Real World Object Based Access to Architecture Learning Material – the MACE Experience

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Abstract: The MACE project aims to support architecture students while searching for learning materials by offering advanced graphical metadata-based access to learning resources in architecture across repository boundaries. Therefore, the MACE system uses real world object representations which serve as connection between learning materials. This enables the students to explore new and more complete learning paths. In this paper we outline the generation and usage of real world object representations within the MACE system and evaluate our approach.

Introduction

Architecture education, specifically in higher education, uses existing entities like buildings and projects for inspiration (Beckmann, 1998, Condotta and Ponte, 2002) and education continuously. These entities that we call real world objects provide a real world insight into what has been done in architecture, what is possible and what has not yet been explored. Therefore, real world objects provide excellent study objects for architecture students, supporting the paradigm of "learning by example" but also by providing examples for theoretical concepts and calculations. Consequently, students need to get access to learning material about the real world objects and related architectural concepts, architects, legislative information, construction, design, etc.

Today, relevant information and learning materials are available in rather distributed repositories. The learning material is not related with each other if stored in different repositories so that pointers from one learning resource to another are available only within the respective repository. Students searching for learning material need to access all repositories to find the relevant learning material. They have to create the relations among the learning resources manually, thereby being required to spend a significant amount of time on the administration of the learning material instead of focusing on the learning activity at hand. For example, educational resources are scattered over many repositories like the Dynamo repository (http://dynamo.asro.kuleuven.be/dynamovi/) providing information about architectural projects or ICONDA (http://www.iconda.org/) providing access to legislative documents important to building construction and design. Students would have to access both repositories to find a certain architectural project and related legislative documentation.

Finding appropriate resources is further hindered by the often used methods of search, namely simple keyword search. Instead, students need simple and personalized access to vast amounts of architectural information using advanced, visually based, discovery-oriented mechanisms for access to the learning material (Marchionini 2006). Examples might be image and location-based search and classification browsing. Such advanced methods of access require rich information about the learning resources.

Within the European project MACE (Metadata for Architectural Contents in Europe, Stefaner et al., 2007, http://www.mace-project.eu), we enable searching through and finding of appropriate learning resources in a more discovery-riented way. By automatically and manually linking related architecture learning resources of various non-related repositories with each other, we establish connections among them to enable simple and unified access to these learning resources scattered throughout repositories world-wide. Furthermore, using the visually and contextually oriented search facilities as well as the relations among learning resources, learners are able to browse the collection of learning resources without hindrance by repository borders. Consequently, learners are able to discover new learning resources that can serve as additional sources of inspiration. Repositories on the other hand willingly provide access to their learning resource descriptions in order to increase access to their learning resources. By subscribing to the cooperation paradigm of MACE, repositories also gain access to additional information about their learning resources, either through relations of learning resources or by employing the MACE crowd sourcing approaches.

The MACE crowd sourcing approaches are based on the necessary tools to setup and maintain communities around the topic of architecture learning resources. MACE enables these functionalities by incorporating the ALOE system (http://aloe-project.de). ALOE enables the user to contribute, share and access arbitrary types of digital resources such as text documents, music, or video files. Users are able to add learning material by either uploading resources or by referencing a URL. The communities contribute to MACE by creating new relations between learning resources from various repositories. In particular, users are able to annotate learning resources with tags, comments and ratings. Additionally, they can build up personal portfolios. Exploiting this user-generated metadata to its full extend enables richer descriptions of resources and “social browsing”, i.e. new ways to navigate the learning resources.

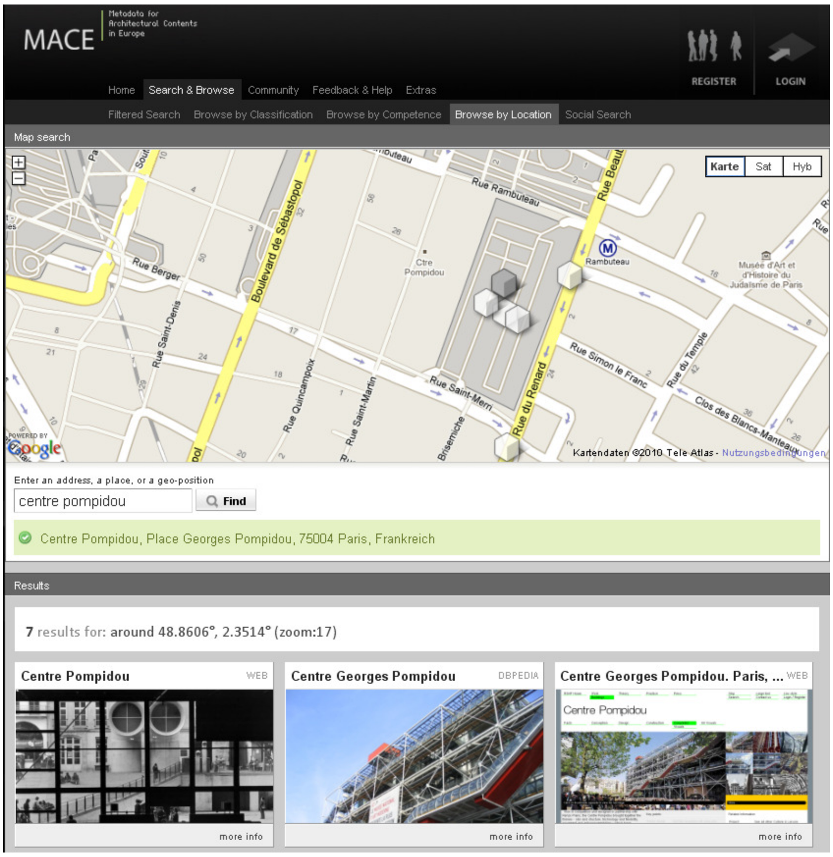

Figure 1: Geographical search interface, here for "Centre Pompidou"

In general, the MACE system supports the learner in finding the appropriate learning resource through a number of search and access methods. By browsing the MACE classification of architectural concepts, the learner finds resources with the same classification. By browsing the competence catalogue and selecting competences, the learner accesses learning resources that help him achieve the respective competences. If the learner needs to find learning resources geographically, she can browse the world-map (Fig. 1) with indications of learning resources associated with real world objects. Furthermore, by using the social community features of MACE, the learner selects tags that lead to appropriate learning material or accesses the portfolio of fellow learners. Currently, MACE also provides the learner with information about the usage of the learning resources, e.g. the most used, most accessed, etc. learning resources. While this already provides suitable information, the future development of MACE will incorporate the identification of similar learners and thereby further simplify finding appropriate learning material.

In the following, we outline the filtered search functionality in more detail as this seems to be the currently most often used search method. The “filtered search” interface of the MACE system is shown in (Fig. 2). The user is able to qualify the keyword search (here: “Renzo Piano”) with several additional facets that describe the context of the learning resource(s) in question: the repositories in which to search, the language of the results, the resource media type, the resource classification, and the associated competency. When choosing a respective facet, the interface is dynamically updated by ordering the filters anew and providing the numbers of results for each facet that match the selected criteria.

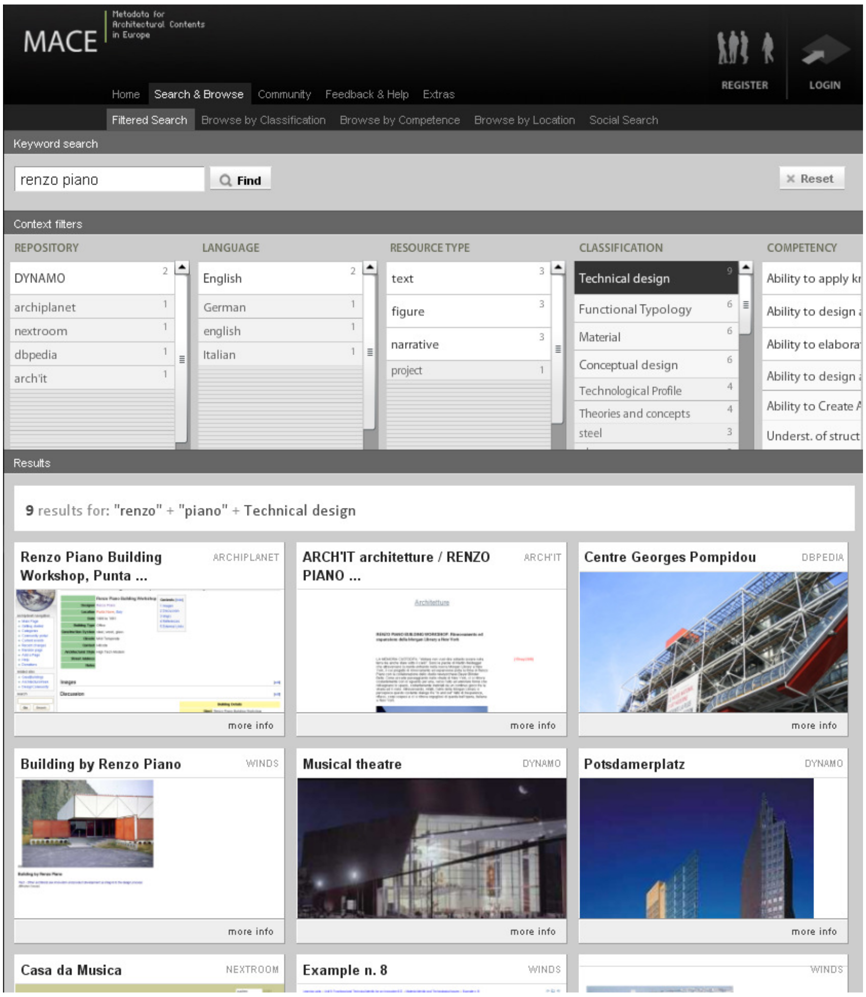

Figure 2: Filtered search interface of the MACE system - searching for learning resources related to the architect "Renzo Piano" and tagged with the classification value „technical design"

The results of a search are shown below the context filters. A thumbnail for each result provides further selection criteria, e.g. the resource title, a short description, and the repository where it was found. The user can decide to either immediately go to the result, or to view more metadata about the resource on the respective MACE detail page (link titled "more info"). The detail page, apart from information about accessibility of the learning resource, i.e. access and usage rights, author, title, etc., also shows relations to learning resources that are somehow associated to the current one.

The creation of the real world objects and the creation of relations among learning resources is described in this paper. We will focus on the usage of real world object representations as one of the main tools for bridging repositories and thus for the provision of a unified view on available related learning resources. In (Wolpers et al. 2009a) we already very briefly described our approach. In this paper, we will elaborate on the creation, usage, evaluation and the implications of real world objects within the MACE system. Therefore, section 2 will describe the nature of real world objects in MACE, while section 3 deals with their creation. Section 4 outlines how real world objects link learning resources with each other. Section 5 will present the successful evaluation of our approach and section 6 concludes the paper.

Real World Objects in MACE

Real world objects form one of the cornerstones of education in architecture. They can be buildings, projects and plans, but also architects and building material. Teachers use them as examples to demonstrate architectural concepts, ideas and examples. Students explore them to understand concepts, for inspiration, and also for demonstration purposes. Therefore, the MACE system also includes digital representations of real world objects which are called RWOs. RWOs are used to store contextual information of learning resources similar to the context model of (Zimmermann et al., 2007). In the following, the expression “real world object” always refers to an actual person, architectural project etc. while the term “RWO” refer to its digital representation stored in the MACE repository.

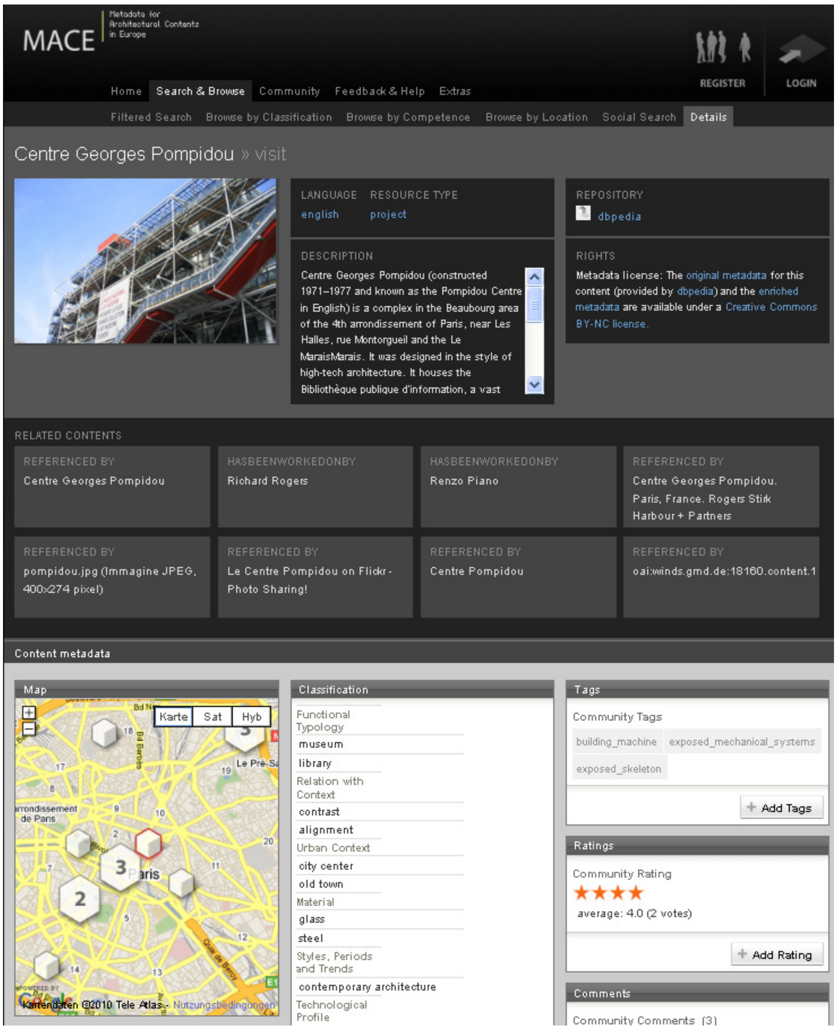

Figure 3: The real world object representation of „Centre Georges Pompidou”

The approach relies on the idea that each object in the physical world has exactly one RWO in MACE, which serves as a reference between reality and the MACE system. The references enable the MACE system to include descriptions of objects of the real world within its virtual realm and therefore provide the bridge between digitally represented architecture learning resources in MACE with objects of the real world.

Within MACE, RWOs are realized as bags which collect all related learning resources (that we call media objects as they most often have some type of media directly affiliated with them). For example, the RWO of the “Centre Georges Pompidou” references all media objects that deal with related topics, see (Figure 3).

The nature of the RWO therefore allows us to add specific metadata to each RWO that cannot be added to the related media objects. For example, the geographical location of a building like the „Centre Georges Pompidou" exists only at one specific location, while media learning resources might deal with an architectural concept like "Contrast" which has been applied when designing the "Centre Georges Pompidou". Such a media learning resource cannot have one geographical location but needs to be referenced by all those RWOs that are related to its content. The respective RWOs feature the geographical location if they represent objects that have fixed geographical locations.

Finally, real world objects do not only relate to respective learning resources. They also relate to each other as real world objects might feature relations among them. For example, the "Centre Georges Pompidou" was built by the architect "Renzo Piano". Both, the building and the architect, are real world objects. A relation between their representations in MACE is the "hasWorkedOn" relation to describe that the architect Renzo Piano worked on the building of the "Centre Georges Pompidou".

Learners are able to navigate from the RWO to all related aspects, e.g. the architect, the material used, the legislative documentation, building plans, etc. As the related aspects are described in either other real world objects or media learning resources, learners can navigate to them. This simple structure provides the ability to build additional access paths to the learning material. For example, a learner might want to know more about specific construction details of the "Centre Georges Pompidou". By navigating to the RWO of the "Centre Georges Pompidou", she would be able to access the information about the construction details without the need to explicitly search for them, browse the classification or browse the catalog of learning resources.

Generation and Representation of RWOs

In the following the automatic generation of RWOs using different sources and their representation relying on the LOMv1.0 standard are described in more detail.

MACE Application Profile

The unifying MACE metadata schema (http://www.mace-project.eu/index.php?option=com_docman&task=cat_view&gid=58&Itemid=154), which is used to represent the metadata of learning objects, i.e. media objects (digital or non-digital learning objects like an exercise or a figure) and real world objects, has been defined as an application profile of the LOMv1.0 standard (IEEE 2002). It extends the LOMv1.0 base schema with data elements, vocabulary values, a faceted classification of architectural terms and a taxonomy of learning competences in order to integrate the different types of metadata considered in MACE. Given that real world objects have certain characteristics that distinguish them from media objects, the MACE application profile defines several rules for representing them. Exemplarily, the shortened LOM instance for the real world object „Centre George Pompidou" is shown in (Fig. 4). The LOMv1.0 general category holds attributes like the identifier, the titles and the descriptions of the learning object; additionally, it is extended to also store the kind of the learning object e.g., "exercise", "figure" or "real world object". The LOMv1.0 educational category states whether a RWO describes a "designer" or a "project". The terms "designer" and "project" are generic terms representing architectural projects like buildings and bridges, respectively persons working in the architectural domain like architects and engineers.

Depending on the type of the real world object, additional data elements and vocabulary values can be used to describe it. For example, the status of a project in the LOMv1.0 lifecycle category can be "built", "demolished", "rebuilt", "renovated" or "unbuilt" and the contributors of a project can have the roles "architect", "constructor", "engineer" or "owner". In the example shown, it is stated that "Richard Rogers" worked as a designer on the "Centre George Pompidou". Additionally, RWOs referring to a project can hold geographical coordinates, i.e. latitude and longitude that are stored according to the OGC KML standard (Wilson, 2008). This enables the user to find the real world objects using the geographical search. Furthermore, a textual description of the location is stored, e.g. "Saint-Merri, Paris, Ile-de-France, FR, France" in the example. Since this description is considered in the keyword search, the search possibilities are enhanced.

The LOMv1.0 relation category was extended with values like "has worked on", "has collaborated with" or "references" to express relationships among real world objects and between real world objects and media objects. These relations can be used to express facts describing the relation between the learning objects. For example, a media object references a real world object (a text about the world's most famous buildings contains a section about the "Piazza del Duomo" in Pisa) or two designers collaborated with each other ("Renzo Piano" and "Richard Rogers" worked together on the "Centre Georges Pompidou" in Paris). It is important to state that in the relation category only relations among learning objects for which the MACE repository holds the corresponding RWOs can be expressed. For example, it is possible that an architect is mentioned in the life cycle section of a RWO for a project, even when there is no RWO in the MACE repository yet representing this architect. Additionally, it is possible that a relation between a RWO representing a designer and a RWO representing a project is recognized by analyzing the RWOs'metadata which would lead to a relation between the RWOs in the relation category, but not in the lifecycle.


```xml
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		<identifier>
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			<entry>mace:rwo:9d8b82ac-d851-11de-ad90-5389720d87e1</entry>
		</identifier>
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			<string language="es">Centro Pompidou</string>
			<string language="fr">Centre national d'art et de culture Georges-Pompidou</string>
			<string language="it">Centro Georges Pompidou</string>
			<string language="nl">Centre Georges Pompidou</string>
			<string language="no">Pompidou-senteret</string>
			<string language="sv">Centre Pompidou</string>
		</title>
		<description> [...] </description>
		<mace:learningObjectKind>
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			<mace:value>real world object</mace:value>
		</mace:learningObjectKind>
	</general>
	<educational>
		<learningResourceType>
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		</learningResourceType>
	</educational>
	<lifeCycle>
		<contribute>
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				<source>MACEv4.4</source>
				<value>designer</value>
			</role>
		</contribute>
		<contribute>
			<entity><![CDATA[BEGIN:VCARD FN:Richard Rogers VERSION:3.0 END:VCARD]]></entity>
			<role>
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				<value>designer</value>
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		</contribute>
		[...]
	</lifeCycle>
	<technical>
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					<kml:description>Saint-Merri, Paris, Ile-de-France, FR, France</kml:description>
					<kml:Point>
						<kml:coordinates>48.86065292358398, 2.352411031723022</kml:coordinates>
					</kml:Point>
				</kml:Placemark>
			</kml:kml>
		</mace:geolocation>
	</technical>
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			<value>hasbeenworkedonby</value>
		</kind>
		<resource>
			<identifier>
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				<entry>mace:rwo:a9facc90-d851-11de-ad90-5389720d87e1MD</entry>
			</identifier>
			<description>
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			</description>
		</resource>

	</relation>
	[...]
</lom>
```


Figure 4: LOM instance for the real world object "Centre George Pompidou"

Integrated Repositories

Currently the MACE repository contains RWOs describing designers and projects generated from data offered by DBpedia (Bizer et al., 2009), the UNESCO World Heritage List (http://whc.unesco.org/en/list) and Mimoa (http://www.mimoa.eu). The DBpedia knowledge base holds more than 2.6 million entities derived from Wikipedia and provides different classification schemata, e.g. the Wikipedia categories and the Yago Classification (Suchanek et al., 2007). These classification schemata are used to find the entities that describe designers or projects. Additionally, DBpedia offers several relations like "significant building" or "significant project" between designers and projects that can be derived and used to connect the real world objects in MACE.

The UNESCO World Heritage List includes 890 items forming part of the cultural and natural heritage which the World Heritage Committee considers as having outstanding universal value. An XML file containing the name, an English description and geographical coordinates for all items are accessible at the UNESCO World Heritage website. Mimoa (MI MOdern Architecture) is a free online architecture guide containing about 3000 architectural projects in Europe and offers an XML feed that contains information for all projects.

Uniqueness of RWOs

The usage of several repositories for the generation of RWOs leads to the problem of duplicate entries. For example, there is an entry for the "Pont du Gard" in the UNESCO World Heritage List and in DBpedia. To avoid such duplicates, new RWOs are compared to already existing ones before they are added to the MACE repository using the titles and geographical coordinates of the RWOs. If the new RWO holds geographical coordinates, only RWOs that hold similar coordinates or no coordinates are considered for the comparison of the titles. If all tokens of the RWO's title devoid of stopwords are contained in the title of another one or vice versa, they are considered to be similar. Since the titles do not need to match completely, it is ensured that related titles are considered to reference the same building e.g. two RWOs with the titles "Centre Pompidou", resp. "Centre Georges Pompidou" as well as two real world object representations with the titles "Airport Brussels", resp. "Brussels Airport" are assumed to be similar.

Connecting Learning Objects

The proposed approach to connect learning objects, i.e. media objects and real world objects, in the MACE repository is based on named entity recognition (NER). Therefore the names of persons and buildings are automatically extracted from the learning resource's metadata. Thereafter, the found entity names are used to find the RWOs stored in the MACE repository representing the referenced real world object.

Named Entity Recognition

Occurrences of persons and buildings in the learning resource's metadata are identified through the usage of the ANNIE information extraction system which consists of a set of information extractioncomponents included in GATE (General Architecture for Text Engineering, Cunningham et al, 2002). First the *Tokenizer* splits the text into individual tokens and classifies them into words, numbers, punctuation, symbols and spaces. The *Sentence Splitter* splits the text into individual sentences using the output of the *Tokenizer*. Then the *Part-of-Speech Tagger* produces a part-of-speech tag like noun or verb for each recognized token and the ANNIE *Gazetteer* uses 100 predefined lists of names and keywords to identify and tag proper names. These tags are used by the *Semantic Tagger* which annotates the text with new information such as entity types. By reason that traditional NER approaches do not recognize building names, an additional *Gazetteer* must be used. Hence, the *Gazetteer* uses a predefined list of building names containing the titles of all RWOs stored in the MACE repository. If a title contains brackets, it is added twice, one time with and one time without the brackets, e.g. "Missouri Kansas Texas (MKT) Bridge" is also added as "Missouri Kansas Texas Bridge". Currently, the list contains 66,893 names of buildings.

Connecting Learning Objects and Real World Objects

The system performs the named entity recognition process for each LOM instance stored in the MACE repository. When the name of a designer or a project is recognized, the system tries to find the associated RWO by comparing the name to all titles of RWOs that represent designers and projects respectively. This process is similar to the process of finding duplicate RWOs. All titles of a RWO irrespective of their language are considered to ensure that the associated RWO is found independent of the language of the reference. The titles do not need to match completely, but all tokens of one title devoid of stopwords and abbreviations need to be contained in the other one. In contrast to the process described above to merge RWOs, the order of the tokens is considered. For project names, this is due to our using a gazetteer to recognize the names which ensures that the tokens of the found project names are in the same order as the tokens of the names of the referenced projects. Person names can be written in a variety of forms depending on whether titles, first names, or initials are used. However, it is unconventional that running text contains person names in reverse order and person names are stored as „first name middle name surname" in the MACE repository.

If an associated RWO is found, the system adds a relation to the RWO capturing the relation. A textual reference can also be ambiguous and more than one RWO of the MACE repository can match the name found. For example, the name “Bank Tower” can refer to several real world objects, since there are RWOs for the Bank Towers in Los Angeles, Toronto, Doha and Shanghai stored in the MACE repository. If more than one RWO is found for a reference, the system searches through the matching RWOs to find further entities, i.e. person, building and location names. If only one RWO contains at least one of these entities or if only one RWO contains all of these entities, the system assumes that the real world object represented by this RWO is referenced, otherwise the reference is neglected. For example, if a learning object’s textual description contains the project name “Bank Tower” and the location name “Toronto” the system will assume that the Bank Tower in Toronto is referenced.

Evaluation

Currently, the MACE repository holds 51,652 RWOs from which 2,980 represent designers and 48,672 represent architectural projects. When connecting RWOs, a high precision is aspired because faulty connections impede the learners in finding the right learning paths. Therefore, two strategies are applied. First the named entity recognition process is conducted aspiring a high recall in order not to lose any possibly valuable information. Thereafter the extracted entities are used to find the according RWOs to connect them to the learning object. References that cannot be clearly disambiguated are not used so as to reach a high precision. For the evaluation of this approach, the 100 most used learning objects were taken while each learning object was assigned with tags that represent the referenced designers and projects. The tagging process was performed by three experts of the architectural domain and only tags that were used by at least two of the experts were considered for the evaluation to ensure the quality of the tags. 67 of the 100 learning objects hold at least one tag after this process.

Completeness of the MACE Repository

The considered learning objects hold references to 73 designers and 61 architectural projects. The MACE repository holds RWOs for 40 of these designers (54.8%) and 21 of these architectural projects (34.4%). Referenced real world objects that do not have a representation in the MACE repository yet are for example metro or bus stations, designs of not yet built constructions as well as only locally known buildings or architects.

Connecting Learning Objects and Real World Objects

For the identification of RWOs that represent designers and that are referenced by the considered learning objects, a precision of 90.6% and a recall of 72.5% were reached. The precision is promising due to the fact that in the second step, while the referenced real world objects are identified, most of the wrongly identified person names are filtered out. Since the metadata not always consist of whole sentences but also of single keywords, not all person names are found by the named entity recognition process.

For the identification of RWOs that represent architectural projects a precision of 92.9% and a recall of 61.9% were achieved. Just as it was for the identification of persons, the precision here is high due to the filtering process. Many buildings are not found by the *Gazetteer* as they were referred to using abbreviations like “HUHKA” instead of the full name “Het Museum van Hedendaagse Kunst” or imprecise descriptions like “Schlikker’sche villa” instead of the official name “Villa Schlikker”.

Uniqueness of Real World Object Representations in the MACE Repository

The RWOs generated using the DBpedia API serve as a basis in the MACE repository. When integrating new repositories the system needs to check if the new RWOs already exist in the MACE repository to not generate duplicates. If a representation for a real world object exists, the new information is added otherwise a new RWO is generated and stored. 100 randomly chosen entries from the UNESCO World Heritage List were used to evaluate the described approach. For 14 of these 100 objects the MACE repository already holds a RWO. While integrating the objects a precision of 85.7% and a recall of 57.1% were reached. Due to the fact that not only the titles but also the geographical coordinates were used when comparing RWOs, the precision shows that only in one case, two RWOs were merged that are not related. However, we aim for a higher precision and therefore plan to make use of location names contained in the descriptions when no geographical coordinates are given.

Conclusion

In this paper, we presented the generation and usage of RWOs within the MACE system. RWOs provide the connection between related learning objects that are used in higher education in architecture. They enable the students to explore new learning paths while browsing through the MACE portal. We described the information retrieval technologies applied to automatically generate the RWOs while ensuring that there is a RWO for each object of the real world mentioned in the learning resource descriptions that are included in MACE but no duplicates. The overall evaluation of the MACE system in respect to learning improvements is presented in (Wolpers et al., 2009b). Here, we showed and evaluated the technology bases needed to enable the real world object experience in MACE and its successful application.

We plan to increase the completeness of the MACE repository by integrating further repositories and by offering logged in users the possibility to add RWOs by themselves. Additionally, we further investigate the identification of referenced real world objects in the learning object's metadata by extending the lists used by the gazetteers.

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