MACE – enriching architectural learning objects for experience multiplication

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Abstract. Education in architecture requires access to a broad range of architectural learning material to develop flexibility and creativity in design. The learning material is compromised of digital information captured in textual and visual media including single images, videos, description of architectural concepts or complete architectural projects, i.e. digital artifacts on different aggregation levels. The repositories storing such information are not interrelated and do not provide unified access so that retrieval of architectural learning objects is cumbersome and time consuming. In this paper, we describe how an infrastructure of federated architectural learning repositories will provide unique, integrated access facilities for high quality architectural content. The integration of various types of content, usage, social and contextual metadata enables users to develop multiple perspectives and navigation paths that support experience multiplication for the user. A service–oriented software architecture that is based on open standards, and a flexible user interface design solutions based on widgets ensure easy integration and re-combinability of contents, metadata and functionalities.

Keywords. Metadata, learning objects, experience multiplication, architectural design, content enrichment, technology enhanced learning

Introduction

Architecture is a complex discipline, where technical and artistic knowledge blend, and influence each other. Due to this double influence, it happens that there is not an “exact” and “unique” solution to architectural design problems. Therefore the architect, while developing a project, will remember, compare, choose and re-elaborate a large stock of possible solutions, moving towards the final outcome step by step. The background of this process is the architect’s self personal stock of erudition and culture, which mainly consists of images and visual inputs, stored through years in his memory in a life-long process. These visual memories can be about the most different aspects of the subject: from architectonic solutions and shapes to examples of applied theory, suggestions, or personal experiences…

The design solutions produced by an architect therefore are, most of the time, the outcome of a process of images recalling and reworking: the aim of achieving new solutions and shapes is reached through the designer’s personal contribution in the interpretation of something already seen and known. [Condotta, Del Ponte 2002 - Beckmann 1998]. In fact, the mnemonic process which leads the design activity is based on “the repeated view of the same objects”,: this condition “entails the setting up, in the nervous system, of experiences (or better, of habits) by virtue of elements (notions, images, …) that are repeatedly near in space and time” [Vicario 1991]; so, while an architect is working on his personal stock of erudition and culture, his mind will mostly return back only the notions that are perceived as more familiar: in this way, a first selection, and therefore a limitation, is operated on the architect’s personal knowledge set.

Evidently, when we focus on architecture education, the case-based aspects of these mental processes are amplified and carried to extremes: when the students are little experienced, they will need a very wide range of possible suggestion providers, and a higher number of examples to look at. This not only entails a broad information need during architectural design; moreover, the same piece of information might be interesting for several reasons, depending on the actual state of the design process.

It should finally be considered that in architecture, as in other disciplines, a large amount of information is held in visual media (images, photos, sketches…), which are in general hard to index and find. Most currently available search tools do not offer the multiple perspectives and exploratory search needed to support effective and seamless interaction within the domain of architecture and engineering.

For these reasons, non-expert designers and students spend a lot of time in libraries, searching for a large number of cases similar to their actual situation, to get cues and suggestions on how to proceed, thus carrying out this activity in a very inefficient and time-wasting way. This happens because of the great variety of information that can be inferred from a single volume, despite its title or general subject (i.e. a technical solution for a window frame detail may often be deduced observing a picture in a monograph on a great architect, and not from a technology manual).

It would probably be of great help to architecture students to spread around all the pages from their books, like the tesserae of a muddle up mosaic of images, drawings, sketches, graphic schemes, to be able to walk through them - ready to catch those contents that can solve the problem.

Given the fact that a considerable part of the knowledge which was once ink-written in architecture books is being moved to digital media, we can get closer to enabling this vision: We can use an enormous mass of factored notions (the single Learning Objects and Assets), which at the moment is spread in a cloud-like shape of notions, but may be re-structured for multiple experiences.

One of MACE project aims is to create the core of a possible future common indexing strategy to structure all these actually rambling “pieces” of architectural information. The final goal is to allow learners to have, through strengthening and optimizing the on–going knowledge digitalization process, a new way of exploring notions and knowledge: a multiplication of the learning opportunity held using the web as a *collective external memory*.

Digital media for experience multiplication in architectural design process

In the field of computer aided architectural design (CAD), the computer can be useful in the generative process of a project [Lynn 1999 - Pongratz, Perbellini 2000 – Imperiale 2000]. Through 3D-modelling software (and other kinds of graphic and technical software), a computer can assist the designer to create sharable, storable and visible representations of personal ideas and suggestions. By proposing an infinite range of new and unexpected shapes, diagrams, or colours or by applying different clustering, ordering, or indexing strategies, computer systems can extend the limit of obtaining and getting solutions from a finite cluster of elements (the personal background of the designer).

This multiplication of perspectives and experiences is important for digital media to allow architects and students to have a new way of exploring notions and knowledge.

One consequence of the ongoing data digitalization process is the so-called “micro-chunking” of information. This is not only an effect of the technologies used to search, publish and communicate information (such as search engines, blogging software, or federated learning object repositories) but also the changing consumption behavior of the users and the according social practices [Beale 2005]. Providing the right tools for exploration and recombination of these information chunks can lead to novel and rich experiences: the revising of the project’s formative elements (context, suggestions, ideas, diagrams, functions, shapes, images, etc.) as factored digital data, as a re-mix of dynamic collections, recombination and juxtapositions, can lead to previously unavailable insights and discoveries.

A second consequence is the availability of a large amount of meta-information for a given piece of notion: who links to that page, how did others like this book, etc. — all these kinds of contextual information are already accessible on the web, however, still distributed over different services and not yet specific for the architectural domain.

In the domain of architectural design, (but also in various sectors of the discipline like history research, representation techniques, urban studies, etc…), we can regard digital media and the web as ***experience multipliers***: a digitally assisted design process can have a more complex recombination of multi-facetted, mosaic-like agglomerate of loosely connected information and meta-information. In particular, these additional information can be used not only as raw data, but they can trigger new mental processes.

The tasks of the MACE project is to support the shaping and reorganization this already existing cloud of floating, unorganized information by making it navigable, usable and accessible to an architectural learner. The goal will be reached by creating a system which allows the end user both to enlarge his set of visual memories and to enrich the existing online *"collective external memory"* by recognizing, catching and linking the contents through an interactive navigation system, which has to reflect the typical logical behaviour of an architectural learner.

Architectural digital media characteristics: strategies for mosaic recomposition

This kind of access to the contents is not yet enabled, for both the architectural discipline and visual media peculiar features. It is necessary to find new indexing strategies, capable to structure a high number of Learning Objects (LO), with the aim of reaching the maximum utility for the final user. Obviously, indexing strategies have to be suitable to the treated discipline; they will have to follow the logic pattern of the user navigating through this contents cloud, and they will have to support his choice criteria.

Choice criteria are many, but can refer to four main typical features of the signifier/signified binomial composing a LO. At first, obviously, the *content* and the *domain* meta-information of the LO will drive the choice of the user, even if this choice is very often influenced or led by *usage* experiences made by others and by the comprehension of their exploration and learning paths. In other situations, the user's and content's *levels of competence,* or the *context,* in which the LO is inserted, might be key to accessing the right kind of information.

MACE—Metadata for Architectural Contents in Europe

MACE sets out to integrate architectural learning contents from Learning Object Repositories (LORs) spread around Europe, and enrich them with different types of metadata and classification structures in order to enable improved access and experience multiplication for students, teachers and professionals. Enrichment here includes both the manual and automatic provision of metadata about the learning object itself, its contents or the context of their usage (including social metadata, competence metadata and contextual metadata).

An overview of currently integrated content repositories can be seen in Table 1. The available contents range from multimedia resources about architectural projects over technology enhanced learning courses to literature references and regulations. Our open, standards–based infrastructure allows an integration of further content databases in the future.

Content source	# Objects	# Metadata	Metadata level
WINDS	5529 compound objects, 10542 single content blocks (text, image, multi-media)	1744 index terms (text)	3521 of 5529 objects enriched with content metadata
ARIADNE	5000+ objects, of which several hundreds can be used for MACE	Technical and educational metadata, keywords	Almost all objects have mandatory technical and educational metadata, some content metadata, no context and a few social metadata
DYNAMO	544 architecture projects, 7351 files (text, image)	1944 index terms (text)	High level of content metadata
MONUDOC	15,000 Facts and Literature Reference covering preservation of monuments and historic buildings	bibliographic description, Index terms, classification	All units with classification, bibliographic data and index terms
BAUFO	13000 descriptions of building research projects	Index terms, classifications	All units with classifications and index terms

Table 1. MACE core content repositories

Figure 1 gives an overview of the different layers in the MACE approach. Based on a shared technical infrastructure for federated access to the repositories, metadata harvesting and content enrichment, we provide web services for metadata manipulation and retrieval and metadata-based content access. These are the basis for both automatic as well as manual content enrichment. As user interfaces, we develop compact, modular components with rich visualization and interaction possibilities — so–called widgets. These can be used standalone, combined in a search portal or embedded into existing applications. This framework allows usage of our solutions in a variety of scenarios relevant to learning and work situations in the architectural world.

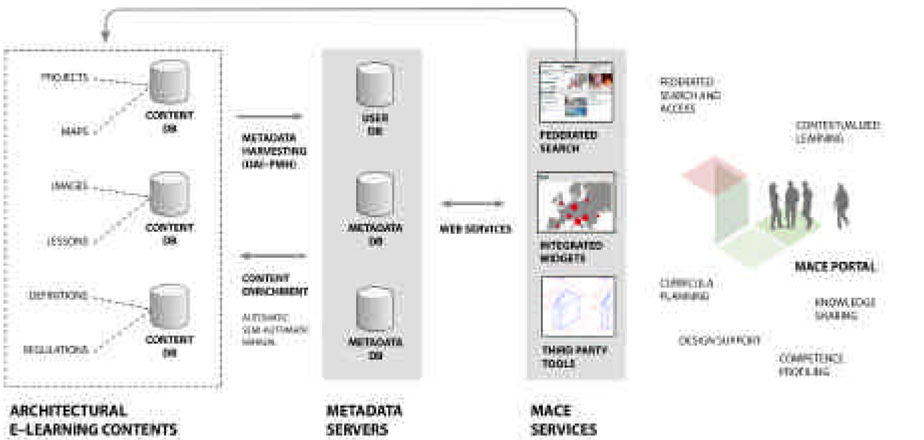

Fig. 1. MACE infrastructure overview

Connecting LORs for Architecture

The MACE infrastructure strives to open up the existing Learning Object Repositories (LORs) to enable the access to Learning Objects (LOs) through MACE tools. Therefore, we rely on a hybrid combination of harvesting metadata from and federating searches to existing content repositories. Additionally, the infrastructure enables the enrichment of LO's descriptions with metadata about their usage including contexts of use, necessary competencies, etc. The approach aims to make the learning objects in all repositories jointly searchable and retrievable.

The technical infrastructure allows searching over the contents of all content repositories based on metadata. In order to enable "semantic interoperability" among LORs, the LOs are described through the MACE application profile of the Learning Object Metadata standard (LOM) [Duval, 2005].

Existing metadata from the connected repositories are collected via metadata harvesting, based on the Open Archive Initiative Protocol for Managing Harvesting OAI-PMH (OAI, 2002). Harvesting in this context means the transfer of the content metadata from the providing repository into the central content metadata repository on a regular basis. Note that only the metadata describing the learning objects is transferred; the learning objects themselves will remain in the repository, and thus in control of their owner, without changing the access conditions. In turn, the central content metadata repository also offers an OAI-PMH interface so that interested content metadata providers can retrieve enriched metadata suitable for their learning objects.

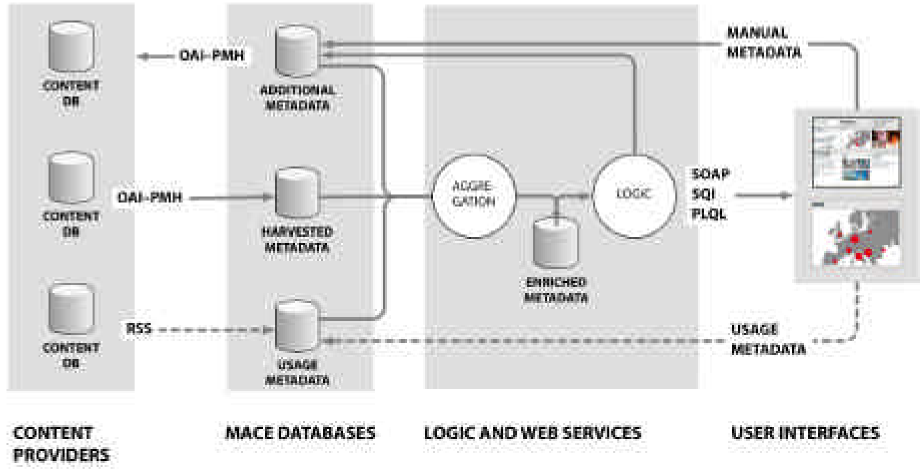

Fig. 2. MACE technical infrastructure

Figure 2 shows how harvesting works in MACE: existing metadata, describing the learning resources, are harvested through the OAI-PMH protocol into the MACE central metadata store. The metadata store supports a search facility that provides references to available and suitable learning objects. In order to access the learning object, the user accesses the learning resource directly at the provider.

Within the database layer, OAI-PMH is used for harvesting content and domain metadata. Data describing the usage (usage metadata) will be collected using the RSS (Rich site summary) protocol [RSS, 2007]. While OAI-PMH is suited to collect changing metadata, we suggest to use RSS when only new metadata instances (like in log files) are added. Usage metadata is obtained from the providers, as well as the MACE tools and bases on the access logs provided by the different applications. In the case of usage metadata captured from front-end tools and widgets, contextual data like the position of the user, or date and time, can be captured to complement the user profile. Exchanged with RSS, the usage data is unified relying on the contextualized attention metadata schema (CAMs) to enable deriving new knowledge about the usage of LOs by correlating usage data from different sources [Wolpers et al, 2007].

MACE Services

Services in MACE connect the presentation layer – in the form of widgets[1] – with data sources. They process user queries and return results, handle user management and provide means for gathering and manipulating metadata. Some services provide simple functions while others are more complex and can even aggregate functionality.

Besides metadata and content retrieval, MACE services will allow users to annotate contents with own metadata, track activities and generate metadata from user actions. Examples for basic services are: “Searching” which takes in a request,

[1] See following section : “Interface design strategy” for a deeper treatment of widgets.

queries the appropriate metadata databases and returns the results; "UserHandling" which provides authentication and user management functions; "ServiceRegistry", a directory for discovery and use of services; and so on.

Based on these basic services, more complex services can be realized in order to aggregate and combine various functionalities. Examples may include combinations of widget functionality, as shown in figure 4. In the sample search widget, a user search for "Renzo Piano", handled by the federated search services, is combined with a geolocation widget connected to a context metadata service, and also to a usage data widget that highlights users with previous access to similar data sets. The described combination triggers services on the basis of different metadata repositories including usage metadata, contextual metadata and domain metadata. In this way, user will experience a richer information set than expected, increasing the possibility to link to other useful learning objects.

Under this perspective, services in the logic layer are used to encapsulate and hide complexity. They also greatly enhance technology reuse by providing a uniform interface to the presentation layer, which can be used by widgets as well as third party applications like plugins for e.g. Microsoft Office or AutoCAD. These applications can then connect to MACE and make use of the technical infrastructure to search for and retrieve contents and metadata.

It will be possible to physically distribute MACE services over several server systems that are connected through the Internet. Some parts like metadata stores, MACE user accounting and a registry for distributed services will have to be centralized, other services can run anywhere on the Internet. This allows a wide range of options to be used, from simple, single-server installations to a complex and distributed infrastructure.

To ensure full interoperability, all services will be based on open standards. As mentioned above, we use OAI-PMH for metadata harvesting and SOAP for remote web service connectivity. The search service is enabled through the Simple Query Interface (SQI, 2005) in order to be able for MACE to join LOR federations like Globe[2] and Ariadne[3]. SQI allows for the federation of queries and the collection of the query results. SQI can be combined with any query language, and is, for example, employed in the GLOBE consortium to federate queries over the global network of learning repositories (Ternier et al., 2005).

Interface design strategy

MACE builds on existing portals, bringing in their existing contents and metadata collections, as well as pre-existing facilities for search, access, navigation and browsing. Our goal is to connect these contents via metadata and make them jointly accessible, thus enabling multiple navigation paths and perspectives on the existing collections.

The vision of an experience multiplier is the leading idea for the interface design strategy in MACE. For the interface design, this means we need to:

[2] http://globe.edna.edu.au/

[3] http://www.ariadne-eu.org

- ? Provide convenient and effective ways to enrich the existing contents with metadata
- ? Make connections between contents accessible to the user, thus enabling inter-repository navigation paths
- ? Provide a search interface that allows users to benefit from multiple types of metadata for content retrieval.

As the main objective of the project is content enrichment, based on existing tools and the mentioned portals, we developed an interface design strategy taking both the project aims as well as the site owner interests into account, whilst maximizing the impact of our developed solutions.

Composing widgets for flexible access

Based on these considerations, we developed an interface design strategy based on the notion of "*widgets*", which are compact, specialized applications or application components. They can not only be combined to build more complex applications, but also be integrated into existing portals and content management solutions on their own. On the one hand, this provides immediate incentives for content providers and site owners to embed and use MACE service widgets, since they can enhance their existing sites with functionality, in a focused manner and with little effort. On the other hand, the MACE project benefits by having more contents available, generating more metadata, thus improving the findability of relevant resources and increasing inter–repository traffic.

The widget paradigm has been made popular in several domains over the last years: Apple's dashboard widgets[4] allow users to add mini-applications on a semi-transparent desktop layer, which can be activated by a hotkey. Also Yahoo widgets[5] or yourminis.com[6] provide widgets for use on a personalized web desktop, the OS desktop and embedded into other web pages. The range of available applications reaches from simple clock or weather forecast over dictionaries, games, content subscription up to planners, search engines or messaging services. Other online services such as del.icio.us[7], Technorati[8] or Plazes[9] provide HTML snippets to embed functional components into other web pages. There is a diversity of embeddable widgets available — displaying site statistics, allowing to search for contents, or displaying the site owner's latest bookmarks, music listened to or books read.

In MACE, all functionality for end users is made available in specialized widgets. For different metadata types or service functionality, a dedicated widget can be used to visualize metadata values, edit metadata, filter searches and navigate contents.

[4] http://www.apple.com/macosx/features/dashboard/
[5] http://widgets.yahoo.com/
[6] http://yourminis.com
[7] http://del.icio.us
[8] http://technorati.com
[9] http://plazes.com

The following MACE widget types can be distinguished:

- **Basic widgets** handle basic user management and navigation tasks.
  Examples are a login widget, a simple search box (triggering a search on the MACE portal) or a link list widget.
- **Content presentation widgets** can be used to display content collections from the repositories, such as related pictures for a given article, a list of search results or a single content item.
- **Metadata widgets** visualize metadata values and aggregations of metadata values (so-called metadata profiles). Additionally, they allow editing of metadata as well as meta-data based navigation, search and filtering.

We can further differentiate widgets by their **awareness and adaptation** with regard to context established by

- The host application or web site (e.g. currently presented contents)
- The user (e.g. log-in status, previously viewed pages, preferences).
  Here, we distinguish user *recognition* (e.g. via cookie) and user *login* (via authentification mechanism). Some personalized functionality might be available also for recognized, but not logged-in users.
- Other widgets (e.g. selections, navigation behavior)

To give a concrete example from our repositories: a map widget for displaying geo-location could be used to display the location of a building in a DYNAMO project (content-aware), the locations associated with the user’s browsing history (user-aware) or related places for a selected keyword in a different widget (widget-aware).

The general goal is to make the “right” kind of information — fitting the user’s current situation and preferences as well as the currently focussed contents — visually accessible and editable directly in place.

Embedding and combining widgets

The chosen technical and conceptual framework allows re-use and combination of widgets in many different usage scenarios: MACE widgets can be embedded into existing web portals, thus making MACE functionality and contents available directly to portal owners and their users (see Figure 3).

Furthermore, for example, a combination of widgets can be used for searching, browsing and filtering in a facetted search application (see Figure 4). Where applicable, the chosen technologies also allow an easy adaptation to desktop tools or browser extensions. MACE widgets are combinable and will be available for download and integration into web applications at the MACE portal.

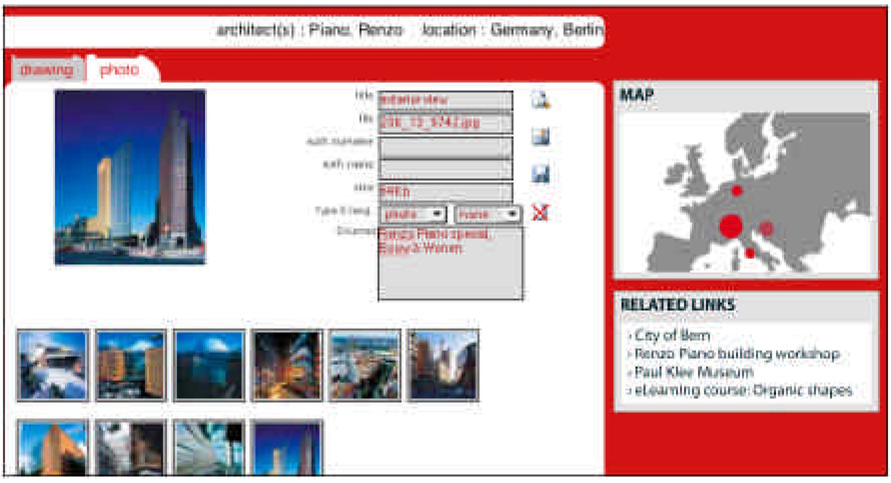

Fig. 3. Mockup of map widget and related links widget integration into the DYNAMO portal

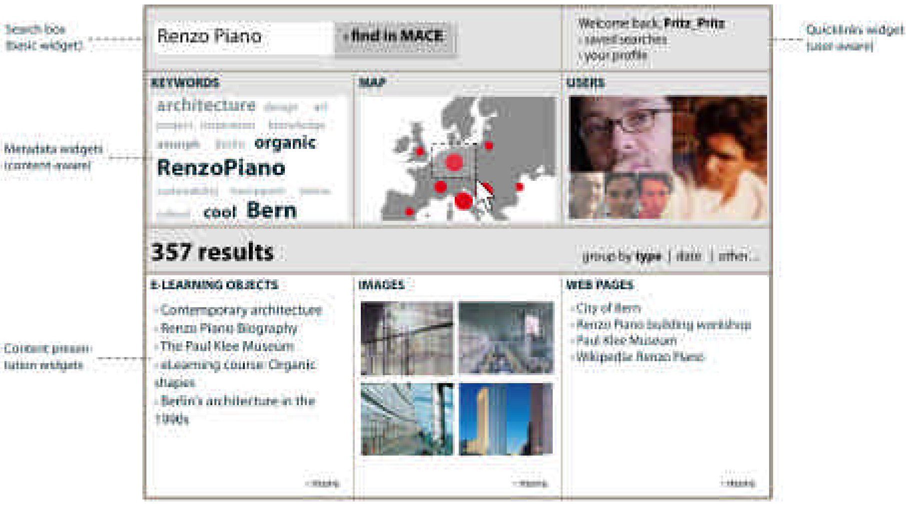

Fig. 4. Combining widgets for facetted search and browsing

Add and edit in place

Our approach relies on a multitude of available metadata. Whilst some of it is automatically generated, experts and other user can contribute meaningful information as well. For this reason, MACE widgets are used to edit metadata (see Figure 5). Where applicable, direct manipulation interfaces will enable visual, interactive access and manipulation, instead of tedious and error-prone form filling.

Fig. 5. Editing mode for widgets

We aim at making interaction with metadata not only as easy and natural as possible, but also open for all users. The recent success of collaborative tagging systems[10] has shown that providing users with a framework to tag publicly available resources in a ”socially translucent” [Erickson et al., 1999] manner can lead to rich and user-centered information architectures. A crucial component is making the users aware of both self-assigned tags as well as the tags and content that others contribute to the community: only immediate self and social feedback gives rise to the emergent, stable, community–wide patterns in tag usage [Golder & Huberman, 2005]. The resulting multi–faceted, bottom–up organization is often referred to as folksonomy — a neologism based on the words ”folk” and ”taxonomy” [Quintarelli, 2005]. We aim at generalizing this principle also for other metadata types.

Concerning incentives for actively contributing, we aim at win-win situations: if for the user, tagging contents is valuable for re–finding contents, helps succeeding in a “tagging game” or to enrich his online portfolio, the repositories benefit at the same time from the enriched contents. A variety of incentive mechanisms in online collaboration can be identified (see e.g. [Obreiter&Nimis, 2003]). A further, promising perspective is the “undercover” creation of metadata from joyful activities such as gaming [von Ahn & Dabbish, 2004]. We are currently investigating, which of these techniques are best suited for our content partners and user groups.

Using widgets for browsing and navigation

Additionally, our embedded widget approach fosters meaningful navigation and browsing across repositories: by presenting related metadata values and contents directly on the content pages, users can not only understand the nature and relevance of the presented contents, but also directly navigate to related items or query the MACE database for further contents based on metadata values. By presenting a variety of metadata fields, we enable multi-facetted navigation — not only on a semantic, but also a social and contextual level.

To enable meaningful, multiple navigation paths, value selection as well as weighting of the displayed values is crucial. This is especially important for

[10] such as e.g. http://del.icio.us

inherently multi-valued metadata types (such as ratings and free-form keywords) as well as for accessing the whole content collections, such as a search result or the contents of a technology enhanced course.

For this purpose, our approach is based on weighting metadata values: if we define a context as a set of contents and their metadata values, a *metadata profile* will express the characteristics of this context in terms of its metadata distribution. In its simplest version, a metadata profile is represented as the set of occurring metadata values weighted by the number of occurrences.

The *global metadata profile* is the metadata profile for all available contents and hence represents the a priori distribution of metadata. A *local metadata profile* characterizes a subset of contents, such as a search result, the result of a filtering operation or a single content.

Mapping these profile values to visual attributes can create meaningful and immediately accessible insights. For example, the currently popular “tag clouds” employ this principle by mapping number of occurrences of term to font size. The established visual hierarchy allows quick skimming of many metadata values and at the same time indicating relative weights of values by visual salience. This allows users to quickly perceive the predominant metadata values and their relative proportions for e.g. a search result or a personal collection of contents. We will apply analogous principles to other types of data, places, time points or graphs, and their visualization.

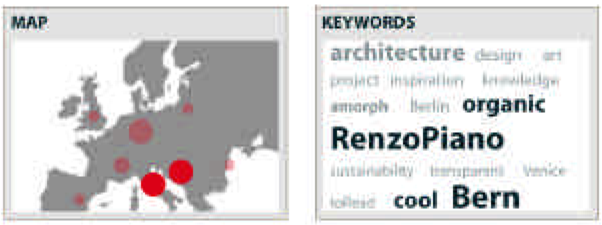

Fig. 6 Weighted display of metadata; higher opacity indicates an unusually high weight in the current context compared to the global profile

An interesting extension of this principle is to highlight unusually high values compared to the a priori values, since these indicate what makes a data set special compared to the whole collection (see Figure 6). To give an example: If the proportion of articles tagged with “architecture” for a search for “Renzo Piano” is the same as for the whole collection, then we can conclude that the tag “architecture” is not especially characteristic for the search results. A high gain in proportion for values like “Bern“, however, indicates that the search term and that metadata value are frequently co–occurring and thus related. Visually highlighting values can lead to interesting insights on the data and provide the user with good candidate values for further navigation and search. This principle has already been tested in a prototype [Stefaner&Müller, 2007] and is currently refined and evaluated.

We hypothesize that this navigation principle is especially suited for navigating multi-facetted and multivalent “long tail” [Anderson, 2006] metadata structures, which typically arise from collaborative tagging activity [Golder & Huberman, 2005], since this approach both allows quick and intuitive drill-down navigation as well as "context hopping". By successively selecting metadata values across facets, a "place" selection can provide an entry point for a concept space, where individual concepts might in turn be related to specific users and so on.

Outlook

Currently, we are in the process of defining a feasible and desirable set of widgets to implement in a user-centered, iterative design approach. First prototypes will be available on the MACE portal by autumn 2007. An overview of widgets considered up to now can be found in Figure 7.

Fig. 7 Overview of considered basic, content and metadata widgets

Conclusion

By enriching and connecting existing portals and their contents, we provide a unique single access point for high quality content from the architectural domain. Enriching contents with various types of metadata, enables multiple perspectives and navigation paths, effectively leading to experience multiplication in technology enhanced learning about architecture and design.

Especially from an informal learning perspective, our interface and system design approach fosters experience multiplication via metadata on many levels:

? We create an open system and provide incentives for actively enriching and sharing knowledge. This opens doors to social navigation and online collaboration, which are both crucial constituents of an active learning experience.

? By linking complementary contents across repositories, we establish valuable connections to complementary knowledge for a given content.

? Displaying metadata values directly in place supports a better judgement of the relevance and context of a single piece of information. By making each metadata value a starting point for a potential query on the MACE portal, a rich web of contextual information is woven around each content component.

? Our facetted search approach creates an intuitively accessible model for navigating multi-dimensional data structures based on tailored, domain-specific tools. It enables directed search and browsing of contents with respect to features relevant for architectural knowledge in a unique combination. The underlying weighted activation model fosters understanding how metadata values and/or search terms relate to each other; revealing these relations can greatly contribute to learning experience.

Moreover, our service-oriented, distributed architecture allows reuse of both MACE contents as well as functionality in applications developed by third parties — by simply embedding ready-made MACE widgets or by connecting proprietary interfaces and applications to the MACE metadata service API. Interoperability is ensured by using open standards and protocols.

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