Concept browsing for multimedia retrieval in the SCULPTEUR project

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Abstract. In this paper we briefly introduce some aspects of the SCULPTEUR project which have adopted semantic web technology to assist with the handling of multimedia information for museums. An ontology, based on the CIDOC CRM, has been developed and museum metadata has been mapped to it. This not only facilitates automated linking between the multimedia museum objects and the semantics captured in the ontology but also provides a basis for interoperability and a foundation for concept based browsing and display. The content-based retrieval features of the system are also briefly outlined in the paper.

1 Introduction

The SCULPTEUR project involves the Uffizi in Florence; the National Gallery and the Victoria and Albert Museum in London; the Musée de Cherbourg and the Centre de Recherche et de Restauration des Musées de France (C2RMF). These museums and galleries are rich in digital collections including images, 3-D models and videos together with rich textual descriptions and metadata. Although such institutions are working towards increased Web accessibility, this content is often held in internal systems with non-standard schemas and descriptions. Exploring and publishing this extra information over the Web is particularly difficult due to lack of tools and standards. We address this problem by using a common ontology for structuring and navigating museum collections and provide a search and retrieval web service that allows remote applications to access the multimedia content of museums.

This paper describes some of the work carried out in the project, in particular the mapping of the museum partners' legacy systems to a common ontology to provide interoperability and integration with the legacy systems and methods for cross collection searching. We also describe how innovative graphical browsers have been developed that allow users unfamiliar with museum collections to navigate, visualise and explore this rich source of cultural heritage information.

2 Mapping

The Conceptual Reference Model (CRM) [1], developed over the last ten years by the museum documentation standards group CIDOC, is in the process of ISO standardisation and is becoming increasingly used in the cultural heritage domain. It is capable of modelling the complex objects and relations within its scope, and can be extended to cover many specialisations. Although domain specific terminology can be modelled with the CRM, no vocabularies or thesauri are provided. Reliable sources of such information are required and in the SCULPTEUR project we have been investigating the use of controlled lists that are defined in the museum metadata.

In SCULPTEUR, we have mapped our museum partners' legacy database systems to the CRM. The efficiency of the CRM at capturing and representing museum information had been demonstrated with attempts to map existing cultural systems [2], but our experiences in SCULPTEUR suggest that mapping is complex and time consuming. The CRM has a steep learning curve, and performing the mapping requires a good understanding of both ontological modelling as well as the source metadata system. Eventually the assistance of a CRM expert was required to complete and validate the mappings.

Table 1. Mapping a database field, Period, to the respective chain of CRM concepts and properties

Database Field	Field Name	Mapping Chain
object.period	Period	E84.Information Carrier → P8B.witnessed → E4.Period
		E4.Period → P1F.is identified by → E41.Appellation (value of object.period)

The result of the mapping process is a table linking the database fields to a chain of CRM concepts and relations. An example is shown in Table 1 for the 'object period' field in the database. The object is mapped to the *E84.Information Carrier* concept in the CRM, and the period is mapped to the *E4.Period* concept. The relationship between the object and the period is indicated by the *P8B.witnessed* property. Note that the actual value from the database is mapped as an instance of the *E41.Appellation* concept, linked to the *E4.Period* concept by the *P1F.is identified by* property.

3 Interoperability

One of the main benefits of mapping to a common ontology is to achieve interoperability and cross-collection searching, both within a set of legacy systems installed at a museum or gallery site, or between multiple museums over the Web. However, there is more to interoperability than just mapping to a shared ontology, especially if the objective is to provide software applications with remote access to museum information.

In SCULPTEUR, we have achieved interoperability using a z39.50 search and retrieve web service (SRW) [3]. Rather than attempting to convert museum and gallery legacy data and schemas into CRM format, we leave the original data structures intact and use the SRW to query the data through the CRM ontology. In our implementation, we attach additional semantics to the legacy database attributes in order to more fully define their meaning in the context of the CRM framework, i.e. the mappings described in Section 2.

The SRW publishes the mapping information in an XML format through the SRW "explain" operation. The CRM ontology is available in the standard ontology language RDFS (http://www.w3.org/RDFS/), and may be used by client applications to manipulate the mappings and query results expressed in the CRM.

The SRW is able to dynamically map Common Query Language (CQL) queries expressed in terms of the CRM mappings to the relevant legacy database fields and return the results as XML structured according to the CRM mappings. The user can explore the CRM ontology and then use the SRW to retrieve corresponding instances. In this way we leverage Semantic Web techniques to describe and visualise the complex space of cultural heritage information, whilst using XML and Web Service standards to provide an easy to use search and retrieval service to access this information. By using the CRM mappings and the common CRM ontology, a common result schema is achieved and cross-collection searching can be done across multiple art object collections.

One of the main aspects of the SCULPTEUR system is the content-based retrieval of 2-D images and 3-D objects. A user can retrieve 2-D images by providing an example 2-D image, or part of an image in the case of sub-image matching, to find 2-D images that are similar in colour, shape or texture. A user can also specify a colour manually using a colour picker tool if they do not have an example to give the system. Similarly shaped 3-D objects can also be retrieved by presenting the system with an example 3-D object.

In the current system it is possible to execute combined metadata and content searches, and we are also investigating ways to do the same for CRM concept browsing and searching.

Although one of the main aims of the interoperability protocol is to enable distributed cross-collection searching, it is not the responsibility of the protocol to manage the breakdown of user specified queries against multiple sites, nor is it the responsibility of the protocol to manage the collation of the various result sets returned by the distributed queries into a single result set for presentation to the user. This functionality can be layered on top of the protocol and implemented either using a peer to peer architecture or a central broker.

4 Concept Browser

Searching and browsing by concepts provides the user with a high-level way to explore a collection by abstracting the relatively low-level text attributes found in many legacy systems. The use of an ontology allows text attributes to be grouped together according to common semantics, for example according to the concepts of people (e.g. artist, curator, owner, restorer), art objects and representations (e.g. painting, sculptures, films, digital representations), events and activities (e.g. creation, acquisition, restoration, loan, birth, death, period), places (e.g. gallery, conservation centre, country, city, town, studio), and methods and techniques (e.g. oil, watercolour, carving, x-ray, restoration technique). These concepts are linked together by relationships specified in the ontology; for example, the ontology specifies that objects are created during production events in which various people participate in different roles.

In SCULPTEUR we have developed a concept browser that allows users to explore the metadata in the museum systems following this approach. The concept browser was initially designed around a graph based visualisation of the CIDOC CRM ontology, where users could navigate to concepts of interest and request to view instances of certain concepts. The graph visualisation interface is based on “TouchGraph” [4], an open source graph layout system that has been extended and adapted to suit our requirements.

Informal user trials involving museum and gallery partners showed that the terminology and complexity of the CRM proved too challenging to visualise in an intuitive way. This led to the creation of CRM simplifications based on each museum’s legacy metadata structure to increase familiarity for the museum users. The interface was still based on the TouchGraph display, as shown in Figure 1.

However, these simplifications were hard to author and manage, and tended to be created by the technical partners. For more flexibility, we have developed a simplification editor that can be used, with some training, by key members of the museum partners’ staff, such as documentation experts. With this editor, users are able to customise the terminology used and merge different concepts,

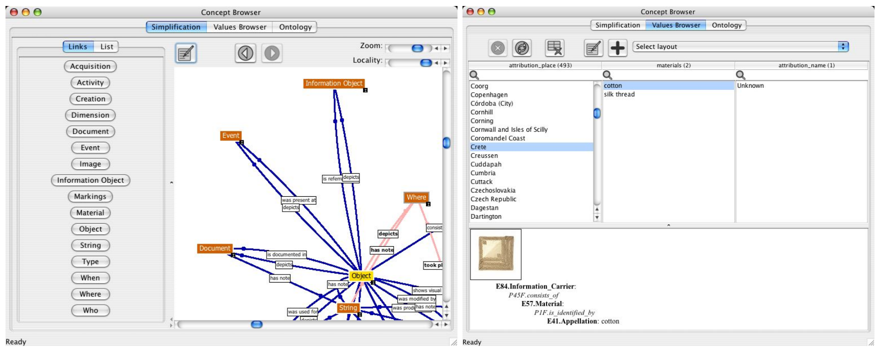

Fig. 1. Graphical visualisation of the ontology simplification in the Concept Browser Interface (left).Example of the mSpaces browser showing which artists used cotton as a material on works of art created in Crete (right)

for example by grouping the various CRM concepts to a single node "When". Mapping chains can be "shrunk", e.g. by reducing the chain in Table 1 to simply *E84.Information Carrier* → *P8B.witnessed* → *E4.Period*. Renaming the terms results in a more usable and friendly display, e.g. *Art Object* → *witnessed* → *Period*. The simplifications can then be loaded by default into the concept browser, with the aim that the majority of the users never have to see the underlying CRM terms or structures.

An important aspect of ontological visualisation tools is querying for instances of concepts. Although the visualisation of instance information within a graph based interface has been investigated [5], complex visualisation challenges must be overcome to cope with the scale of the datasets present/involved in the SCULPTEUR project. For example, the V&A museum database contains information on many thousands of objects; trying to display even a subset of this data in a graph-based visualisation will result in a confusing and messy display for the user.

Instead, the concept browser has based instance visualisation and query on mSpace interfaces [6,7] (see Fig. 1). mSpace is an interaction model designed to allow a user to navigate in a meaningful manner the multi-dimensional space that an ontology can provide. mSpace offers potentially useful slices through this space by selection of ontological categories. mSpace interfaces are extremely well suited to present the information from the museum systems in SCULPTEUR when structured according to the CRM ontology. mSpace interfaces are based on slices through an ontological space, with each slice represented as a list of values. Typically, mSpace interfaces use a multipanel display, where slices are presented as columns arranged from left to right. Selection in a slice will update the display so that the values displayed in the next slice (i.e. to the right of the current slice) are related to that value. For example, if there is a slice of artists and the next slice is painting titles, selecting an artist will display only that artist's paintings in the titles slice. Values in each slice are filtered, so that there are always results to view in the next column when a selection is made. When an item is chosen in a slice, details about that item are displayed in a detail panel; if no details are available for that item, examples of related objects are shown. Slices can be freely interchanged, removed and new slices can be added to the mSpace.

The museum metadata being dealt with in SCULPTEUR is large and varied, so there are many possible slices as well as combinations of slices that users may be interested in. The ontology simplification interface, based on TouchGraph, allows users to browse and add the slices in which they are interested into the mSpace browser, where they can be arranged to suit the user's preference. A preview panel displays the current slice arrangement, so that users can view the mSpace slices as they are put together in this interface. Predefined slice layouts can be selected, and users are able to save and load their own arrangements. As well as the TouchGraph display, we are investigating more traditional interfaces to present the available slices that can be added and removed from the mSpace browser.

5 Content-Based Retrieval

In addition to multimedia object retrieval via the ontology, users of the SCULPTEUR system can also use Content-Based Retrieval (CBR), allowing retrieval of 2-D images or 3-D objects from either an example 2-D image or 3-D object, or by defining the content manually (e.g. specifying a colour). A user can upload a picture of a vase and find similar images of vases, or if they have a 3-D model of a vase, they can find similar 3-D vase objects. To facilitate this, a range of algorithms have been implemented in the system. SCULPTEUR allows 2-D for 2-D matching for retrieval of similarly coloured (Mono Histogram, Colour Histogram [8], Colour Coherence Vector [9]), shaped (Hu Moments) and textured images [10] and multi-scale variants of these allow sub-image matching [11]. The colour picker tool allows manual specification of a colour which is used to find images that contain a large amount of that colour. It is also possible to use 3-D for 3-D matching and retrieval of similarly shaped objects; (Shape Distributions [12], Cord Histograms [13], 3-D Hough Transform s[14], Extended Gaussian Image [15], Area Volume [16]).

Similarity is typically based upon the Euclidean distance between two feature vectors, that of the query object and that of the database object. Some of the

CBR algorithms produce multiple histograms which require extra processing as part of the algorithm to obtain a single similarity score.

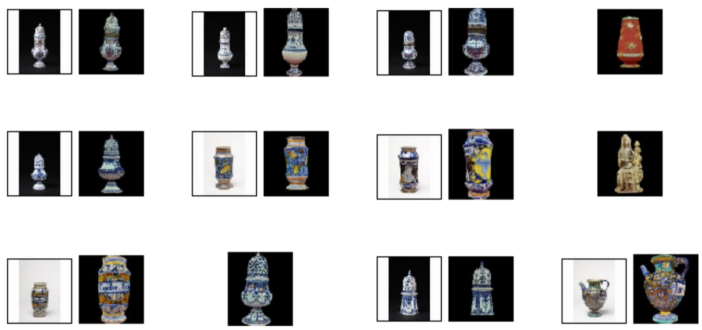

Fig. 2. 3-D Content-Based Retrieval using Cord Histograms

Figure 2 shows the best matches for a query object (a sugar caster) (top left object) which is also the most similar object in the system as would be expected. The other objects in the best match are all fairly similar, although due to the limited number of sugar casters in the system, other types of objects are shown in the list. The system returns a thumbnail of the representation that gave the best match along with the thumbnail for the object. Some objects have many representations, especially 2-D images, where it may not be immediately obvious what the original object looked like.

Content-based retrieval techniques generally give good quality results, however as seen in Figure 2 irrelevant but approximately similar objects can feature high in the most similar results. In SCULPTEUR content based searches can be combined with metadata or concept based searches and retrieval performance can thus be greatly improved.

6 Conclusions

In this paper we have shown how selective graphical visualisation and mSpace based display can assist with concept based multimedia information handling for museums. Some of the content based facilities of the system have also been summarised. The ontology based approach and platform which has been developed, we believe to have the potential for more comprehensive browsing, retrieval and mining of the rich museum data involved. Future work will include the addition of more powerful feature vectors for retrieval and data mining and further machine learning tools to assist users with the exploitation of their data.

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