that typically do not cross-reference each other via link-structures, has such cross-references. Therefore, the link-structures from our aggregated tagcloud opens more sophisticated avenues for resource discovery across contexts (e.g. repository, language, country, curriculum). Future work focusing on using these underlying connections to create measures of resources' importance will offer plenty of research challenges. Similarly to the Page-Rank algorithm [40], tags, creating underlying connections between seemingly random pieces of content in different languages (from repositories in different countries), rely on humans' subjective idea of their importance for a given information-seeking task. Using this new, emerging link-structure, and involving tags as "anchor texts", could offer totally new ways to "organise the world's learning resources and make them universally accessible and useful", similar to what Google claims its mission statement is for world's information. Moreover, resource's potential for crossing across different contexts could be detected from the same link-structure. Resources-specific tags, for example, that appear in many different languages could indicate that the resource is being used in different language contexts and thus has potential to be used across contexts. Similarly, resources with users from a number of different countries could indicate that these resources are being used in different country and curriculum contexts. Conversely, resources that have tags associated to them only in one language or only by users from the same country as the resource is, could be disregarded and given less importance for the across-context discovery.

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Task Patterns to support task-centric Social Software Engineering

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Abstract. Experience sharing to support software engineering is an important, yet difficult task. This paper presents an integration of the Task Pattern concept to support social software engineering. Task Pattern provide information objects and code examples to support software engineering tasks in a community of developers. They are generated based on information resulting from task-centric software development tools, e.g. the Tasktop system. As centrally organized and automatically extended information source they give a valuable insight into the process and product of software development tasks.

Key words: task pattern, social software engineering, social information retrieval

1 Introduction

Software development can be considered as a specific type of knowledge work [11]. Characteristics like weakly-structured processes, high degree of personal decision involvement and only partial knowledge of the outcome are valid. These aspects complicate adequate support of development processes. In this paper we introduce a concept to support task-centric social software engineering in a team, using the concept of Task Patterns [9]. Task Patterns collect information artefacts created and used by developers when executing software development tasks of similar kind. These artefacts are organized with respect to their meaning for the described task class. With our approach we extend tools like Tasktop Pro for Eclipse [12] which support users in executing their tasks by functionalities for Task Pattern creation and enhancement for experience sharing. This is done by a structured re-use of the information collected by these tools for Task Patterns shared within a community.

This paper is structured as follows. First, we introduce our view on social software engineering and the possible fields of application for social information retrieval in software engineering projects. Second, task-centric software development and the Task Pattern concept are presented as foundation for the idea of using task-centric software engineering to support experience transfer. Third, Task Patterns for software engineering are presented as means for transferring personal experience in a collaborative development environment.

2 Conceptual Background

In this section we introduce the concept of social software engineering and show how social information retrieval (SIR) can be applied in software engineering projects.

2.1 Social Software Engineering

Software engineering - especially in Open Source - is carried out in (large) teams. The times when developers worked alone on their code seem definitely to be over. Surely this is not a trend of the recent years, as Gerald M. Weinberg stated in 1971 that software engineering is a social user-centered activity where communication plays a key function [15] and that is supported by computers. Computer supported cooperative work (CSCW) is an interdisciplinary field of research focussing on the connection of collaborative work and technical support for it. As Ellis et al. define it CSCW looks at how groups work and seeks to discover how technology (especially computers) can help them work [3, p. 39]. So CSCW is part of the research conducted in the area of Computer Mediated Communication (CMC). CMC researches how people and groups communicate using web technologies and services like e-mail, blogs or bulletin boards. Restricting this collaborative work in groups to the domain of software engineering leads to the research area of collaborative (or social) software engineering. Regional and temporal distribution of software development teams require specific techniques for communication and coordination, especially with respect to the domain of knowledge sharing. Collaborative development environments (CDEs) are providing optimal support for coordinating activities and communication in the software engineering process conducted in teams [1].

2.2 Social Information Retrieval in Software Engineering projects

Social Information Retrieval (SIR) deals with obtaining information by utilizing social processes. Information can be externalized artefacts as well as personal expertise, so SIR can allow the retrieval of stored data or domain experts. There are different techniques and methods for SIR [14]; techniques include collaborative filtering, subjective relevance judgements and social bookmarking. Methods for SIR comprise recommender systems, social navigation and social search. A mix of the methods and techniques yield an added value for the users of services. In software engineering projects the SIR needs structures to retrieve abstract information like documents and API desciptions as well as more concrete information like source code or best practise examples which fit the engineering requirements and guidelines of the specific team. A CDE can offer a social bookmarking approach allowing developers to bookmark important project-related documents and include these information in the ranking of search results. [6] show how methods and techniques of SIR can be successfully applied in the context of software requirements engineering.

With Task Pattern for software enginnering projects we propose a new type of SIR technique: building patterns from task execution. We will store and analyse tasks of developers, abstract from their specific context and create a Task Pattern from multiple task executions. This Task Pattern will be stored in a central Task Pattern Repository and can be accessed by every developer.

3 Tasks and Task Pattern to support organization and execution of tasks

Tasks have proven as effective and efficient means to structure knowledge work. A recent approach is task-centric software development, indicated by e.g. one million downloads of the task-centric development support tool MyLyn [12]. Still, task concepts in knowledge work and also software development are mainly utilized as mechanism to support a user in executing his tasks by organizing information objects. The Task Pattern concept has been proposed to re-use task execution knowledge to share experience and support the retrieval of structured information in a community.

3.1 Task-centric Software Engineering

Task-centric Software Development is the organization of programming activities based on tasks using e.g. a task management system. One respective application is MyLyn [5], an extension for the Eclipse IDE which observes the lines of code a user works on for a specific task. MyLyn is based on the following assumption: *The longer a user works on a specific element of the code in a task context, the higher is its relevance for the task.* Empirical studies [13] prove that this assumption holds. Thus the software code can be organized in terms of tasks. If a developer interrupts a coding task and has to come back to it later, MyLyn filters the code resources based on the earlier observed relevant lines of code thus increasing the speed of resource access.

MyLyn allows to share the relevant code parts for tasks in a given project in a community. This allows a community to understand certain lines of code as product of a coding task. This is a good first step, but lacks additional information. The process which lead to the product needs to be transferred additionally to provide more understanding, following Floyds process-product complementary view on software development [4]. Code examples might be worthless for a novice who can not access information describing involved technologies and frameworks. This information most probably has been used during the process of coding. This implicitly has been taken up by the developers of MyLyn, as they recently introduced Tasktop. Tasktop extends MyLyn beyond the observation of code relevant for a task: it observes the interaction with different kinds of information objects like e-mails, documents and web-resources as well. The data collected by MyLyn and Tasktop seems to be a valuable basis for task support beyond the individual organization. Both is integrated in Tasktop Pro for Eclipse. A structure to organize the data respectively can be Task Patterns which are introduced in the following.

3.2 Task Patterns to share work experience

Task Patterns are a structure to support individual task execution and to realize tool-supported experience sharing in knowledge work. They hint to working activities and information objects necessary to execute a specific class of tasks. For a user Task Patterns recommend work activities based on Abstraction Services. These Services support users in identifying subtasks, information objects or persons to collaborate with for a specific purpose in a given task class. They are capable to describe aspects of a task on different abstraction levels as described in [10].

Task Patterns are not centrally organized but originate from abstractions of different degrees on user task executions. These executions are explicit in task-centric information system[2] which can be extended by Task Pattern functionality. As such an interplay between a user task and the respective Task Pattern realizes an enhancement life-cycle [7]: by connecting task and Task Pattern and enriching the task by the abstracted pattern data each pattern re-use in the community enhances the pattern, as described in [10]. As such the Task Pattern is a structure for a knowledge worker to learn how to execute a task, meanwhile the structure is implicitly enriched by the knowledge worker himself. The resulting pattern is a community effort as it structures knowledge from real task executions in the community in a re-usable way. In the following we explain the concept of Task Patterns with Abstraction Services to support software engineering activities.

4 Task Patterns for Software Engineering

Software development tasks in general result in the creation of program code as product of the tasks. To create the respective program code developers often need to look up different information or learn specific techniques by using different information objects like API descriptions, wikis, development handbooks etc.

4.1 Structure and life-cycle of Task Pattern in Software Engineering

As described, task-centric software development uses tools like Tasktop Pro to automatically structure code and resources by means of tasks. We re-use this information for Task Patterns which mesh up the different types of information: code examples which stand for the product and abstract descriptions which help to understand the process which lead to the product. Currently these information types are not centrally organized, as code is spread across the development project source files and other resources need to be accessed via folder structure for files and bookmarks for web-resources. This leads to tedious informationretrieval activities by the developer and a retrieval process which often uses external data-sources like e.g. google code or development forums.

Next to Abstraction Services for information objects like documents, bookmarks or persons which help to structure documents or serve as expert finder, a Code Abstraction Service serves as central collector for code examples. A Code Abstraction Service basically collects program code which was created to solve tasks described by the Task Pattern. It allows the user to identify relevant passages which can be re-used to execute a new task. Thus it serves as a cheat-sheet to highlight code solving a certain problem in the context of a program.

As different types of information are included in a Task Pattern, a developer can decide to what extent which type of support is necessary. Experts might get support by code examples meanwhile novices need to understand the context and design process itself and have to refer to abstract information. By combining both, Task Patterns allow developers to balance their information requirements.

The creation of a Task Pattern and the life-cycle of integrated Task Pattern use and Task Pattern enhancement is shown in figure 1. After finishing a development task which has been organized using Tasktop the user decides to transform the information into a Task Pattern. To create a Task Pattern a user only has to name a Task Pattern and decide which elements observed by Tasktop are to be wrapped up by Abstraction Services. Abstraction Services allow to structure similar kinds of information and to describe their purpose for the task (Abstraction layer in figure 1). The program code created during the execution of a task gets included in a Code Abstraction Service. The resulting Task Pattern is stored in a public Task Pattern Repository. This repository can be accessed by all developers which can make use of the pattern and enhance it by their respective activities.



Fig. 1. Realization of a life-cycle

4.2 An example of Task Pattern in software engineering

The following example shows the application of Task Pattern. We assume that there is a community-embedded collaborative development environment (CCDE) that supports informal communication amongst developers and serves as project management tool for multiple different projects at the same time (cf. [8]). Furthermore we assume that the CCDE hosts multiple projects that connect with the social photo sharing site Flickr (http://www.flickr.com). So various developers from different projects try to upload photos to and display photos from Flickr using different programming languages. All developers are structuring their daily work using Tasktop and make use of the possibility to create, enhance and use patterns in the context of their local tasks. This already has resulted in a pattern on accessing and displaying Flickr photos. The pattern includes software code from 5 different tasks of this kind, realizing photo display in different user interfaces. An additional excerpt from the Flickr API and a "how-to" document are attached as well as a short e-mail discussion on caching of photo sets to increase the accessibility.

A developer wants to display Flickr photos. He queries the Task Pattern repository and identifies the described pattern based on its name. He attaches this pattern to his new task. Using Abstraction Services, the developer accesses the code examples but has problems in understanding specific parts of the implemented code. He refers to the attached documents which enable him to understand and re-use parts of the given code. Additionally he asks a colleague on a specific visualization technique including filters and receives a document on this. The document gets included in his tasktop system, as all his activities are tracked by the system. Due to the connection between task and Task Pattern the developer easily can attach the additional information to the pattern. The Code created by him gets automatically attached to the Code Abstraction Service.

4.3 Integrating Task Patterns into the IDE

As a realization we propose the extension of Tasktop Pro for Eclipse by interaction functionalities with Task Patterns and Abstraction Services as visible in the mockup fig. 2. A Task Pattern gives access to the Abstraction Services which provide access to documents, web resources, e-mails and example code (1). The example code can be used by an additional code view to browse the program code collected by the Abstraction Service during all different execution processes (2). The task list has to be extended by a mechanism to attach Task Pattern to tasks and the task list must show the attached Pattern with Abstraction Services to the activated tasks. This application is currently under development at the University of Paderborn.

5 Discussion

Task Patterns in Software Engineering have been introduced as structure which re-uses task information to realize experience sharing. Thereby Task Pattern



Task Patterns to support task-centric Social Software Engineering

Fig. 2. Example for Code Abstraction Service in Eclipse

extend the scope of task-centric software development tools from an organizational and analytical scope towards a tool supported awareness of the execution process. This supports software development as social process, providing shared understanding of problems and awareness of different problem solving types.

The re-use of the Task Pattern concept shows its applicability to different, more specialized domains of knowledge work. The domain of software engineering shows a specific benefit: one can assume that the product of most tasks is code. This allows the easy identification of information resources which represent the process of problem understanding and solving including the resulting code as product. Thus, one can provide a combination of resources to support the process of problem based learning and the examples of working products. The re-use of a tool like Tasktop Pro especially allows the extensive automation of the involved Task Pattern life-cycle [10]. Task Patterns for software engineering focus on support of the individual solution of discrete, individual programming tasks. With embedding Task Patterns for software engineering in a CCDE developers can make use of social processes of recommendation and tagging and thus share experience on similar, re-occurring tasks in a structured form which integrates support for the understanding of the development process as well as for the generated product.

The presented integration of the Task Pattern approach for social software engineering is currently under development at the University of Paderborn within

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the scope of a master's thesis. The results will be evaluated and used to enhance the social experience within software engineering projects and help users to find help from others.

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Abstract

This paper offers an excerpt of a chapter that will appear later in the First Handbook on Recommender Systems. It focuses on the field of Technology enhanced learning (TEL) that aims to design, develop and test socio-technical innovations that support and enhance learning practices of both individuals and organisations. TEL is therefore an application domain that generally covers technologies that support all forms of teaching and learning activities. Since information retrieval (in terms of searching for relevant learning resources to support teachers or learners) is a pivotal activity in TEL, the deployment of recommender systems has attracted increased interest. This chapter attempts to provide an introduction to recommender systems for TEL settings, as well as to highlight their particularities compared to recommender systems for other application domains. 2 Nikos Manouselis1, Hendrik Drachsler2, Riina Vuorikari2,3, Hans Hummel2, Rob Koper2

Introduction

As in any other field where there is a massive increase in product variety, in Technology Enhanced Learning (TEL) there is also a need for better findability of (mainly digital) learning resources. For instance, during the past few years, numerous repositories with digital learning resources have been set up (Tzikopoulos et al., 2007). A prominent European example is European Schoolnet's Learning Resource Exchange (http://lreforschools.eun.org) that federates more than 43,000 learning resources from 25 different content providers in Europe and beyond. The US examples are repositories such as MERLOT (http:// www.merlot.org) that has more than 20,000 learning resources (and about 70,000 registered users) and OER Commons (http://www.oercommons.org) with about 18,000 resources. Apart from learning content, learning resources may also include learning paths (that can help them navigate through appropriate learning resources) or relevant peer-learners (with whom collaborative learning activities can take place).

In this plethora of online learning resources available, and considering the various opportunities for interacting with such resources that often occur in both formal and non-formal settings, all user groups of TEL systems can benefit from services that help them identify suitable learning resources from a potentially overwhelming variety of choices. As a consequence, the concept of recommender systems has already appeared in the TEL-domain. Latest efforts to identify relevant research in this field, and to bring together researchers working on similar topics, have been the annual workshop series of Social Information Retrieval for Technology Enhanced Learning (SIRTEL), and a Special Issue on Social Information Retrieval for TEL in the Journal of Digital Information (Duval et al., 2009). These efforts resulted in a number of interesting conclusions, the main ones being that:

- a) There is a large number of recommender systems that have been deployed (or that are currently under deployment) in TEL settings;
- b) The information retrieval goals that TEL recommenders try to achieve are often different to the ones identified in other systems (e.g. product recommenders);
- c) There is a need to identify the particularities of TEL recommender systems, in order to elaborate on methods for their systematic design, development and evaluation.

In this direction, the present chapter attempts to provide an introduction to issues related to the deployment of recommender systems in TEL settings, keeping in mind the particularities of this application domain. The main contributions of this chapter are the following:

- Discuss the background of recommender systems in TEL, particularly in relation to the particularities of TEL context.
- Reflect on user tasks that are supported in TEL settings, and how they compare to typical user tasks in other recommender systems.
- Review related work coming from adaptive educational hypermedia (AEH) systems and the learning networks (LN) concept.
- Assess the current status of development of TEL recommender systems.
- Provide an outline of particularities and requirements related to the evaluation of TEL recommender systems that can provide a basis for their further application and research in educational applications.

Background

TEL as context

Technology Enhanced Learning and the analysis of the data it generates take place in different types of educational settings which are called macro-context (Vuorikari & Berendt, 2009). It generally has significant influence on what user actions are possible and how they can be interpreted. Examples of these dimensions of macro-context include dimensions such as educational level, formal and informal learning, delivery setting and different user roles.

Examples of the educational level are K-12 education, Higher Education (HE), Vocational Education and Training (VET) and workplace training. A formal setting for learning includes learning offers from educational institutions (e.g. universities, schools) within a curriculum or syllabus framework, and is characterised as highly structured, leading to a specific accreditation and involving domain experts to guarantee quality. This traditionally occurs in teacher-directed environments with person-to-person interactions, in a live and synchronous manner.

An informal setting, on the other hand, is described in the literature as a learning phase of so-called lifelong learners who are not participating in any formal learning and are responsible for their own learning pace and path (Colley, Hodkinson & Malcom, 2002; Longworth, 2003). The learning process depends to a large extent on individual preferences or choices and is often self-directed (Brockett & Hiemstra, 1991). The resources for informal learning might come from sources such as expert communities, work context, training or even friends might offer an opportunity for an informal competence development.

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The TEL involvement can be characterised by the provision of blended learning opportunities to purely distant educational ones (Moore, 2003). Blended learning combines traditional face-to-face learning with computer-supported learning (Graham, 2005). Distance education, on the other hand, can be delivered using TEL environments in either synchronous or asynchronous ways. Traditionally, distance learning was more related to self-paced learning and learning-materials interactions that typically occurred in an asynchronous way (Graham, 2005). However, live streaming and virtual, personal learning environments (e.g. Web 2.0) have facilitated the development of synchronous distance learning services in formal educational settings.

Lastly, different actors and needs can be identified in TEL. A distinction can be made between the teacher-directed interaction and learner-directed learning processes. This has ramifications concerning the intended users of TEL environments. This thesis, for example, considers teachers as main users of the system.

While macro-context has large implications for interpretation and design, its aspects are fairly agreed-upon, and it is comparatively easy to measure. Microcontext is a more contested notion and more difficult to measure. However, while macro-context is domain-specific, concepts for micro-context range over more diverse fields.

TEL Recommendation goals

In the past, the development of recommender systems has been related to a number of relevant user tasks that the recommender system supports within some particular application content. More specifically, Herlocker et al. (2004) have related popular (or less popular) user tasks with recommendation goals:

- Annotation in Context. Providing recommendations while the user is carrying out some other tasks. E.g. Web-recommenders that provide predictions about existing links in the user's typical browsing environment.
- Find Good Items. The core recommendation task, recommending users with a number of suggested items. E.g. systems where good items are recommended, often without explaining why these ones are chosen (e.g. showing predicted rating values).
- Find All Good Items. Providing recommendations in domains where information completeness is a critical factor (e.g. health or legal cases). It concerns recommending users with an exhaustive list of all relevant items.
- **Recommend Sequence**. Very relevant in systems where users are "consuming" items in a sequence (i.e. one after the other), such as personalised radio

and TV applications. It concerns the recommendation of a whole sequence of items, instead of simply a subset of relevant ones.

- Just Browsing. Relevant in cases where recommendation is not supporting relevant or "equally good" items, but is trying to expand the search coverage with novel or serendipitous suggestions. It provides a recommended list of good items or some annotation in context, but the rationale for the recommendation is different.
- Find Credible Recommender. Relevant in the early stages of getting familiarised with a recommender system, when users want to explore and validate the credibility of the system. Good items or annotations in content can be provided, but the rationale of recommendation may differ (e.g. providing very few novel or serendipitous suggestions that could surprise the users).

Generally speaking, most of the above identified recommendation goals and user tasks are valid in the case of TEL recommender systems as well. For example, a recommender system supporting learners to achieve a specific learning goal, "providing annotation in context" or "recommending a sequence" of learning resources are relevant tasks. However, in comparison to the typical item recommendation scenario, there are several particularities to be considered regarding what kind of learning is desired, e.g. learning a new concept or reinforce existing knowledge may require different type of learning resources. Moreover, for learners with no prior knowledge in a specific domain, relevant pedagogical rules such as Vygotsky's "zone of proximal development" should be applied, e.g. 'recommended learning objects should have a level slightly above learners' current competence level', (Vygotsky 1978).

Different from buying products, learning is an effort that often takes more time and interactions compared to a commercial transaction. Learners rarely achieve a final end state after a fixed time. Instead of buying a product and then owning it, learners achieve different levels of competences that have various levels in different domains. In such scenarios, what is important is identifying the relevant learning goals and supporting learners in achieving them. On the other hand, depending on the context, some particular user task may be prioritised. This could call for recommendations whose time span is longer than the one of product recommendations, or recommendations of similar learning resources, since recapitulation and reiteration are central tasks of the learning process (McCalla 2004).

As for teacher-centred learning context, different tasks need to be supported. These tasks can be broadly distinguished into the ones related to the preparation of lessons, the delivery of the lesson (i.e. the actual teaching), and the ones related to the evaluation. For instance, to prepare a lesson the teacher has certain educational goals to fulfil and needs to match the delivery methods to the profile of the learners (e.g. their previous knowledge). Lesson preparation can include a variety of information seeking tasks, such as finding content to motivate the learners, to recall

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existing knowledge, to illustrate, visualise and represent new concepts and information. The delivery can be supported in using different pedagogical methods (either supported with TEL or not), whose effectiveness is evaluated according to the goals set. A TEL recommender system could support one or more of these tasks, leading to a variety of recommendation goals.

Thus, although the previously identified user tasks and recommendation goals can be considered valid in a TEL context, there are several particularities and complexities. This means that simply transferring a recommender system from an existing (e.g. commercial) content to TEL may not accurately meet the needs of the targeted users. In TEL, careful analysis of the targeted users and their supported tasks should be carried out, before a recommendation goal is defined and a recommender system is deployed. This means that the TEL recommendation goals can be rather complex: for example, a typical TEL recommender system could suggest a number of alternative learning paths throughout a variety of learning resources, either in the form of learning sequences or hierarchies of interacting learning resources. This should take place in a pedagogically meaningful way that will reflect the individual learning goals and targeted competence levels of the user, depending on proficiency levels, specific interests and the intended application context.

Therefore, the task analysis of TEL recommender systems has to consider a number of context variables such as user attributes, domain characteristics, and intelligent methods that can be engaged to provide personalised recommendations. Extensive work on these topics has been carried out in the past, in the area of adaptive educational hypermedia systems.

Related Work

Web systems generally suffer from the inability to satisfy the heterogeneous needs of many users. To address this challenge, a particular strand of research that has been called *adaptive web systems* (or *adaptive hypermedia*) tried to overcome the shortcomings of traditional 'one-size-fits-all' approaches by exploring ways in which Web-based could adapt their behaviour to the goals, tasks, interests, and other characteristics of interested users (Brusilovsky & Nejdl, 2004). A particular category of adaptive systems has been the one dealing with educational applications, called *adaptive educational hypermedia* (AEH) systems. Since one can say that AEH systems address issues of high relevance to TEL recommender systems, this section provides a brief overview of related work, trying to identify commonalities and differences that could be of relevance for TEL recommenders.

Adaptive Educational Hypermedia

Adaptive web systems belong to the class of user-adaptive software systems (Schneider-Hufschmidt et al., 1993). According to (Oppermann, 1994) a system is called adaptive "if it is able to change its own characteristics automatically according to the user's needs". Adaptive systems consider the way the user interacts with the system and modify the interface presentation or the system behaviour accordingly (Weibenzahl, 2003). Jameson (2001) adds an important characteristic: "A user-adaptive system is an interactive system which adapts its behaviour to each individual user on the basis of nontrivial inferences from information about that user".

Adaptive systems help users find relevant items in a usually large information space, by essentially engaging three main adaptation technologies (Brusilovsky & Nejdl, 2004): adaptive content selection, adaptive navigation support, and adaptive presentation. The first of these three technologies comes from the field of adaptive information retrieval (IR) (Baudisch, 2001) and is associated with a search-based access to information. When the user searches for relevant information, the system can adaptively select and prioritise the most relevant items. The second technology was introduced by adaptive hypermedia systems (Brusilovsky, 1996) and is associated with a browsing-based access to information. When the user navigates from one item to another, the system can manipulate the links (e.g., hide, sort, annotate) to guide the user adaptively to most relevant information items. The third technology has its roots in the research on adaptive explanation and adaptive presentation in intelligent systems (Moore and Swartout, 1989; Paris, 1988). It deals with presentation, not access to information. When the user gets to a particular page, the system can present its content adaptively.

As Brusilovksy (2001) describes, educational hypermedia was one of the first application areas of adaptive systems. A number of pioneer adaptive educational hypermedia systems were developed between 1990 and 1996, which he roughly divided into two research streams. The systems of one of these streams were created by researchers in the area of intelligent tutoring systems (ITS) who were trying to extend traditional student modelling and adaptation approaches developed in this field to ITS with hypermedia components (Beaumont, 1994; Brusilovsky, Pesin, & Zyryanov, 1993; Gonschorek, & Herzog, 1995; Pérez, Lopistéguy, Gutiérrez, & Usandizaga, 1995). The systems of the other stream were developed by researchers working on educational hypermedia in an attempt to make their systems adapt to individual students (De Bra, 1996; de La Passardiere, & Dufresne, 1992; Hohl, Böcker, & Gunzenhäuser, 1996; Kay, & Kummerfeld, 1994). AEH research has often followed a top- down approach, greatly depending on expert knowledge and involvement in order to identify and model TEL context variables. For example, Cristea (2005) describes a number of expertise-demanding tasks when AEH con-

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tent is authored: initially creating the resources, labelling them, combining them into what is known as a domain model; then, constructing and maintaining the user model in a static or dynamic way, since it is crucial for achieving successful adaptation in AEH. Generally speaking, in AEH a large amount of user-related information (characterising needs and desires) has to be encoded in the content creation phase. This can take place in formal educational settings when the context variables are usually known, and there is a large amount of AEH research (e.g. dealing with learner and domain models) that can be considered and reused within TEL recommender research. On the other hand, in non-formal settings less expertdemanding approaches need to be explored.

Learning Networks

Another strand of work includes research where the context variables are extracted from the contributions of the users. A category of such systems includes *learning networks*, which connect distributed learners and providers in certain domains (Koper & Tattersall, 2004; Koper et al., 2005). The design and development of learning networks is highly flexible, learner-centric and evolving from the bottom upwards, going beyond formal course and programme-centric models that are imposed from the top downwards. A learning network is populated with many learners and learning activities provided by different stakeholders. Each user is allowed to add, edit, delete or evaluate learning resources at any time.





Figure 1: Starting phase of a learning network with a first learner moving through possible learning activities.

Figure 2: Advanced phase of a learning network, showing emerged learning paths caused by the collective behaviour of all learners in the network.

The concept of learning networks (Koper, Rusman, Sloep, 2005) provides meth-

ods and technical infrastructures for distributed lifelong learners to support their personal competence development. It takes advantages of the possibilities of the Web 2.0 developments and describes the new dynamics of learning in the net-worked knowledge society. A learning network is learner-centred and its development emerges from the bottom-up through the participation of the learners. Emergence is the central idea of the learning network concept. Emergence appears when an interacting system of individual actors and resources self-organises to shape higher-level patterns of behavior (Gordon, 1999; Johnson, 2001; Waldrop, 1992).

We can imagine users (e.g. learners) interacting with learning activities in a learning network while their progress is being recorded. Indirect measures like time or learning outcomes, and direct measures like ratings and tags given by users allow identify paths in a learning network which are faster to complete or more attractive than others (e.g. Drachsler at al., 2009; Vuorikari & Koper, 2009). This information can be fed back to other learners in the learning network, providing collective knowledge of the 'swarm of learners' in the learning network. Most learning environments are designed only top-down as oftentimes their structure, learning networks, on the other hand, take advantage of the user-generated content that is created, shared, rated and adjusted by using Web 2.0 technologies. In the field of TEL several European projects address these bottom-up approaches of creating and sharing knowledge. A large EU-initiative that addresses the creation of informal learning networks is the TENcompetence project (Wilson et al., 2008).

Another category of systems that formulate and define their context variables following a bottom-up approach, are Mash-Up Personal Learning Environments (MUPPLE) (Wild et al., 2008). First such approaches were created by (Liber, 2000; Liber & Johnson, 2008; Wild et al., 2008; Wilson, 2005). The iCamp EU initiative explicitly addresses the integration of Web2.0 sources into MUPPLE, by creating a flexible environment that allows learners to create their own environments for certain learning activities. MUPPLEs are a kind of instance of the learning network concept and therefore share several characteristics with it. They also support informal learning as they require no institutional background and focus on the learner instead of institutional needs like student management or assessments. The learners do not participate in formal courses and neither receive any certification for their competence development. A common problem for MUPPLEs is the amount of data that is gathered already in a short time frame and the unstructured way it is collected. This can make the process of user and domain modelling demanding and unstructured. On the other hand, this is often the case in recommender systems as well, when user and item interactions are explored, e.g. in order to identify user and item similarities.

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Similarities and differences

Many of the AEH systems address formal learning (e.g. Aroyo et al. 2003; De Bra et al. 2002; Kravcik et al. 2004), have equally fine-granulated knowledge domains and can therefore offer personalised recommendations to the learners. They take advantage of technologies like metadata and ontologies to define the relationships, conditions, and dependencies of learning resources and learner models. These systems are mainly used in 'closed-corpus' applications (Brusilovsky & Henze, 2007) where the learning resources can be described by an educational designer through semantic relationships and is therefore a formal learning offer. As mentioned before, in formal educational settings (such as universities) there are usually wellstructured formal relationships like predefined learning plans (curriculum) with locations, student/teacher profiles, and accreditation procedures. All this metadata can be used to recommend courses or personalise learning through the adaptation of the learning resources or the learning environment to the students (Baldoni et al. 2007). One interesting direction in this research is the work on adaptive sequencing which takes into account individual characteristics and preferences for sequencing learning resources (Karampiperis & Sampson, 2005). In AEH there are many design activities needed before the runtime and also during the maintenance of the learning environment. In addition, the knowledge domains in the learning environment need to be described in detail. These aspects make adaptive sequencing and other adaptive hypermedia techniques less applicable for TEL recommendation, where informal learning networks emerge without any highly structured domain model representation.

In informal learning networks, mining techniques need to be used in order to create some representation of the user or domain model. For instance, prior knowledge in informal learning is a rather diffuse parameter because it relies on information given by the learners without any standardisation. To handle the dynamic and diffuse characteristic of prior knowledge, and to bridge the absence of a knowledge domain model, probabilistic techniques like latent semantic analysis are promising (van Bruggen et al., 2004). The absence of maintenance and structure in informal learning is also called the 'open corpus problem'. The open corpus problem applies when an unlimited set of documents is given that cannot be manually structured and indexed with domain concepts and metadata from a community (Brusilovsky and Henze 2007). The open corpus problem also applies to informal learning networks. Therefore, bottom-up recommendation techniques like collaborative filtering are more appropriate because they require nearly no maintenance and improve through the emergent behaviour of the community. Drachsler, Hummel and Koper (2008) analysed how various types of collaborative filtering techniques can be used to support learners in informal learning networks. Following their conclusions we have to consider the different environmental conditions of informal learning, such as the lack of maintenance and less formal struc-

tured learning objects, in order to provide an appropriated navigation support to recommender systems. Learning networks are mainly structured by tags and ratings given by their users, being therefore in contrast with the institutionalised Virtual Learning Environments (VLEs) like Moodle or Blackboard that are used to better manage learning activities and distribute learning resources to learners.

Besides the already mentioned differences for prior knowledge in informal learning, there are also differences in the data sets which are derived from environmental conditions. Normally, the numbers of ratings obtained in recommender systems is usually very small compared to the number of ratings that have to be predicted. Effective prediction by ratings based on small amounts is very essential for recommender systems and has an effect on the selection of a specific recommendation technique. Formal learning can rely on regular evaluations of experts or students upon multiple criteria (e.g., pedagogical quality, technical quality, ease of use) (Manouselis et al., 2007), but in informal learning environments such evaluation procedures are unstructured and few. Formal learning environments like universities often have integrated evaluation procedures for a regular quality evaluation to report to their funding body. With these integrated evaluation procedures more dense data sets can be expected. As a conclusion, the data sets in informal learning context are characterised by the "Sparsity problem" caused by sparse ratings in the data set. Multi-criteria ratings could be beneficial for informal learning to overcome the "Sparsity problem" of the data sets. These multi-criteria ratings have to be reasonable for the community of lifelong learners. The community could rate learning resources on various levels, such as required prior knowledge level (novice to expert), the presentation style of learning resources, and even the level of attractiveness, because keeping students satisfied and motivated is a vital criteria in informal learning. These explicit rating procedures should be supported with several indirect measures, such as "Amount of learners using the learning resource", "Amount of adjustments of a learning resources", in order to measure how up-to-date the learning resource is.

Informal learning is therefore different from well-structured domains, like formal learning. Recommender systems for informal learning have no official maintenance by an institution, mostly rely on its community and most of the time do not contain well-defined metadata structures. Moreover, where formal learning is characteristically top-down designed and develop learning offers (closed-corpus), informal learning offers are emerging from the bottom-up through the communities (open-corpus). Therefore, it will be difficult to transfer and apply recommender systems even from formal to non-formal settings (and vice-versa), since user tasks and recommendation goals are often substantially different.

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Survey of TEL Recommender Systems

In the TEL-domain a number of recommender systems have been introduced in order to propose learning resources to users. Such systems could potentially play an important educational role, considering the variety of learning resources that are published online and the benefits of collaboration between tutors and learners (Recker & Wiley, 2000; Recker & Wiley, 2001; Kumar, al., 2005). The following tables provides a selection of some typical approaches, as well as an assessment of their status of development and evaluation.

One of the first attempts to develop a collaborative filtering system for learning resources has been the Altered Vista system (Recker & Walker, 2003; Recker et al., 2003; Walker et al., 2004). The aim of this study was to explore how to collect user-provided evaluations of learning resources, and then to propagate them in the form of word-of-mouth recommendations about the qualities of the resources. The team working on Altered Vista explored several relevant issues, such as the design of its interface (Recker & Wiley, 2000), the development of non-authoritative metadata to store user-provided evaluations (Recker & Wiley, 2001), the design of the system and the review scheme it uses (Recker & Walker, 2003), as well as results from pilot and empirical studies from using the system to recommend to the members of a community both interesting resources and people with similar tastes and beliefs (Recker et a., 2003; Walker et al., 2004).

Another system that has been proposed for the recommendation of learning resources is the RACOFI (Rule-Applying Collaborative Filtering) Composer system (Anderson et al., 2003; Lemire et al., 2005; Lemire, 2005). RACOFI combines two recommendation approaches by integrating a collaborative filtering engine, that works with ratings that users provide for learning resources, with an inference rule engine that is mining association rules between the learning resources and using them for recommendation. RACOFI studies have not yet assessed the pedagogical value of the recommender, nor do they report some evaluation of the system by users. The RACOFI technology is supporting the commercial site inDiscover (http://www.indiscover.net) for music tracks recommendation. In addition, other researchers have reported adopting RACOFI's approach in their own systems as well (Fiaidhi, 2004).

The QSIA (Questions Sharing and Interactive Assignments) for learning resources sharing, assessing and recommendation has been developed by Rafaeli et al. (2004; 2005). This system is used in the context of online communities, in order to harness the social perspective in learning and to promote collaboration, online recommendation, and further formation of learner communities. Instead of developing a typical automated recommendation process. That is, the user can decide

whether to assume control on who advises (friends) or to use a collaborative filtering service. The system has been implemented and used in the context of several learning situations, such as knowledge sharing among faculty and teaching assistants, high school teachers and among students, but no evaluation results have been reported so far (Rafaeli et al., 2004; 2005).

In this strand of systems for collaborative filtering of learning resources, the CYCLADES system (Avancini & Straccia, 2005) has proposed an environment where users search, access, and evaluate (rate) digital resources available in repositories found through the Open Archives Initiative (OAI, http://www.openarchives.org). Informally, OAI is an agreement between several digital archives providers in order to offer some minimum level of interoperability between them. Thus, such a system can offer recommendations over resources that are stored in different archives and accessed through an open scheme. The recommendations offered by CYCLADES have been evaluated through a pilot study with about 60 users, which focused on testing the performance (predictive accuracy) of several collaborative filtering algorithms.

A related system is the CoFind prototype (Dron et al., 2000a; Dron et al., 2000b). It also used digital resources that are freely available on the Web but it followed a new approach by applying for the first time folksonomies (tags) for recommendations. The CoFind developers stated that predictions according to preferences were inadequate in a learning context and therefore more user driven bottom-up categories like folksonomies are important. A typical, neighbourhood-based set of collaborative filtering algorithms have been tried in order to support learning object recommendation by Manouselis et al. (2007). The innovative aspect of this study is that the engaged algorithms have been multi-attribute ones, allowing the recommendation service to consider multi-dimensional ratings that users provider on learning resources.

A different approach to learning resources' recommendation has been followed by Shen & Shen (2004). They have developed a recommender system for learning objects that is based on sequencing rules that help users be guided through the concepts of an ontology of topics. The rules are fired when gaps in the competencies of the learners are identified, and then appropriate resources are proposed to the learners. A pilot study with the students of a Network Education college has taken place, providing feedback regarding the users' opinion about the system.

Tang and McCalla proposed an evolving e-learning system, open into new learning resources that may be found online, which includes a hybrid recommendation service (Tang & McCalla 2003; 2004a; 2004b; 2004c; 2005). Their system is mainly used for storing and sharing research papers and glossary terms among university students and industry practitioners. Resources are described (tagged) according to their content and technical aspects, but learners also provide feedback about them in the form of ratings. Recommendation takes place both by engaging a Clustering Module (using data clustering techniques to group learners with similar interests) and a Collaborative Filtering Module (using classic collaborative filtering techniques to identify learners with similar interests in each cluster). The authors studied several techniques to enhance the performance of their system, such as the usage of artificial (simulated) learners (Tang & McCalla, 2004c). They have also performed an evaluation study of the system with real learners (Tang & McCalla, 2005).

A rather simple recommender system without taking into account any preferences or profile information of the learners was applied by Janssen et al. (2005). However, they conducted a large experiment with a control group and an experimental group. They found positive effects on the effectiveness (completion rates of learning objects) though not on efficiency (time taken to complete the learning resources) for the experimental group as compared to the control group.

Nadolski et al. (2009) created a simulation environment for different combination of recommendation algorithms in hybrid recommender system in order to compare them against each other regarding their impact on learners in informal learning networks. They compared various cost intensive ontology based recommendation strategies with light-weight collaborative filtering strategies. Therefore, they created treatment groups for the simulation through combining the recommendation techniques in various ways. Nadolski et al. tested which combination of recommendation techniques in recommendation strategies had a higher effect on the learning outcomes of the learners in a learning network. They concluded that the light-weight collaborative filtering recommendation strategies are not as accurate as the ontology-based strategies but worth-while for informal learning networks when considering the environmental conditions like the lack of maintenance in learning networks. Nadolski et al. study confirmed that providing recommendations leads towards more effective, more satisfied, and faster goal achievement than no recommendation. Furthermore, their study reveals that a light-weight collaborative filtering recommendation technique including a rating mechanism is a good alternative to maintain intensive top-down ontology recommendation techniques.

Moreover, the ISIS system adopts a hybrid approach for recommending learning resources is the one recently proposed by Hummel et al. (2006). The authors build upon a previous simulation study by Koper (2005) in order to propose a system that combines social-based (using data from other learners) with information-based (using metadata from learner profiles and learning activities) in a hybrid recommender system. They also designed an experiment with real learners. Drachsler (accepted) recently reported the experimental results the ISIS experiment. They found a positive significant effect on efficiency (time taken to complete the learning objects) of the learners after a runtime of four months. It is a

very good example of a system that is following the latest trends in learning specifications for representing learner profiles and learning activities.

The same group recently developed a recommender system called ReMashed (Drachsler et. al, 2009a,b) that addresses learners in informal learning networks. They created a mash-up environment that combines sources of users from different Web2.0 services like flickr, delicious.com or Sildeshare. Again they applied a hybrid recommender system that takes advantage of the tag and rating data of the combined Web2.0 sources. The tags that are already given to the Web2.0 sources are used for the cold-start of the recommender system. The users of ReMashed are able to rate the emerging data of all users in the system. The ratings are used for classic collaborative filtering recommendations based on the Duine prediction engine (Van Setten, M., 2005).

The same approach is followed by the proposed Learning Object Recommendation Model (LORM) that also follows a hybrid recommendation algorithmic approach and that describes resources upon multiple attributes, but has not yet reported to be implemented in an actual system (Tsai et al., 2006).

Finally, there have been some recent proposals for systems or algorithms that could be used to support recommendation of learning resources. These included and a case-based reasoning recommender that Gomez-Albarran & Jimenez-Diaz (2009) recently proposed.

Nevertheless, despite the increasing number of systems proposed for recommending learning resources, a closer look to the current status of their development and evaluation reveals the lack of systematic evaluation studies in the context of reallife applications. As Table 1 indicates:

- More than half of the proposed systems (10 out of 16) still remain at a design or prototyping stage of development;
- Only 7 systems have been evaluated through trials that involved human users.

Another interesting observation is that very often, experimental investigation of the recommendation algorithms does not take place. This is a common evaluation practice in systems examined for other domains (e.g. Breese et al., 1998; Deshpande & Karypis, 2004; Papagelis & Plexousakis, 2005; Herlocker et al., 2002), which indicate that careful testing and parameterisation has to be carried out before a recommender system is finally deployed in a real setting. One of the main reasons is that the performance of recommendation algorithms seems to be dependent on the particularities of the application context, therefore, it is advised to experimentally analyse various design choices for a recommender system, before its actual deployment.

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System	Status	Evaluator focus	Evaluation roles
Altered Vista (Recker & Walker, 2000; Recker & Wiley, 2000; Recker & Walker, 2003; Recker et al., 2003; Walker et al., 2003)	Full system	Interface, Algorithm, System usage	Human users
RACOFI (Anderson et al., 2003; Lemire et al., 2005)	Prototype	Algorithm	System designers
QSAI (Rafaeli et al., 2004; Rafaeli et al., 2005)	Full system	-	-
CYCLADES (Avancini & Straccia, 2005)	Full system	Algorithm	System designers
CoFind (Dron et al. 200 a,b)	Prototype	System usage	Human users
Learning object sequencing (Shen & Shen, 2004)	Prototype	System usage	Human users
Evolving e-learning system (Tang & McCalla, 2003; 2004a; 2004b; 2004c; 2005)	Full system	Algorithm, System usage	Simulated users, Human users
ISIS - Hybrid Personalised Recom- mender System (Drachsler et al., 2009)	Prototype	Algorithm, System usage	Human users
Multi-Attribute Recommendation Service (Manouselis et al., 2007)	Prototype	Algorithm	System designers
Learning Object Recommendation Model (Tsai et al., 2006)	Design	-	-
RecoSearch (Fiaidhi, 2004)	Design	-	-
Simulation environment (Nadolski et al., 2009)	Full system	Algorithm	Simulated users

Table 1. Implemented TEL systems reported in literature

ReMashed (Drachsler et al., 2009a,b)	Full system	Algorithm, System usage	Human users
CBR Recommender Interface (Gomez-Albarran & Jimenez-Diaz, 2009)	Prototype	-	-
A2M Recommending System (Santos, 2008)	Prototype	-	-
Moodle Recommender System (Janssen et al., 2005)	Prototype	Algorithm, System usage	Human users

Conclusions and further work

This papers provides an excerpt of a chapter that will appear later in the First Handbook on Recommender Systems. It offers an introduction to the issues related to the deployment of recommender systems in the TEL settings emphasising the particularities of this application domain. To our knowledge, this is the first study attempting to systematically cover the design and deployment of recommender systems in the TEL settings. Nevertheless, it can only provide a brief overview of related issues, leaving several aspects to be further explored and researched.

The paper first discussed the context in which TEL recommenders are deployed, and reflected on related user tasks and recommendation goals. A review of related work coming from the research strands of Adaptive Educational Hypermedia and Learning networks has been provided, with a particular emphasis on how it applies to TEL recommenders for formal and informal learning settings. Then, a survey of TEL recommenders proposed in the literature was presented with a critical view on the actual implementation of systems. This paper has left out the part with a particular emphasis on the evaluation and the discussion on evaluation requirements and issues for TEL recommender systems.

The main research challenge for the future is the one of the systematic development and evaluation of TEL recommender systems. In addition, for the various groups of researchers involved in TEL, a number of topics are of high research interest. For example, the recommendation support for learners in formal and informal learning that takes advantage of contextualised recommender systems has become an important one. These recommender systems, also called context-aware recommender Systems (Lemire et al, 2005), use for example geographical location of a user to recommend relevant resources. Such contextualisation becomes im18 Nikos Manouselis1, Hendrik Drachsler2, Riina Vuorikari2,3, Hans Hummel2, Rob Koper2

portant in situations where multilingual educational resources are recommended from a federation of repositories from a number of countries with different learning standards and/or institutions with different curricula (Vuorikari & Ochoa, 2009). Additionally, context awareness could include pedagogical aspects like prior knowledge, learning goals or study time to embed pedagogical reasoning into collaborative filtering driven recommendations.

Another promising approach is the use of multi-criteria input for recommender system in TEL. Users (learners and teachers) can not only rate learning resource based on the level of complexity, curriculum alignment or how much time is required to cover the learning material, but input also could be inferred from different implicit sources. Such multidimensional input can potentially have a high impact on the suitability of recommendations. A related problem is the lack of TEL specific data sets for informal and formal learning. Different to the recommender system world, where many data sets are available (e.g. MovieLens, BookCrossing, Jester Collaborative Filtering Dataset), the TEL community is still working with rather small home-made data sets, which are rarely public available.

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