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MACE:
Connecting and Enriching Repositories for Architectural Learning

› digital libraries
› domain-specific architectures
› interoperability
› interactive data exploration and discovery
› user interfaces

Education in architecture requires access to a broad range of learning materials, so as to develop flexibility and creativity in design. The learning material is comprised of textual and visual media including images, videos, descriptions of architectural concepts or projects, i.e. digital artifacts on different aggregation levels. Until now, repositories storing such information have not been interrelated and have not provided unified access. Consequently, finding and retrieving 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 standards–based, service–oriented software architecture, and flexible user interface design solutions, based on embeddable widgets, ensure easy integration and re-combinability of contents, metadata and functionalities.

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INTRODUCTION

education

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architectural design

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In architecture, technical and artistic knowledge blend and influence each other. Due to this double influence, 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 personal erudition and culture, mainly consisting of images and visual inputs, collected in a life-long process. Visual memories can be about the most different aspects of the subject: from architectonic solutions and shapes to examples of applied theories, suggestions, or personal experiences.

The design solutions produced by an architect therefore are, most of the time, the outcome of a process of recalling and reworking images: 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 [1,2].

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 [3], while leaving in the background the less seen, or understood, ones : in this way, a first selection, and therefore a limitation, is unconsciously 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 students are not very experienced, they need a very wide range of possible suggestion providers, and a high number of examples to look at. Indeed, non-expert designers and students spend a lot of time in libraries, searching for a large number of cases similar to their current 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 heterogeneity of information that can be inferred from a single book: for instance, 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. Probably, if architecture students only could, they would spread around all the pages of architecture books, like the tesserae of a muddle up mosaic of images, drawings, sketches, graphic schemes and they would walk through this cloud of information ready to catch from the corner of their eyes the contents helping in their documentation or design problem solving activity.

Digital media for experience multiplication in architectural design process

digital media
collective external memory

Given the fact that a considerable part of the knowledge which was once printed in architecture books is being moved to digital media, we can get closer to enabling and improving this vision.

It is possible to reshape the existing enormous mass of digitally factored information to create an organized and structured "cloud" of notions, and to consequently allow its exploration in a logical and intuitive way: a multiplication of the learning opportunity using the web as a collective external memory.

One consequence is the availability of a large amount of meta-information for a

indexing strategy
visual media

digitization

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MACE

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given resource: 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, they are still distributed over different services and not yet specific for the architectural domain.

A second consequence of the ongoing digitization 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 of the changing consumption behavior and social practices [4]. Moreover, in architecture, a large amount of information is held in visual media (images, photos, sketches…), which are generally hard to index and find. Most search tools currently available do not offer the multiple perspectives and exploratory search needed to support effective and seamless interaction within the domain of architecture and engineering. Providing the right tools can lead to novel and rich experiences: the revising of the formative elements (context, suggestions, ideas, diagrams, functions, shapes, images, etc.) as a remix of dynamic collections, recombination and juxtapositions, can lead to previously unavailable insights and discoveries.

The computer can be useful in many ways in the generative phase of a project, for intance in the field of computer aided architectural design [5,6]. Through 3D-modelling and other kinds of representation software, a computer can assist the designer to create sharable, storable and visible representations of personal ideas and suggestions. By proposing a wide 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 limited number of elements (the personal background of the designer).

The potentiality of multiplying experiences and perspectives can also come to an architect, with an even deeper impact, in the earlier project conceiving phases, if the digitalized knowledge management allows him to access resources in a way that reflects the typical logical behaviour of an architectural learner. In MACE, we concentrate our efforts on this aspect.

In the domain of architectural design we can therefore regard digital media and the web as experience multipliers: a digitally assisted design process can have a more complex recombination of a multi-faceted, mosaic-like agglomerate of loosely connected information and meta-information. In particular, this additional information can be used not only as raw data, but can trigger new mental processes.

MACE aims to support the shaping and reorganization of the large number of already existing, but uncoordinated, pieces of architectural information by creating the core of an indexing strategy to structure them and their following addition. The system will allow the end user to both enlarge his set of visual memories and enrich the online collective external memory by recognizing, catching and linking the contents through an interactive navigation system.

Architectural digital media characteristics: strategies for mosaic recomposition

intuitive navigation
learning objects
visual media

Currently, an architectural-like intuitive navigation, as the one MACE aims for, has still not been enabled for either the architectural discipline or peculiar visual media features. One of MACE aims then is to find new indexing strategies, capable of structuring 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 support the logic pattern of the user navigating through this cloud of contents, and they will have to support his search criteria.

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 and content competence profile, or the context, in which the LO is inserted or used, might be key to accessing the right kind of information.

MACE – METADATA FOR ARCHITECTURAL CONTENTS IN EUROPE

classification winds

metadata

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MACE sets out to integrate architectural learning contents from Learning Object Repositories (LORs) spread around Europe and beyond, and to 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[1] about the learning object itself, its contents or the context of its use (including social metadata, competence metadata and contextual metadata).

An overview of currently integrated content repositories (adopted as contents base in the first phase of the project, but intended to be increased) can be seen in Tab. 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.

As will be detailed below, Fig. 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 technical infrastructure (p. 320).

Content source	Objects	Metadata	Metadata level
WINDS (An ensemble of several universitary courses featured by a data model with two alternative structures – hierarchical course and concept network – enabled learner centred education via more navigational control and personalized adaptive learning.)	5,529 compound objects, 10,542 single content blocks (text, image, multimedia)	1,744 index terms (text)	3,521 of 5,529 objects enriched with content metadata
ARIADNE (The ARIADNE Foundation is one of the early pioneers having a “share and reuse” vision for education and training. It provides access to several tens of thousands of additional objects, several hundreds of which are relevant for the MACE context.)	5,000+ 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 (Dynamic Architectural Memory Online is a database developed in order to stimulate and support architects’ life-long process of learning from previous design experience.)	544 architecture projects, 7351 files (text, image)	1,944 index terms (text)	High level of content metadata
MONUDOC (MONUment DOCumentation is a fulltext database to all questions of the restoration of worth preserving buildings and their interior.)	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 (Is a database that serves as basis for finding ongoing and completed projects from all fields of building research? It covers projects, which have been realised inside the Federal Republic of Germany and a row of international research projects.)	13,000 descriptions of building research projects	Index terms, classifications	All units with classifications and index terms

Tab. 1: Overview of MACE repositories.

CONNECTING LORS FOR ARCHITECTURE

learning objects
harvesting metadata

The MACE infrastructure aims to open up the existing Learning Object Repositories (LORs) to enable the access to Learning Objects (LOs) through MACE tools. We rely on a hybrid combination of harvesting metadata from and federating searches to existing content repositories. Additionally, the infrastructure enables the enrichment of LOs with metadata about their use including contexts of use, necessary competencies, etc.

The project aims to make the learning objects in all repositories jointly searchable and retrievable.

OAI

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application profile

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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) [7].
Existing metadata from the connected repositories are collected via metadata harvesting, based on the Open Archive Initiative Protocol for Managing Harvesting OAI-PMH [8]. 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 providers can retrieve enriched metadata suitable for their learning objects.

Educational metadata and the MACE application profile

classification

IEEE defines metadata as information about an object, be it physical or digital [7]. Different communities have defined metadata standards that fit their needs. A simple standard such as Dublin Core allows for expressing key-value pairs and is widely used in the digital library community. Domain specific initiatives such as LOM (educational) or MPEG-7 (multimedia) cover more elements within a domain. Concrete implementations usually do not use all of these fields. Furthermore, implementers often need to choose between many standards that are both complementary, but are also overlapping.
[9] presents a number of mechanisms through which a community or organization can adopt a metadata standard. One can impose restrictions on existing metadata standards and for instance constrain the value space on some elements. [10] defines an application profile as a schema that consists of data elements drawn from one or more namespaces, combined by implementers and optimized for a particular local application. Thus, an application profile can allow for the construction of mixed metadata sets. A metadata instance validates using an application profile to check it does not violate any of the rules that are set in the profile.
The MACE metadata application profile builds on LOM and gives some LOM fields a mandatory status: eg. title, description, identifier and technical location. Because these – rather trivial – metadata fields are mandatory, MACE metadata instances validate against the GLOBE metadata application profile[2]. As a result, the GLOBE federated search infrastructures are interoperable with the MACE metadata application profile, which enables transparent search into MACE at the level of the worldwide GLOBE learning repository federation.

In order to meet the specific information needs in architecture engineering and design, the MACE metadata application profile includes additional attributes from architectural taxonomies and classification systems.

Encoding the various information requirements for MACE services into the application profile simplifies the extensibility of the MACE system by providing a general mechanism to access the information for all MACE services.
The MACE application profile captures all sorts of metadata that are defined in the following sections. It specifies how architectural taxonomies or competency classifications can be encoded in a LOM metadata instance.
Because the MACE metadata application profile unambiguously specifies how the various kinds of MACE metadata are to be encoded, MACE applications, but also third parties can uniformly search the different MACE content providers using these metadata features.

MACE real world objects

metatagging

As described, the MACE infrastructure allows the description of digital Learning Objects, such as texts, pictures, lessons etc. However, one of the key features of architecture is the work towards the building as a physical manifestation of a design; for this reason, in architecture education, it is fundamental to identify, discuss and compare architectural projects in their context. Consequently, we also support the description of "real world objects" (RWO): design projects, buildings, or other artifacts of interest in architectural learning.

Following the W3C recommendations these are represented as "non-information resources" [11]. RWOs differ from traditional digital documents by having no direct digital representation. Instead, RWO metadata sets capture attributes of the RWO, such as, for instance, the creation date of a building, as opposed to the creation date of a photograph of the building. RWOs are connected to their associated media or text resources using LOM relations. In summary, RWOs serve as a reference point for storing facts about objects in the real world, and also as reference sets to all related media in the database.

This approach supports example-based learning and a natural grouping of documents around concepts and topics.

From a metatagging[3] point of view, we produce more precise and expressive metadata, by distinguishing tags assigned to e.g. a photograph or, in contrast, the object depicted in the photograph. Furthermore, we avoid redundant metadata, thus making our tagging more effective: Instead of applying the same "architectural style" tag to numerous photos of the same building, we apply the tag only once by storing it into the RWO metadata set that represents the building. Moreover, we can connect our metadata more easily to existing repositories and open databases dealing specifically with architectural projects. Of special importance in this context is the URI design identifier [12], in order to relate MACE metadata to existing information resources. Where applicable, MACE RWOs are identified with their respective DBPedia[4] or freebase[5] counterparts, in order to facilitate interoperability with existing and future repositories of architectural knowledge.

MACE METADATA TYPES

Several different kinds of metadata need to be used to index and tag the critical mass of factored LOs, in order to create the desired organized and structured “cloud” of notion.

collaborative learning platform
intuitive navigation

The wish to create an architectural-like intuitive navigation system to search through the concepts, but also the need for a colaborative educational/learning platform, triggered the necessity to base the indexing system on four different kinds of metadata: Social and usage metadata to describe events and user activities; Competence metadata to show which digital contents can be used to obtain a specific competence; Context metadata to describe the context of an object (or subject) depicted in a digital content; and moreover Content and domain metadata containing information about the digital objects’ contents as well as the real-world objects they refer to.

Usage and Social metadata

ALOE project

OAI

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Usage metadata describes how, by whom and in which context a learning resource is used. It is obtained from the learning resource providers as well as the MACE tools and for instance is extracted from the access logs provided by the different applications. Within the database layer, usage metadata will be collected using the RSS (Rich site summary) protocol [8]. We chose RSS instead of OAI-PMH, because the latter is well suited to collect up-dated metadata, while RSS enables the continuous provision of new metadata instances as a stream. In the case of usage information captured from frontend tools and widgets, contextual data like the position of the user, or date and time, are captured to complement the user profile. Exchanged with RSS, usage metadata is unified relying on the contextualized attention metadata schema (CAMs) [13]. By correlating usage metadata, new information about learning objects is generated, e.g. the most downloaded objects or trends in the interest of users in learning objects over time.

In order to capture social metadata (or user-generated metadata), we integrated the ALOE project [14] into our infrastructure. The ALOE system gives users a variety of options to organise, share and search resources based on their personal interests. In MACE, the ALOE project will enable the user to annotate, rate, tag and store architectural learning resources in personal portfolios. The social software functionality provided by ALOE enables the MACE user to actively share and discuss learning resources and thus also the learning paradigm of communities of practice for MACE supported learning scenarios. Designed as an open, adaptable system, most of the ALOE functionality is available via web services, which allows an easy integration into the MACE infrastructure.

Competence metadata

Competencies can be defined in a manifold way and there have been many approaches including functional, cognitive and behaviouristic. For a good overview and

competence card schema
metatagging

education

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integration see [15]. In coordination, MACE and the TENCompetence consortium interpret competence as all the factors for an actor to perfo rm in an ecological niche. Performance in that sense includes the specific context that is necessary for the interpretation of a competence. Of course, competencies include competencies and knowledge that are necessary to put the competence into performance.
In the context of previous projects in the field of architecture, competence taxonomies have been defined for the different areas relevant for architecture and design. Nevertheless, there is a high need to standardize those competence taxonomies and descriptions from different perspectives. On the one hand, there is a European need for standardisation of the competencies described and implemented in the European curricula for architects, on the other hand, there is a need in competence driven education to have a shared and common set of competencies or at least a common understanding of what competencies are and of their role in the educational process.
For MACE several problems are related to competence metadata:
1. Selecting and defining a competence metadata schema that is compatible with the current approaches in ongoing standardisation efforts. Basically, the defined schema must allow the import and export from and to existing standards like IMS [16], and HR-XML [17] and foster the exchangeability of competence taxonomies and furthermore be conformant with the current agreements, as for example in the European Qualification Framework[6].
2. Support the definition of competence taxonomies for the domain of architecture and design, and in this context take into account the different approaches and granularity of competencies that are described in the professional development of architectural education. That means that on the one hand the schema must be able to support competence driven applications based on competence taxonomies on a fine granular level describing 200-500 competencies, on the other hand it should be possible to represent higher level approaches like those of the European directive describing the profession of an architect with 11 high level competencies.
3. Defining the schema in a way that it supports bottom up and top down approaches for competence taxonomy definitions. Basically the schema should allow the definition of a starting set of competencies but also support the continuous update and be able to manage multiple interpretations of competencies.
4. Enable the easy metatagging of knowledge resources with competence metadata in an approach with little overhead and as a side effect of using resources.
5. Support the integration of competence metadata with other types of metadata and explore the possibilities for educational applications in enabling the user to explore competence descriptions that are contextualized in a community of practice.

As a key issue to enable a cost effective and enduring enrichment process in MACE, the main requirements for the schema design were on the one hand to be compliant to standards, and on the other hand to enable an easy and understandable communication about competencies. MACE uses a simplified competence schema, which is compliant and extensible towards the above described standards, but which enables us to use competence cards as the main mean to communicate competencies and allow the users to metatag and annotate contents and competencies.
The Competence Card Schema contains the following core elements:
› Domain: a domain to which the competence belongs;
› Competence: the information about the competence itself (title, description, etc.);
› Competence maps: combine competencies in profiles that can be used either as personal learning objectives or professional profiles;
› Proficiency scales: describes which proficiency scales are used to rate relations to the competence, which is also in conformance with the EQF;
› Related resources: a list of resources related to the competence;
› Related persons: a list of persons related to the competence;

› Related evidences: a list of evidences related to the competence.

The elements in the Competence Card Schema allow us to export/import the competence information to/from the standards IMS/IEEE RDCEO or HR-XML.
Interaction with competencies is complex, as normal users do not think about competencies as educators. Most common approaches use everyday language to describe competencies and connect them to underlying competence structures, such as e.g. the social web application 43things[7]. For allowing users to interact with competence profiles and competence cards, we are implementing a simple bar chart component that allows the assignment, manipulation and the viewing of competence metadata for single learning objects and sets of learning objects.

Contextual metadata

real world objects

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As mentioned above, much of our content is related to objects in the real world, like places, buildings and towns. For these real world objects, it is important to capture and store the object context. Interested parties can later retrieve it and either search objects by context parameters or find similar objects for a given object and context. Contextual metadata in that sense can be position (Where is the object located?), history (When was the object built?), surroundings (What other objects are located nearby? How are they situated?) and geography (What is the climate around the object? Is it prone to natural disasters?). The list is not complete and can be extended to fit additional purposes.
As a large number of cases and examples already exist, it would not be feasible for a small group of experts to create contextual information manually. The good thing is that almost all of the information needed is already available online in a variety of data sources like Wikipedia[8], history websites, place descriptions[9], location and disaster databases[10] and can be connected and harvested in automatic or semi-automatic (with manual oversight) ways.
While some of the information is highly structured (e.g. like in Freebase[11] or DBpedia[12]), a large part of the data is badly or not at all structured and needs sophisticated approaches for data mining, merging and filtering out useless items.
In MACE, we have been making good progress with connecting GPS positioning information with LO contents and displaying these contents on a map. The positions information is collected by data mining content full texts and matching keywords against the Geonames location database, the resulting matches are being stored in a separate data store.
We are currently further adjusting the matching algorithm beyond syntactic matching to include more data sources.

Content and domain metadata

education classification

community

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Content and domain metadata, i.e. descriptive metadata with relevance in the architectural domain, is harvested from the various connected architectural learning repositories using the OAI-PMH protocol. It is enhanced with additional architectural information through two mechanisms. First, the group of architecture experts provides enhancements through tagging activities using controlled vocabularies. Second, the community of architecture education (students, teachers, etc.) provides their own tags and comments on the learning objects using the Adaptable Learning Object Environment (ALOE[13]) system [14].

The architects expert group within the consortium has agreed on using a number of architectural terms in a hierarchical controlled vocabulary to enhance the descriptions of the learning resources.

The vocabulary is documented in the MACE classification schema. It complements the definition of the MACE application profile and is used within the LOM classification category. The classification schema consists of facets, each of which addresses and describes a different feature of the architectural content. A facet consists of a number of non-exclusive categories, containing architectural concepts in a hierarchical order (see Table 2 for an overview of facets and categories and the following paragraph for theoretical notions at the bases of this classification). Each concept has one or more terms associated, which enables us to merge existing vocabularies and group conceptually close index terms. The MACE classification schema is based on existing thesauri: UniClass[14], ISO12006[15], the AAT Getty Vocabulary[16], and the Ci/SfB[17]. Where necessary, it has been extended based on [13–20] to reflect additional information needs in architecture, which emerged in the requirements analysis process and have not been addressed yet in established taxonomies.

Facet	Categories
Identification	Intervention type, Project type, Functional typology, Form typology
Context	Location, Geographic context, Urban context
Technical design	Materials, Construction form, Building element, Technological profile, Structure profile, Systems and equipments, Technical performance, Maintenance and conservation
Constructing	Construction management, Construction phase, Construction activity, Machinery and equipments
Theories and concepts	Styles, periods and trends, Theoretical concepts
Conceptual design	Project cues, Project actions, Form characteristics, Perceptive qualities, Relation with the context

Tab. 2: MACE content and domain metadata: facets and categories.

FACETS AND CATEGORIES IN THE MACE CLASSIFICATION SCHEMA

An architectural project constitutes a great syntheses effort, where different knowledge fields – may they be connected to the poetic-artistic side (ideas, cultural and social message of a project) or to the technical one (functionality, living wellness, building ease) – are called to simultaneously gather a project.

architectural design classification

facet

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To find a coherent strategy to develop a classification schema of such a heterogeneous subject, the various and interconnected issues have been separated and re-ordered on the basis of two possible end users' point of view, which are:

› the researcher, interested in the world of architecture, aiming to deepen descriptive aspects, documentation and technical knowledge, but without any design-applied goal (Documentation activity);

› the designer, may he be a professional or a student, active in sectors such as architecture, city planning or civil engineering design (Design Problem Solving activity).

The Documentation activity is a work that can be held both by students as well as other users using MACE to obtain information about history, geographical locations, typologies, techniques and general documentation in the world of architecture. To allow this kind of activity, part of the classification system needs to be based on objective fields that should cover all the objective aspects of the domain. With objective fields we mean all those aspects of architecture that refers to objective (non-interpretational) data and for this reason aren't influenced by architectural trends or by theoretical and personal concerns. The main challenge in this case is to develop a standardized and shared taxonomy, able to cover all the aspects of the discipline featured in the architectural and engineering domain.

It is however, more complicated to identify the rules and structures to create such schema to support the Design Problem Solving Activity. This is because architectural design deals with complex shapes, which represent, through the architect's personality and his conceptual filters, deeper messages. Therefore, architecture and the built environment is not only the technical production of concrete "facts" of various dimensions (from a city to a small object), but it is also a "sign" featuring a message conveyed through materially sensible signs (materials, colors, shapes, etc.). Conceiving a project is therefore similar to the process of creating and communicating a message. When classifying and organizing the knowledge and the artistic production related to these kinds of mental processes it is not wise to rely only on objective data (as in the Documentation Activity), but also on a personal and intuitive interpretation, which is both individual, when choosing among many ambiguity factors, and partial, when focusing on some complexity factors.
At first glance, trying to classify non-objective data may seem to be an oxymoronic task. But if we consider modern and contemporary artistic production, we can see that often the oeuvre represents a true challenge sent by the author to the spectator, who is called to participate to the work's creation and to the research of a meaning through the eyes of his/her own personal history and personality. Semiotics theory, notwithstanding its slow and sometimes contradicting evolution during the last half century, gives us the basis to help us perceive and understand messages in art. Thanks to those studies and methodologies we can try to develop strategies to classify non-objective data. It's not our intention to summarize here a balance of the results of semiotics studies, even if limited to the visual arts field. Among the complex and variegated interpretative models offered by the current state of this discipline, we decided to rely on the Hjelmslev's interpretative model, to find the personal and intuitive data, used as reading keys to an architectural project. This model is based on the double opposition of contents/expression and substance/form [26] and on its following interpretation and adaptation held by A. J. Greimas [27] and his young pupils in a Paris school during the 1970s. The model, initially evolved in urban analysis research, has then been first extrapolated and enlarged to a system of categories and levels devoted to the reading of any visual work[18], and then reduced and focused on architectural works[19] [29-30] (Fig. 2).

Fig. 2: The Hjelmslev's interpretative semiotic model, based on the double opposition of contents/expression and substance/form, reduced and focused on architectural works [29]. We can produce hypothetical examples, referring to well-known architectures, to clarify how the logic scheme is used to classify architectural features, principles that will be used in the MACE knowledge organization system. Let's imagine there is a student who tries to find an example of a building expressing the concept of "lightness". He can trigger a combined search with "aerial" (in a symbolic-metaphorical meaning, substance of contents) and "metallic structures" (substance of expression: tectonic /

building elements"). These two search-keys may lead to the Eiffel Tower in Paris and to the Crystal palace of Joseph Paxton in London, both being correspondent to an oeuvre expressing the combination of a signifying element ("aerial") and a perceptible significant ("metallic structures"). If a further filter "glass" (substance of expression: plastic / materials) is used, he would only find the Paxton's building: a glass and steel architecture, expressing aerial lightness (p. 320).

The conceptual factorization of the architectural domain based on these studies and and it's interpretative semiotic model, has been used as a filter to convert the results of the MACE analysis requirements[20] activity carried out to fix all the concepts, which will be useful to decompose and classify the whole aspects of the architectural domain (Fig. 3-4). The result of this operation is the MACE classification schema and it's taxonomy. It has been organised in 27 "facets", grouped in 6 "categories" (Tab. 2). This taxonomy features categories able to decompose and classify all aspects of the architectural domain covering both objective data used in the design and documentation activity (e.g. Materials, Structural Profile, Functional Typology, etc.) and personal and intuitive data used in the design activity (e.g. Perceptive Qualities, Project Cue, etc.).

Fig. 3: The first level of the Mind Map Taxonomy: decomposition and classification of the architectural domain; result of the MACE analysis requirements activity (p. 320).

Fig. 4: The whole Mind Map Taxonomy (p. 321).

METADATA CREATION AND REFINEMENT

Our approach relies on a multitude of available metadata. Whilst some of it is automatically generated – such as usage metadata – experts and other users can contribute meaningful information as well. This affects especially the areas of content and domain, but also context and competence metadata.

classification

Content and domain metadata is harvested from the existing repositories, but also manually enriched, refined and consolidated by a group of MACE experts. Periodically, the glossary is refined in order to integrate expert and community suggestions, based on the following mechanism: while tagging, users can also add not yet existing keywords to a LO. These are stored in a freeform text field, not only to be included for search and retrieval, but also for later review by experts. If the keyword is commonly used and approved in a periodical check, it will be added to the classification vocabulary. This hybrid of a predefined top-down hierarchy and a bottom-up folksonomy allows us to utilize the wisdom of the users in a controlled manner.

Competence metadata is treated in a similar way: while the core competencies are pre-defined, users can add personal sub-competencies in order to reflect their personal interests and abilities, and thus organize learning objects according to their information needs.

Context metadata, on the other hand, is generated through a combination of automatic and manual techniques: while most of it is generated automatically, or extracted from existing databases, users and experts have, for instance, the option of correcting and fine-tuning an only approximately right position.

On the other side of the spectrum, usage metadata is generated in a fully automated manner, with only the results, such as recommendations and access statistics accessible to the end user.

Generally speaking, 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[21] has shown that providing users with a framework to tag publicly available resources in a ”socially translucent” [31] manner can lead to rich and user-centered information architectures. A crucial component is to make 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 [32]. The resulting multi-faceted, bottom-up organization is often referred to as folksonomy – a neologism based on the words ”folk” and ”taxonomy” [33].

Concerning incentives for actively contributing, we aim at win-win situations: if for the user, tagging contents is valuable for re-finding contents or for enriching his online portfolio, we can encourage this by introducing a “tagging game”, with the repositories benefiting at the same time from the enriched contents. A variety of incentive mechanisms in online collaboration can be identified (see e.g. [34]). A further, promising perspective is the “undercover” creation of metadata from joyful activities such as gaming [35]. We are currently investigating, which of these techniques are best suited for our content partners and user groups.

MACE SERVICES

Services in MACE connect the presentation layer with data sources and provide most of the business logic. 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 manipulation and content retrieval, MACE services allow users to annotate contents with their own metadata, track activities and generate metadata from user actions. Examples for basic services are: “Searching” which takes in a request, queries the appropriate metadata databases and returns the results; “User-Handling” which provides authentication and user management functions; “Service-Registry”, 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. For example, a combination of a timeline and a map application might query our services for buildings from the 1920s and plot the results on a map. In a second query step, related theoretical concepts for these contents can be retrieved, leading to new insights and novel navigation possibilities.

In 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 example 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 is 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 are centralized to reduce complexity and improve performance. 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 are 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) [36] in order to be able for MACE to join LOR federations like Globe[22] and Ariadne[23]. 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 [37].

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.
Accordingly, we identified the following high-level goals for the interface design:

› 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;
› Foster knowledge discovery by making emerging metadata structures and connections accessible in interactive visualisations; and
› Provide search and browsing interfaces that allow users to benefit from multiple types of metadata for content retrieval.

Based on an analysis of the use cases, scenarios and information requirements [38], we extracted recurring functionalities and information constellations. These include, for example, the grouping of contents by different criteria, automatic suggestions of related contents, options to refine search results, etc.
On the basis of these observed patterns, we designed a set of basic user interface components in the form of wireframes. These are low fidelity sketches for drafting a user interface with respect to its essential components, but without going into layout detail. Wireframes were mostly used to define a shared user interface vocabulary, and were used for visually prototyping larger applications, but also to discuss technical requirements on a focussed, granular level. The set of available components is continuously updated to reflect the current state of discussion and the technical possibilities.
A number of applications are further developed into functional prototypes, in order to test interaction flows and allow early evaluation from potential end users, which are continuously evaluated by domain experts from the MACE consortium. In the following development phases, the group of beta testers will also be extended to externals. If the development of a prototype is technically too demanding, mock-ups are used to communicate the central idea and potential look and feel of an application.

Based on these considerations, we developed an interface design strategy based on the notion of “widgets”, which are compact, specialized applications or application components. These cannot only be combined to build more complex applications, but also be integrated into existing portals and content management solutions on their own.

MACE widget

visual browsing

⑥

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.

Fig. 5: Mockup of map widget and related links widget integration into the DYNAMO portal (p. 322).

The widget paradigm has been made popular in several domains over the last years: Apple’s dashboard widgets[24] allow users to add mini-applications on a semi-transparent desktop layer, which can be activated by a hotkey. Also, Yahoo widgets[25] or yourminis.com[26] 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, to dictionaries, games, content subscription, to planners, search engines or messaging services. Other online services such as del.icio.us[27], Technorati[28] or Plazes[29] 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.
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 metadata 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. login 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 history).

To give a concrete example from our repositories: a map widget for displaying geolocation 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.

In the following, we will describe the different use cases enabled in our widget framework: from embeddable widgets, widgets for metadata editing and creation, over search refinement to visual browsing of contents and classification values.

Embeddable widgets

MACE widget

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 e.g. Fig. 5 for an example for embedding MACE widgets on external pages). To allow deeper integration in third party websites and other existing tools we are designing an extended widget API so that site owners are able to not only embed widgets, but also interact with these components directly. The exchange is planned to be bi-directional, i.e. the external web application is able to pass over a resource identifier, and MACE will provide related information. A user-case for the other way around is an asset search widget from which the user selects appropriate images and connects these to contents of the web page. Hence, more sophisticated communications between the embedding web page and the MACE infrastructure will be possible. 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 at the MACE portal.

Add and edit in place

MACE widgets are also used to edit metadata: Direct manipulation interfaces enable visual, interactive access and manipulation, instead of tedious and error-prone form filling.

Fig. 6 shows two examples of MACE widgets for metadata editing: A compact version of our classification widget allows the application of over 1800 index terms based on auto-completion. Not only values are matched, but also field names and hierarchical elements for structuring the values. Consequently, users can either start typing "glass" and see immediately which index terms containing "glass" for tagging are available, but also type "period" and see a list of available styles and periods. The map widget displays automatically generated content positions. Any of the markers can be dragged to a new, more precise location, if the user is not satisfied with the result of the automatic assignment.

Using widgets for browsing and navigation

Additionally, our embedded widget approach fosters meaningful navigation and browsing across repositories: MACE details pages of a resource feature; a patchwork of metadata widgets (Fig. 7), which displays and makes accessible metadata for this content. Users can not only understand the nature and relevance of the presented resource, but also directly navigate to related items or query the MACE database based on metadata values. As every metadata value presented in the individual widgets can constitute a search re-orientation, we generalize the now ubiquituous "pivot browsing" principle first described in [39]. This way, MACE widgets enable multi-faceted navigation – not only on a semantic, but also a social and contextual level.

Fig. 6: Add and edit metadata in place (p. 322).

Fig. 7: The detail view of a Learning Object shows a patchwork of all its available metadata in widget form, resulting in various pivot points for further browsing and search (p. 322).

Widgets for orienteering and filtering in a faceted search application

facet

⑰ ⑳

In general, there is a limit to the quality of search results merely based on keyword matching in metadata fields [see e.g. 40]. In order to fully exploit the potential of metadata in content access and browsing, not only more sophisticated search mechanisms, but also improved forms of metadata visualisation are necessary.
The exploration of dynamic taxonomies [41] in faceted browsing applications [42], are often seen as most promising candidates for "rich exploration of a domain across a variety of sources from a user-determined perspective" [43]. These make different aspects of the underlying data accessible in parallel. Selecting one of the values, and thus filtering the result set, restricts the available metadata values to only those occurring in the results. Consequently, the user is visually guided through an iterative refinement process, effectively never encountering situations with zero results.
The field was pioneered by [43] and gained wider attention with the Flamenco system [44]; other implementations include the Exhibit browser developed in the MIT SIMILE project [45], the "/facet" system [46] or the mspace browser [47].
In a faceted search setting, wigets display aggregations of metadata values, rather than single resource values. In a search for "churches" for example, the map widget will display the number of churches found in each country or region. On the one hand, this often constitutes interesting information already; on the other hand, a click on the respective region offers drill-down possibilities for search refinement.

Fig. 8: (a) MACE advanced search (b) experimental faceted browsing interface (p. 323).

Especially in combination with the widget patchwork on MACE resource detail pages, this navigation principle is especially suited for navigating multi-faceted and multivalent "long tail" [48] metadata structures, which typically arise from a collaborative tagging activity, since this approach allows both quick and intuitive drill-down navigation as well as "context hopping". By successively selecting metadata values across facets, a "place" query can provide an entry point for a concept space, where individual concepts might in turn be related to specific users and so on.
We are currently experimenting with variants of the principle for different content access situations and investigating the technical feasibility of making parts of our contents available in a dedicated facet browsing application and coordinated view applications.
As a proof of concept, the elastic lists interface for facet browsing [49] has been adapted to browsing architectural contents based on architectural style, architects, and building types (Fig. 8b)[30].

Visual browsing of content classification

classification

The MACE classification glossary plays a central role not only in the tagging activity, but also in content retrieval and access. Accordingly, special care has been taken to make the terms and their organization structure optimally available in different situations. While for structured tagging, a type-and-autocomplete approach (Fig. 7) proved to be most effective, the browsing of the vocabulary as such, and also contents associated with the terms, is supported by an interactive visualization of the terms and their relations (Fig. 7). We extended the classical radial tree layout mechanism presented in [50] towards a structured tag cloud, where more frequently applied terms are presented larger (Fig. 7). Additionally, special care has been taken to produce a visually pleasing visualization, that, e.g. respects the Gestalt law of good continuation for the edge drawing, in order to improve joy of use and satisfaction with the interface, as this has been shown to have a measurable effect on performance as well [51].

THE MACE PORTAL

The MACE portal[31] serves as a direct access point to discover architectural contents and make use of the aggregated metadata. Further, by providing easy mechanisms for contribution and incentives for participation, we use the MACE portal to generate usage and social metadata, which in turn improves our services. In the end, more traffic on the repositories makes it more attractive for further partners to join; on the other hand, an active and committed user base is the best basis for a self-sustaining knowledge network.

Consequently, our services will be developed and made public in a successive manner: starting from content access and applications for discovering and learning to appreciate MACE metadata and contents, we gradually introduce features for personal information management. Once these are used sufficiently, enough data and users will be available to focus on personalisation, recommendation and social software features for advanced users.

For developers and content owners, the MACE portal will also be a central access point for the documentation of the MACE API for adding contents to MACE, but also for the download and integration of MACE embeddable widgets. However, as a first step, we will prioritize the development and testing of metadata services and the development of a growing user base.

Fig. 9: Browsing the hierarchical classification glossary in structured tag cloud visualizations (p. 323).

CONCLUSION

By enriching and connecting existing portals and their contents, we aim to provide a unique, single access point to high quality contents in the architectural domain. The MACE system, enriching and connecting a large number of architectural contents through various kinds of metadata, allows navigation through multiple paths and many parallel logical perspectives. Besides this being a dedicated instrument, supporting the Documentation and Design problem solving activities of architects and civil engineers, it effectively leads to a multiplication of learning experiences and to a serendipitous finding of results.

Especially from an informal learning perspective, MACE interface and system architecture will foster experience multiplication via metadata on many levels:

› An open system will be created, and incentives will be provided to actively enrich contents and share 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 direct, valuable connections among conceptually interweaved notions;
› 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;
› Faceted search in combination with our metadata widget approach represents a flexible, intuitively accessible model for navigating multidimensional data structures in 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 in how metadata values and/or search terms relate to each other; revealing these relations can greatly contribute to the 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. Using open standards and protocols ensures interoperability.

NOTES + REFERENCES + BIBLIOGRAPHY →

NOTES

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[2] http://globe-info.org.
[3] Metatagging is the automatic or manual operation of assign metadata to an object.
[4] http://dbpedia.org.
[5] http://freebase.org.
[6] http://ec.europa.eu/education/policies/educ/eqf/index_en.html.
[7] http://43things.com.
[8] http://wikipedia.org.
[9] http://mimoa.eu.
[10] http://mrnathan.munichre.com.
[11] http://freebase.com.
[12] http://dbpedia.org.
[13] http://aloe-project.de.
[14] http://www.connet.org/uk/esc/classification.jsp?node1=root&node2=&format=html.
[15] http://www.iso.org.
[16] http://www.getty.edu/research/conducting_research/vocabularies/aat.
[17] http://www.ascinfo.co.uk.
[18] Our choice is supported by similar addresses we find in some more recent studies: Thürlemann's work for painting, especially addressed to Klee's and Kandinsky's oeuvres [28]; Castiglioni's interpretative model focusing on urban design; models followed by Eco's and Calabresi's pupils at D.A.M.S. in Bologna during the '80s.
[19] The sequence of concepts involved in the design activity has been thoroughly studied by IUAV of Venice (Prof. V. Spigai), in collaboration with UNIVPM in Ancona (Prof. M. De Grassi), during the period 1994-2004.
[20] This analysis work was performed by the MACE consortium under the coordination of UNIVPM (Università Politecnica delle Marche, research group leaded by prof. M. De Grassi and A. Giretti).
[21] E.g. such as http://del.icio.us.
[22] http://globe-info.org.
[23] http://www.ariadne-eu.org.
[24] http://www.apple.com/macosx/features/dashboard.
[25] http://widgets.yahoo.com.
[26] http://yourminis.com.
[27] http://del.icio.us.
[28] http://technorati.com.
[29] http://plazes.com.
[30] http://interface.mace-project.eu/projectSearch.
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ISBN: 978-3-540-75194-6 / ISSN: 0302-9743

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ISBN: 978-951-758-492-0 / ISSN: 0356-9403