Int J Digit Libr (2005) 5: 179–192 / Digital Object Identifier (DOI) 10.1007/s00799-004-0104-x

Metadata requirements for digital museum environments

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Published online: 18 January 2005 –

Abstract. We describe a system which addresses all the processes involved in digitally acquiring, modelling, storing, manipulating and creating virtual exhibitions from 3D museum artefacts. More specifically, we examine the significance of metadata in enabling and supporting all of these processes and describe the extensive facilities provided for authoring, maintaining and managing metadata. The development of the system has been heavily influenced by factors relating to interoperability, standards, museum best practice and feedback from two museum pilot sites. Finally, we briefly consider the system in the wider context of applications such as virtual learning environments and distributed repositories of archives.

Keywords: Metadata for digital museums – 3D digital museum artefacts – Virtual and augmented reality environments

1 Introduction

Advances in virtual and augmented reality technologies [11, 28, 47] have recently heralded the dawning of a new age in the cultural heritage sector. For museums and other memory institutions they hold the promise of being able to alleviate many of the dilemmas that such organisations have struggled with for some time now. One of the major issues is that of making valuable artefacts available to the masses while at the same time being charged with custodianship of such national and international treasures. This problem becomes even more acute when the artefacts involved are fragile in nature. Matters of accessibility are also of concern due to disabilities and geographical barriers which prevent interested parties from physically visiting a museum, and the fact that museums do not have sufficient exhibition space to place on display all of their holdings simultaneously. For example, the Victoria and Albert Museum [38] in London has over 4 million objects in its collections, while the Sussex Archaeological Society [37] has 500 000 objects.

We describe the metadata requirements of a system that helps in the conservation of museum artefacts, while at the same time making them widely available in digital form to scientists, researchers, curators, historians and the general public.

Metadata have always been a critical aspect of describing and managing museum holdings; they continue to play a key role in digital asset management systems as well as virtual museum environment systems such as the one under discussion here. Metadata are defined as "structured data about data" [22]; they can also be considered information or data about resources. Their purposes are too many to list, but they include: description, management, resource discovery, preservation, curation and rights management of information objects.

In Sect. 2 below we begin with a review of metadata in the cultural heritage domain relevant to building a system for managing and displaying digital representations of museum collections. We then go on to consider the processes involved in such a system and their metadata requirements in Sects. 3 and 4. The resulting data model and metadata vocabulary are described in Sect. 5, followed by a look at the metadata management tools in Sect. 6. Section 7 addresses metadata visualisation in virtual and augmented reality interfaces.

2 Metadata in the cultural heritage domain

A number of organisations and initiatives have attempted to address the wide-ranging metadata requirements of the cultural heritage sector. Amongst these, some of the most notable are: the Consortium for the Computer Interchange of Museum Information (CIMI), the mda

(formerly the Museum Documentation Association), the Art Museum Image Consortium (AMICO), the International Committee for Documentation (CIDOC), the European Museum's Information Institute (EMII), the Research Libraries Group (RLG), and the Visual Resources Association (VRA).

One of the most important standards in this area is SPECTRUM [36]. This standard is coordinated by the mda [30]; it was originally a standard for documentation of UK museum collections. SPECTRUM has resulted from a collaboration of over 100 practitioners working in the area of documentation in museums. It comprises procedures for documenting objects and the processes that they undergo. It also identifies and describes the information that needs to be maintained to support those procedures. The intention is that the standard should contain all those functions that are common to most museums. A particular institution would then choose and use those procedures that are most relevant to its own requirements. The advantage of adhering to SPECTRUM is that data exchange between organisations becomes much easier.

CIMI [15] is committed to bringing museum information to a wide audience, encouraging an open-standards-based approach to the management and delivery of digital museum information, focused on interoperability and usage of common tools in a museum context. CIMI has also developed a metadata test bed based on SPECTRUM, the XML binding for which became publicly available in March 2003 [16].

The Art Museum Image Consortium (AMICO) [1] is building The AMICO Library, a resource that makes digitised versions of artworks available to educational institutions and other museums by subscription. The metadata schema associated with each item in the AMICO Data Dictionary [2] can record detailed information about the type of object being described.

CIDOC [13] has an international focus on the documentation interests of museums and similar organisations. The CIDOC Conceptual Reference Model (CRM) [14], now ISO/CD 21127, is intended to cover all concepts relevant to museum documentation, but most particularly those needed for wide area data exchange. Due to the diversity of museum subjects, that goal can ultimately be achieved only by extensions to the CRM.

In 1997, the Research Libraries Group (RLG) launched the REACH project [35]. The aim of the project was to explore how existing information in museum collection management systems could be extracted and repurposed to provide online access to museum object descriptive information. The REACH Element Set was to be used for exporting data from disparate museum collection management systems. The set has many commonalities with other cultural heritage data standards; it allows details of provenance, dimensions, materials and production techniques to be recorded alongside information such as title, subject, place of origin, and date of creation.

The European Museums' Information Institute (EMII) [20] aims to establish a working model for the provision of various types of content (text, images, film, video, etc.) from various sources (museums, broadcasters, archives, libraries, etc.). The objective is to identify specific issues that content holders need to have addressed before they make the content in their care available for research purposes.

The Visual Resources Association [40] is a multidisciplinary community of image management professionals working in educational and cultural heritage environments. The Association is committed to providing leadership in the field, developing and advocating standards, and providing educational tools and opportunities for its members. Development of the VRA Core Categories, version 3.0 [41], reflects that the VRA is largely concerned with 2D images. The VRA Core Categories consist of a single element set that can be applied as many times as necessary to create records to describe works of visual culture as well as the images that document them.

Two other initiatives are worth mentioning in relation to metadata for images: Iconclass [24] and the NISO Technical Metadata for Digital Still Images (currently in draft) [32]. Iconclass is a collection of ready-made definitions of objects, persons, events, situations and abstract ideas that can be the subject of an image. Iconclass organizes iconography into ten main divisions, each containing hierarchically ordered definitions. The goal of the NISO standard is to facilitate the development of applications to validate, manage, migrate and process images of enduring value.

Although the Dublin Core Metadata Initiative (DCMI) [17] does not deal specifically with museum archives, the Dublin Core Metadata Element Set (DCMES) [27] is of importance for resource discovery across domains and hence of great relevance to any system proposing information retrieval over the Internet. It is also pertinent to issues of interoperability and information exchange.

3 Digital capture to visualisation

The goal of the Augmented Representation of Cultural Objects (ARCO) system [3] is to develop innovative technologies and expertise to help museums create, manipulate, manage and present small to medium artefacts in virtual exhibitions both internally within museum environments and over the Web.

It is notable that although many museums have now established an online presence on the Internet, currently this presence is almost invariably a 2D one; that is associated Web sites comprise 2D images and textual descriptions. ARCO on the hand recognises that objects are 3D in nature, that they have a front and back, top and bottom, mass and volume. ARCO seeks to enhance the awareness and experience of cultural objects by providing

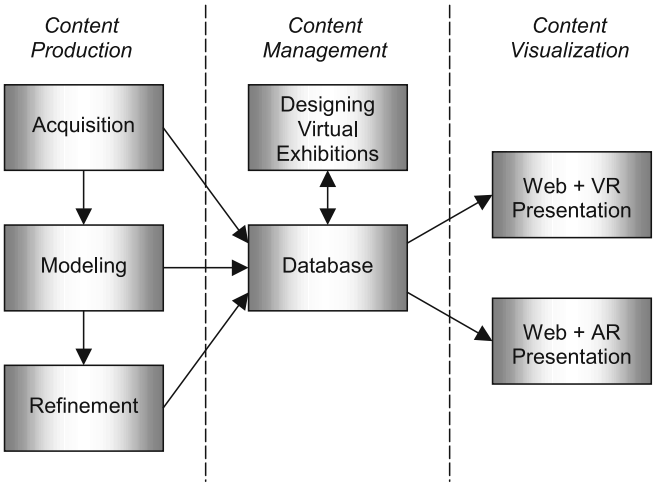

Fig. 1. Overview of ARCO system architecture

technologies for creating 3D digital surrogates of artefacts and allowing users to interact with them.

To efficiently use virtual reality and associated technologies in cultural heritage applications, the problems of automatic or semi-automatic creation, efficient storage, management and retrieval, and advanced interactive visualisation of digital representations of cultural artefacts must be addressed. Metadata are a key component in such a system.

Figure 1 provides an overview of the architecture of the ARCO system. Conceptually, it comprises the three major functions of: content production, content management and content visualisation. Content production itself consists of several procedures: artefact selection, digital acquisition, 3D modelling and interactive refinement. Content management comprises storage of all related data in a multimedia database and design of virtual exhibitions and scenes. Content visualisation is through either virtual or augmented reality environments over the Web or locally within a museum.

4 Metadata requirements

Metadata requirements, as well as the whole of the ARCO system, have evolved through a process of iterative refinement. In all, four prototypes have been developed through a recursive process consisting of specification, implementation, assessment and evaluation, and feedback from user groups. In assessing metadata requirements, the following aspects were taken into account: user requirements, functional requirements, interoperability and standards, and museum best practice.

4.1 User requirements

Since the functionality of the ARCO system extends all the way from digital acquisition to the creation of virtual and augmented reality environments and applications, several groups have been identified as users of the system [8]. Each of these groups has differing metadata requirements:

A *cataloguer* is likely to need to store, edit and perform searches based on descriptive curatorial metadata.

A *photographer* will need to provide, modify and query metadata related to digital photographs of artefacts.

An *object modeller* is a person who creates 3D models of artefacts using digitisation and modelling tools. This type of user will need to input, edit and search metadata associated with 3D models.

An *object refiner* is a person who makes interpretations of artefacts and modifies their representations. This group of users need to work with metadata associated with refined objects.

An *exhibition designer* is responsible for the composition of virtual exhibitions, which may have either 2D or 3D visualisations. The designer needs to select a number of cultural objects and a visualisation template by querying the database using metadata terms.

The *end user* represents those involved purely in the access of artefacts and exhibitions. This group of users need to be able to browse and query the repository of 3D objects using various metadata terms.

Identification of the above groups highlighted the types of metadata as well as many of the metadata terms that would be useful in the system. Furthermore, given the differing user groups and the variances in their use of metadata, it became clear that a strategy for controlling who could enter and modify subsets of the metadata and at what stages would also be necessary.

4.2 Functional requirements

The architecture of the ARCO system is component based. As indicated in Sect. 3, the process of creating virtual environments can be broken down into a pipeline of discrete and independent processes. Hence the functional requirements and technical constraints were investigated for individual parts of the system: artefact selection, digital acquisition, storage and management, model refinement, building exhibitions and visualisation using a number of different scenarios (remotely over the Web, touch-screen displays in-house within a museum, and table-top AR environments). It was necessary to examine the metadata requirements not only for each of these processes but also for the interactions between the processes and the necessary data exchange between various components. The ARCO processes and related metadata operations are presented in Fig. 2.

4.3 Interoperability and standards

Interoperability has been considered at two levels: in terms of internal data exchange and in terms of openness

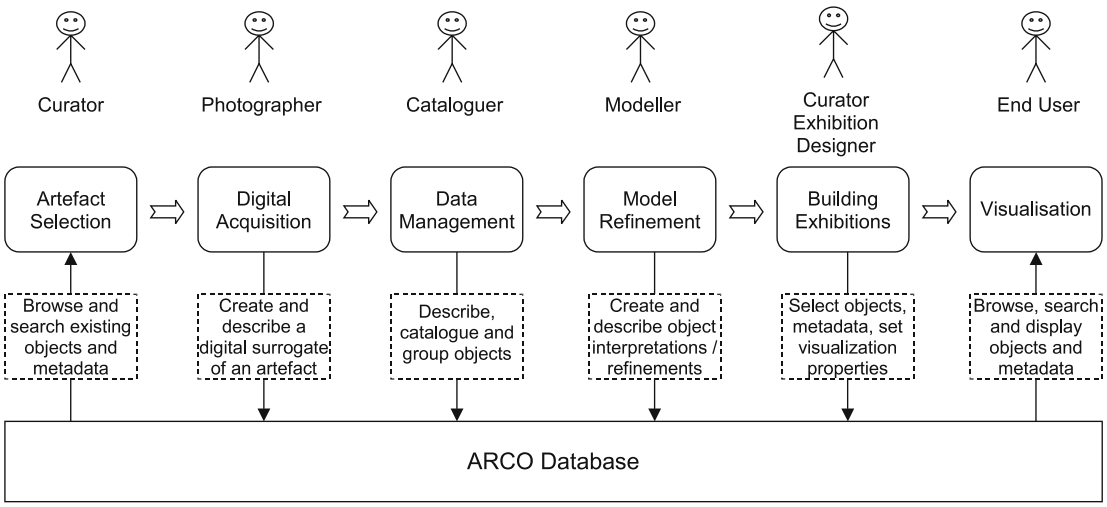

Fig. 2. ARCO processes and related metadata operations

of the system in communication with other external systems. Data exchange in ARCO is based on the W3C Recommendations, XML and XML Schemas (XSD) [42]. Semantic Web technologies such as RDF [43] and OWL [44] were not sufficiently mature or robust at the time of development.

ARCO specifies an internal format, the XML Data Exchange format (XDE), which is used within the system for interaction between the components. This format can easily be converted to a more appropriate format for external data exchange through the use of technologies such as XSLT [45].

Use of standards is important for any system intending to operate in a context wider than that of itself and in particular in the heterogeneous environment of the Web. ARCO makes use of several different standards: Internet (HTML, HTTP); 3D graphics (X3D [21], VRML [39], OpenGL [34]); W3C Recommendations (XML, XSD); and metadata standards and best practice (Dublin Core, SPECTRUM).

4.4 Museum best practice

We have taken the view that ARCO should draw on, incorporate and build on extant museum best practice as far as possible. However, a metadata review [29] revealed that no single existing metadata element set was suitable for the range of processes envisaged in the ARCO system. More specifically, there are no metadata standards that cater for the digitisation, storage and management, and dynamic creation of virtual exhibitions of 3D cultural heritage objects.

In crafting the ARCO Metadata Element Set (AMS) [7] the initiatives described in Sect. 2 were taken into account and in fact, the AMS draws on elements from a number of these, in particular the DCMES and SPECTRUM using the concept of *application profiles* [9, 19, 23]. An application profile is a metadata schema that draws on existing metadata element sets, adapting and customising specific elements for a particular local application.

The cataloguing system of the SussexPast Archeological Society, MODES, which is based on SPECTRUM, was closely examined. The metadata used in the picture library of the VAM were also taken into account in developing the metadata terms associated with digital images in the ARCO system.

5 Metadata for digital museums

An iterative process of specification, prototype development, assessment and evaluation, and feedback from two pilot museum sites has resulted in an evolution of the AMS as the functionality and user requirements have been refined and reviewed.

5.1 The ARCO data model

In order to meet the functional requirements of the ARCO system, the data model depicted in Fig. 3 was developed. The model describes the entities, as well as their relationships, which are involved in transforming a physical artefact into its digital form. We define a class, Cultural Object (CO), as an abstract representation of a physical artefact. This surrogate object is represented in terms of descriptive metadata, which provide a reference back to actual museum holdings. There are also two non-abstract entities, which are subclasses of the CO: the Acquired Object (AO) and the Refined Object (RO).

An AO is a digitisation of the physical artefact used in the ARCO system, whilst the RO is a refinement of an AO or another RO. There may be more than one RO created from a single AO or RO. Digital representation of a CO (i.e. AO or RO) may be composed of one or more Media Objects (MO). The MOs are representations of the CO in a particular medium represented by some MIME type. Examples of MOs are *3D Model*, *Simple Image*,

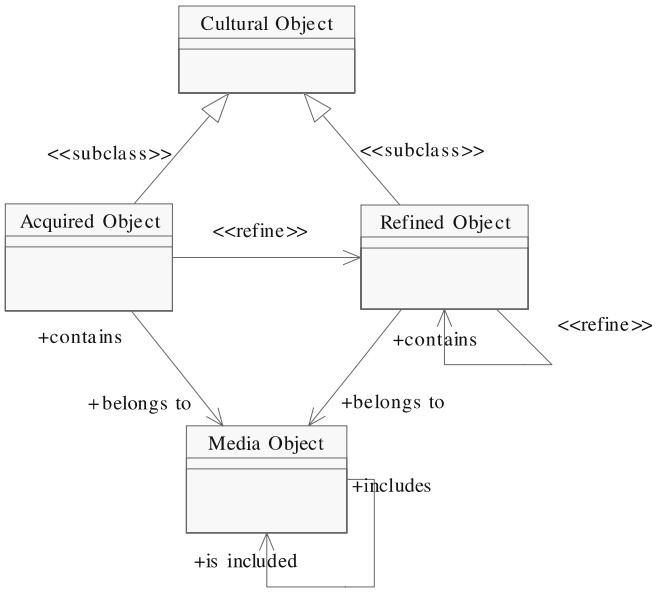

Fig. 3. ARCO data model

Panoramic Image, and *Description* – each with differing MIME types. An RO may inherit MOs from the CO it refines and may add new ones. For example, a museum curator may create an RO from an AO by adding a 3D Model or Description.

This data model loosely conforms to the definitions provided in the IFLA Functional Requirements for Bibliographic Records (FRBR) [26], in particular the products of intellectual or artistic endeavour, i.e. *work, expression, manifestation* and *item*. In ARCO, the physical object is the product of intellectual or artistic effort corresponding to a manifestation or item (denoted by curatorial metadata), whilst its digital representation (the AO) and any modifications to this (the RO) can be regarded as derivative expressions in the FRBR sense.

5.2 Types of metadata

An initial specification of the functionality and user requirements of the system [4] indicated that several different types of metadata would be necessary in the ARCO system. In the interests of interoperability and to avoid reinventing metadata elements, the terms in the AMS comprise those from standards, but are also supplemented with ARCO specific metadata terms. Table 1 provides the names of the metadata terms used in the AMS; a full specification can be referenced on the ARCO Web site [7]. The main categories of metadata include: curatorial, technical, resource discovery, thematic grouping, presentation and administrative; they are discussed below.

5.2.1 Descriptive curatorial metadata

This is essentially curatorial knowledge and comprises descriptive elements drawn from SPECTRUM. It represents similar details to those recorded for the actual physical cultural object which was used to create the AO. As far as possible, compatibility has been maintained with the metadata being used at museum pilot sites. It is pos-

Table 1. AMS vocabulary terms associated with data model entities

Type of metadata		**AMS vocabulary terms**
Administrative		Creator, Date Created, Date Modified
Cultural Object		Source, name (title), name (title) alternative, Creator, contributor, object production date, object production place, type, description, rights, completeness, condition, production period, production technique, material, dimension, components, owner, acquisition source, accession date, field collection date, field collection method, field collection place, field collector, current location
Acquired Object		Identifier, name, creator, contributor, publisher, date created, description, rights, format, format extent
Refined object		Relation is version of
Media object		Name, type, subject, description, date created, technique, creator, format extent, rights, skill level, person effort
Media Type Specific	Simple image	Image size, resolution, compression method, compression factor, colour depth
	Description	Length, character set
	3ds max Project	Software version, required extensions
	VRML model	VRML version, number of textures, composite, animated
	Panorama image	Number of images, step angle
	Multiresolution image	Resolutions, software, algorithms
Presentation (examples)		Caption text, transform, quiz question, quiz answers, ...

sible to gain additional information by cross-referencing the value of the *source* element with a museum's own holdings information. Curatorial metadata are recorded as being associated with CO entities in the data model described in Fig. 3 and acts as a surrogate representation of the actual artefact.

The reader may observe that Table 1 lists a set of metadata relating to field collection. The granularity of this metadata is required in the AMS in order to adequately describe artefacts from history museums such as the Sussex Archaeological Society [37], which is one of our pilot museum sites.

5.2.2 Technical metadata

Technical metadata record the multimedia data formats, types of hardware, versions of software and various other technical parameters used in the creation, storage and manipulation of the digital object. This type of metadata is often required to address issues relating to digital preservation and provenance. Note that it is necessary to maintain metadata for individual photographs used in the creation of a digital representation of the artefact. The photographic metadata are modelled on the VAM photographic schema.

Technical metadata are recorded at the level of MOs (Fig. 3). Some of the elements are associated directly with particular MOs, while others are associated with a parent-child relationship between MOs (e.g. image angle is related to the association between parent Panoramic Image and child Simple Image).

5.2.3 Metadata for resource discovery

The DCMES was initially developed for resource discovery on the Web. It has subsequently been adopted for cross-domain resource discovery by many projects and initiatives in a bid to make their resources universally accessible. The ARCO project has adopted suitable elements (*identifier*, *subject*, *creator*, *contributor*, *publisher*, *date created*, *date modified*, *source*, *title*, *title alternative*, *type*, *description*, *rights*, *format*, *format extent*, *relation is-version-of*) from the DCMES to enhance the potential for cross-domain discovery of museum artefacts. Subsets of the terms selected form part of the metadata for CO, AO, RO and MO entities as indicated in the specification of the AMS [7]. Where there is a direct correspondence or overlap with specific information units in SPECTRUM we have chosen to use DC and note the mapping in the usage guidelines.

5.2.4 Thematically grouped metadata

This type of metadata is defined as "metadata related to the level and type of use of information resources" [22]. Within the ARCO project this concept is used to provide additional functionality.

Feedback from museum pilot sites indicated it would be useful to get an estimate of time and effort required in digitising and modelling objects using the ARCO system. To facilitate acquisition of such information we have incorporated a grouping of terms that provide such information; this is known as effort report metadata.

5.2.5 Presentation metadata

In order to describe the appearance of cultural and media objects in virtual galleries, we use presentation metadata. Such metadata elements are recorded for the ternary association: Media Object – Cultural Object – Exhibition Space. The MO in this association may be left empty, meaning that the value describes visualisation of the CO. If both MO and CO are empty, the value describes the whole exhibition space.

Use of presentation metadata depends on the employed visualisation templates, and each template may use a different subset of the metadata. For example, the element *Caption* may be used by a 2D, a 3D and an AR visualisation template, but each template may use this element in a slightly different way. The element *Transform* will be used only by the 3D visualisation template. ARCO defines an initial element set for the presentation metadata, but enables extension of the element set to allow an exhibition designer to incorporate new visualisation templates.

5.2.6 Administrative metadata

Basic administrative metadata using appropriate elements from the DCMES is used to keep track of the creator, the creation and modification dates of a metadata description. Since different user groups are responsible for maintaining metadata associated with the entities in the data model (Fig. 3), administrative metadata are recorded for each CO, AO, RO and MO.

6 Metadata management

Management of museum collections, whether physical or digital, relies on the integrity of associated metadata. In addition, proliferation of digital resources has led the digital library community to raise various concerns with regard to upholding the quality of metadata [10, 18]. Below we see that ARCO provides comprehensive facilities to make metadata management as simple, easy and consistent as possible.

6.1 Implementation of AMS

The central element of the ARCO system architecture is the ARCO database implemented on top of the Oracle 9i ORDBMS. All ARCO components use the database to store and retrieve persistent data produced and used in the system. All cultural and media objects stored in

the ARCO database are described with appropriate XML metadata records. The use of XML enables us to leverage the rich XML-based functionality provided by modern DBMSs.

The choice of XML [5, 6] for storing metadata also provides a good degree of flexibility in the definition of metadata element sets. In addition to storing descriptive metadata instances, the ARCO database also stores the XSD schema definitions of the AMS. Museums can modify the schemas, and therefore change the way objects are described, in order to reflect their own particular needs or current practices.

The ARCO database holds separate AMS schema definitions for different types of objects (e.g. Acquired Object, Refined Object, Simple Image Media Object), and the AMS specifications can be changed independently. Metadata schema definitions are encoded in XSD and stored in the database in native XML format. Further details regarding the implementation of the AMS can be found in [31].

6.2 Managing AMS schemas

The AMS schema definitions stored in the database can be managed by the use of the AMS Schema Manager, illustrated in Fig. 4. The Schema Manager is a part of *ACMA – ARCO Content Management Application* integrating a number of tools for user-friendly management of different types of data in the ARCO database.

When the metadata requirements change, new versions of an existing AMS schema definition can be created. Such an operation does not require modification of the ARCO database structure, the ARCO tools, and the existing AMS instances. This allows museums to have objects of the same type with different metadata schemas and step-by-step migration from one AMS specification to another without the need to change the descriptions of all objects. This approach provides flexibility in extending and maintaining the AMS specification.

The ARCO system is extensible and allows addition of new types of media objects. The Schema Manager allows an administrator to define new AMS schemas describing a newly created media object type.

Since the schema definitions are stored in the database as XSD files, a standard XML Schema editor may be used to create a new schema or modify an existing one.

6.3 Managing AMS records

The ACMA application provides an intuitive and easy-to-use AMS Instance Editor, which is embedded in the ACMA *Cultural Object Manager* – a tool used to manage data related to digital representations of cultural objects. A user may select any cultural or media object and view or edit the associated metadata record, which is represented as a tree (Fig. 5). The tree is built according to the version of the AMS specification associated with the particular object.

All mandatory metadata elements are inserted automatically, while optional metadata elements may be added manually. Every action, such as editing an element value, adding or deleting an element, is verified against the specific version of the AMS schema and may be disallowed or automatically annulled if it is not valid. This ensures quality and consistency of the metadata descriptions.

The AMS Instance Editor provides some additional mechanisms to simplify the creation of metadata. It auto-

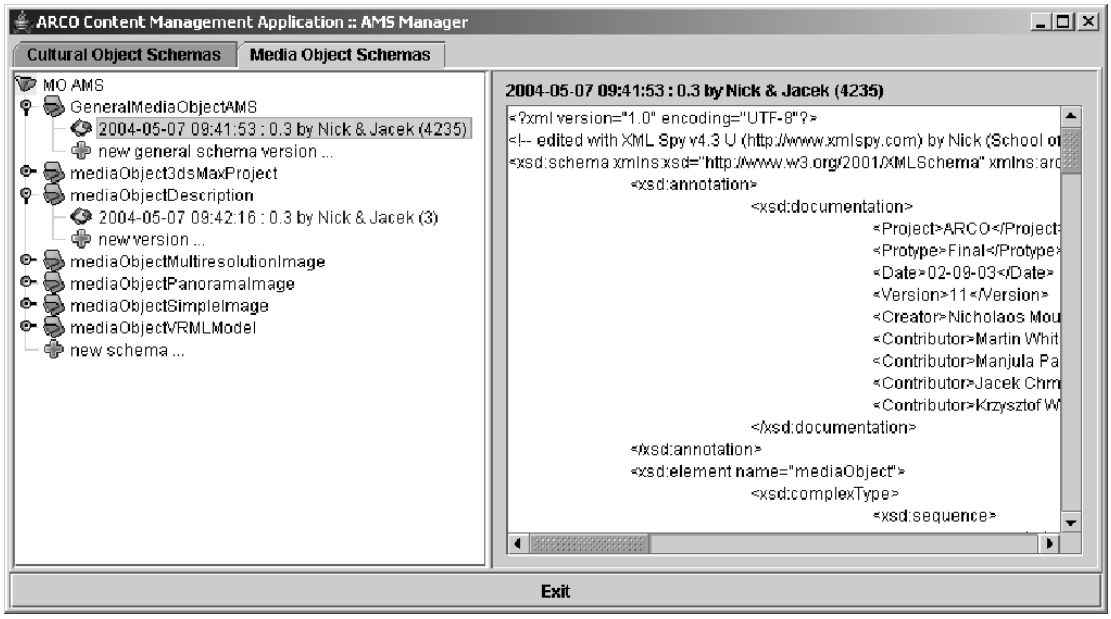

Fig. 4. AMS Schema Manager

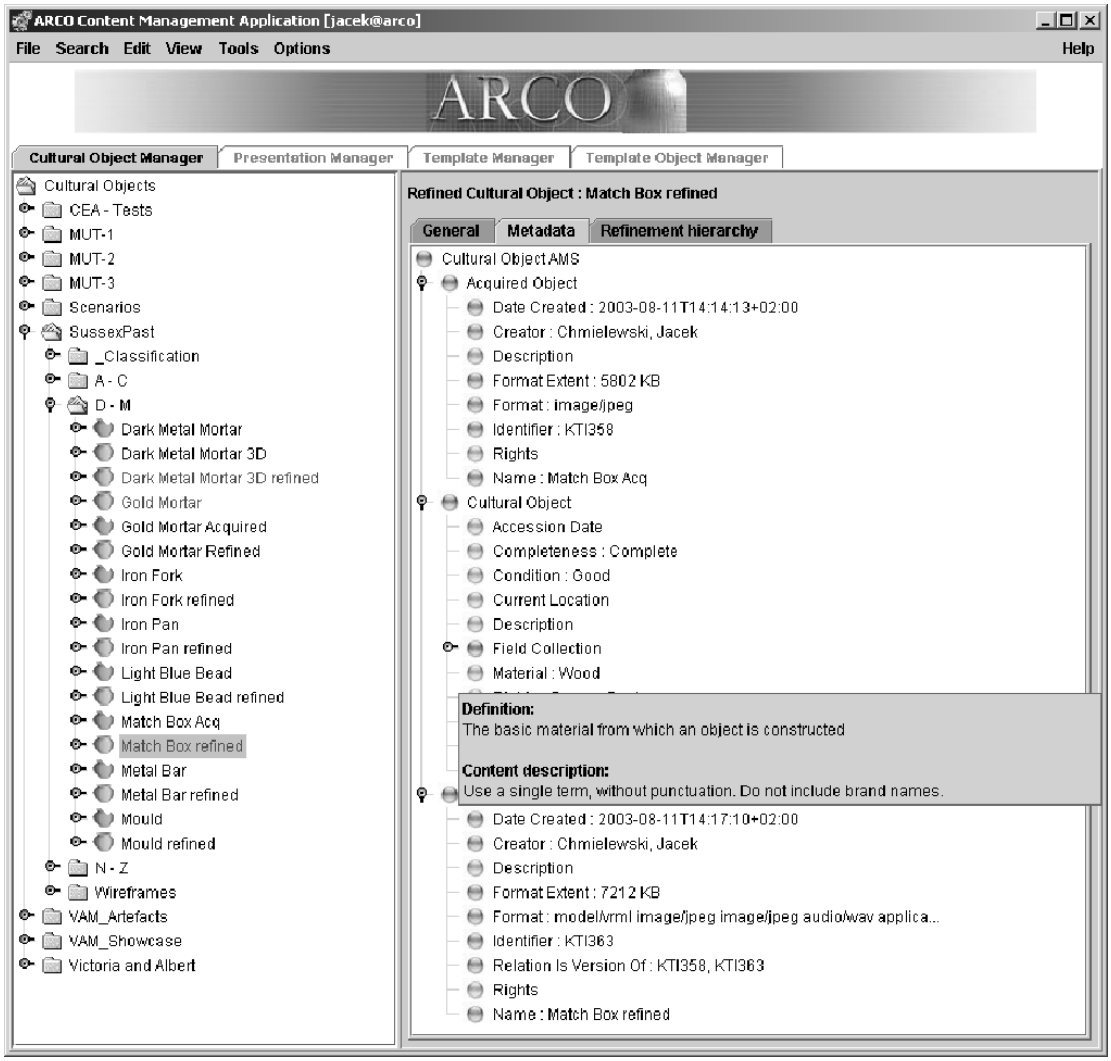

Fig. 5. ARCO AMS Instance Editor: metadata tree for a Refined Object

matically generates metadata values for some specifically defined technical elements (elements with a grey icon), such as *Format Extent*, which provides size (in bytes) of the object representation. For elements that are constrained by an enumeration or controlled vocabulary defined in the AMS specification, the editor displays a drop-down list indicating permitted values.

Using additional <*appinfo*> elements in the AMS schema, the creator of the AMS is able to include some additional information and content guidelines for the user. Such information is displayed as a tool tip for the selected metadata element (Fig. 5).

6.4 Searching with AMS

The ACMA provides an integrated search tool, which enables easy location of specific Cultural Objects, Cultural Object Folders or Media Objects (Fig. 6). In addition to simple search based on the object name or type, an advanced search based on all metadata elements defined in the AMS schema can be used. Since the AMS specification is extensible, the search interface is built dynamically to provide the full set of AMS elements. The most recent AMS specification is always used to build the interface. The AMS search system provides a set of Boolean operators, which can be used to build complex search queries. Advanced search features like finding all words with the same word root as the specified word or finding all words that sound similar to the specified one are also available.

The search results are displayed as a list of objects with a 'link' bound to each of them, allowing the user to jump directly to the selected object in the folder hierarchy. In addition to this basic functionality, all objects that are found may be assigned to a selected object folder, exported into an XDE file, or assigned to a presentation folder – forming a virtual exhibition. This simplifies the management and visualisation of objects from the same historical period, made from the same material, or – in general – similar in terms of any combination of metadata elements.

To enable dynamic creation of virtual exhibitions based on the search results, another mechanism called

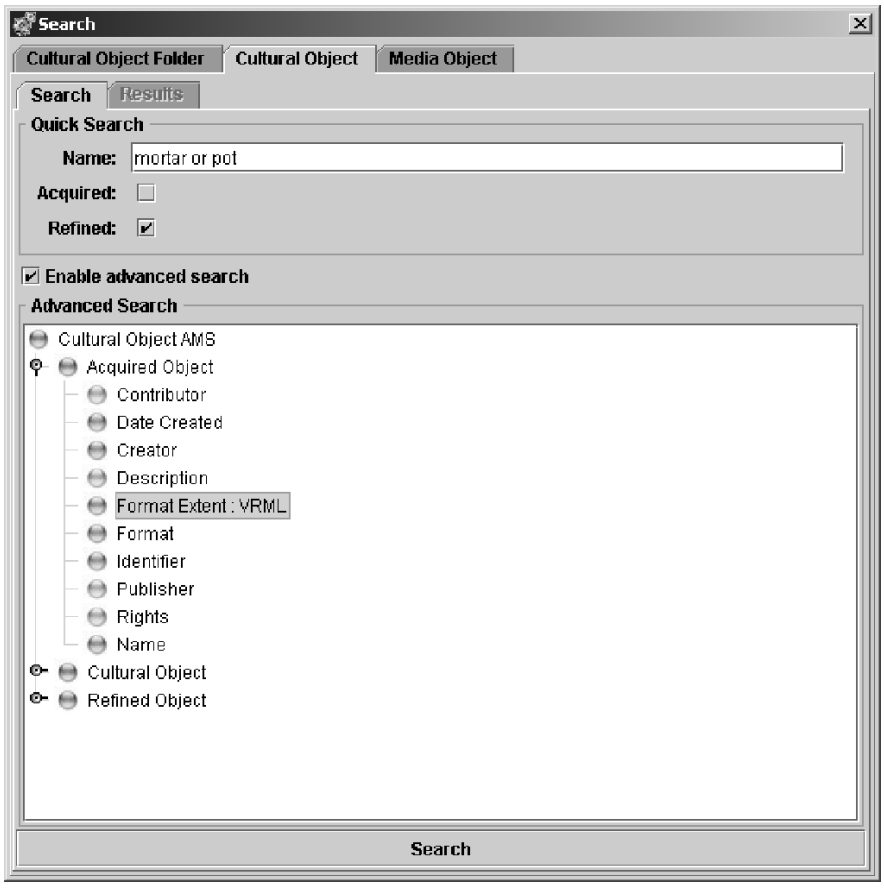

Fig. 6. AMS search window

Search Selectors has been implemented. In addition to fixed references to cultural objects, a presentation folder may contain a list of Search Selectors. Search Selectors select objects in a similar way to the AMS search tool, but the selection is performed dynamically when a user accesses the virtual exhibition. This guarantees that the most up-to-date list of cultural objects that meet the criteria specified in the Search Selectors are included in the exhibition.

7 Metadata in visualisation interfaces

Visualisation of metadata in end-user interfaces is essential to provide context and to enable understanding of an artefact's history. In ARCO, cultural objects can be visualised in virtual exhibitions in *Web interfaces*, which comprise 2D Web pages or 3D galleries with embedded multimedia objects, and *Augmented Reality (AR) interfaces.* The virtual exhibitions can be presented both on local displays inside a museum and remotely over the Internet.

The *Web interfaces* require a standard Web browser such as Internet Explorer with a VRML plug-in. In the case of *AR interfaces*, a special application is required to enable visualisation of selected COs in an augmented reality environment (i.e. in the context of real scenes). The application, developed within the ARCO project and called the *AR Application*, integrates the Web-based presentation with the AR visualisation of cultural objects and accompanying metadata. It requires a camera and a set of physical markers for positioning of virtual objects in a real environment.

The contents displayed in the visualisation interfaces are created dynamically based on X-VRML visualisation templates [46, 47]. Different templates can be used to visualise the same contents in different ways. The template parameterisation allows an exhibition designer to further differentiate visualisations based on the same set of templates. In particular, the content designer can choose both the metadata terms and the form in which they should be presented to a user within a virtual exhibition.

7.1 Metadata in Web interfaces

Through the Web interface users can browse a hierarchy of exhibition spaces containing COs with MOs and associated metadata. Depending on the context, either CO metadata describing the original physical artefact or AO/RO metadata describing its digital representation in the database can be displayed. Figure 7 shows an example of metadata visualisation accessible over the In-

ternet. A different method of metadata visualization may be used on local touch-screen displays installed inside a museum.

Virtual exhibitions can also be visualised in the Web interface as 3D galleries (Fig. 8). Users can browse objects simply by walking along the exhibition and can retrieve more detailed information using interaction elements integrated into object stands. Each cultural object is represented by its 3D VRML model, image on the wall and name – retrieved from the metadata description – presented on the stand. A user may turn on and off a semi-transparent window presenting selected metadata elements describing the closest visible cultural object.

Based on the metadata descriptions of cultural and media objects a search system has been built that enables end users to quickly locate objects within the visualisation interfaces. An example online search form integrated into a local touch-screen interface together with example results is presented in Fig. 9.

Using the search form, a user may submit a search query composed of up to ten search patterns. In each pattern a user specifies the search scope, the search type and a text string (keyword) to be located. The scope determines whether the keyword should appear in any AMS field or in a specific one such as: name, description, creator, etc. The search type determines the meaning of the entered text string, which may represent an exact word, part of a word, a similar word or a word that sounds alike. Boolean operators (AND, OR, AND-NOT) can be used to connect search patterns.

The search results can be presented either in 2D or 3D. In the case of 2D presentation, object names, descriptions and thumbnails are presented, along with emphasised fragments of the AMS metadata where the keyword has been found (Fig. 9).

7.2 Metadata in AR interfaces

With the use of the *AR Application* it is possible to browse virtual exhibitions using the Web interface and then to switch to the AR mode. In the AR mode, users can manipulate the virtual objects in the AR scene using special physical markers, as if the virtual objects actually existed in the real environment. In ARCO, the markers are based on patterns (i.e. letters, figures) printed on square cardboard pieces [28] and on pages of a specially designed book [11]. The AR application can display a wide range of virtual scenes created dynamically based on visualisation templates determining which MOs and metadata should be presented and how these elements should be composed into a scene.

An example virtual exhibition of cultural objects is illustrated in Fig. 10. This AR scene contains three representations of COs assigned to three different markers, which can be manipulated separately. Each object is represented by two MOs: a 3D model (rotating) and an image, and selected metadata elements displayed in the foreground.

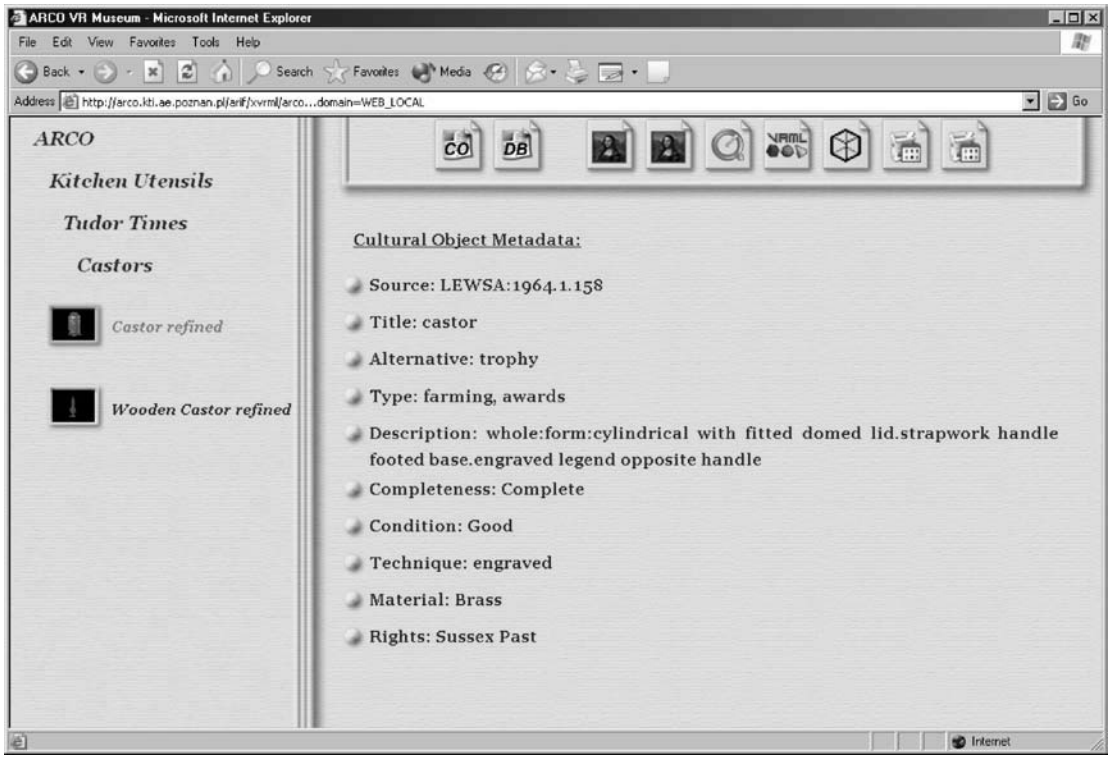

Fig. 7. Metadata visualisation over the Web

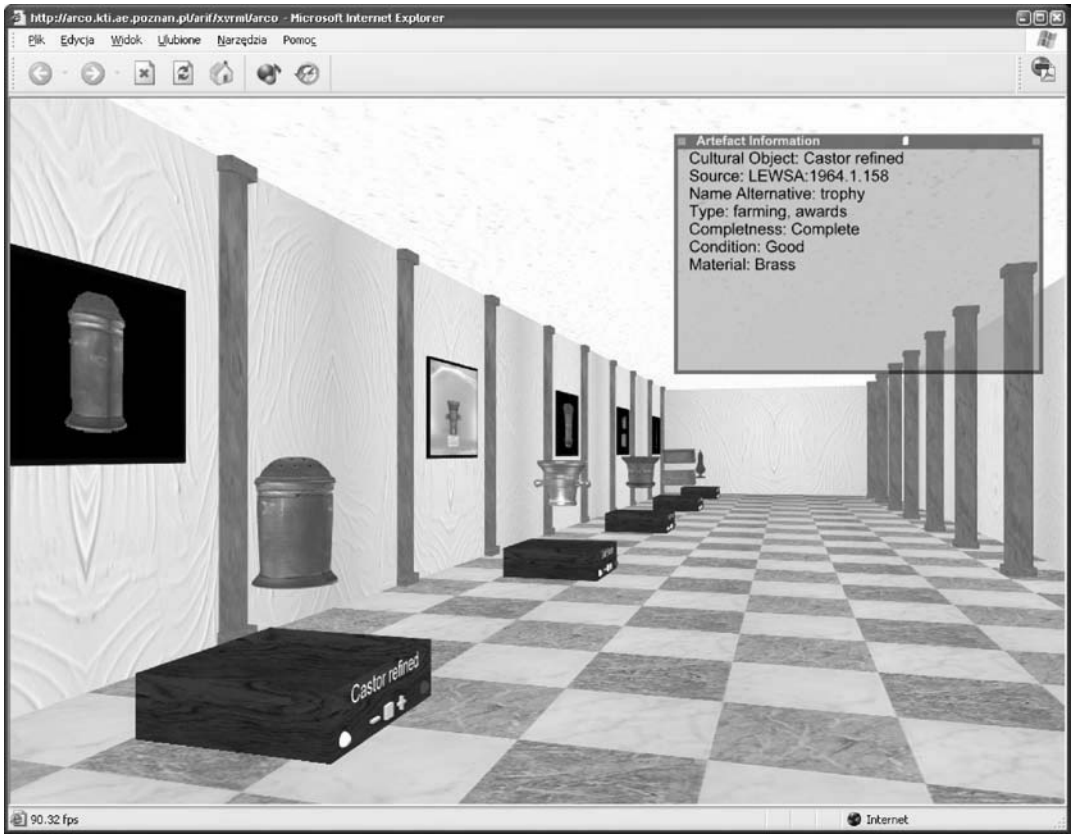

Fig. 8. Metadata visualisation in a 3D virtual gallery

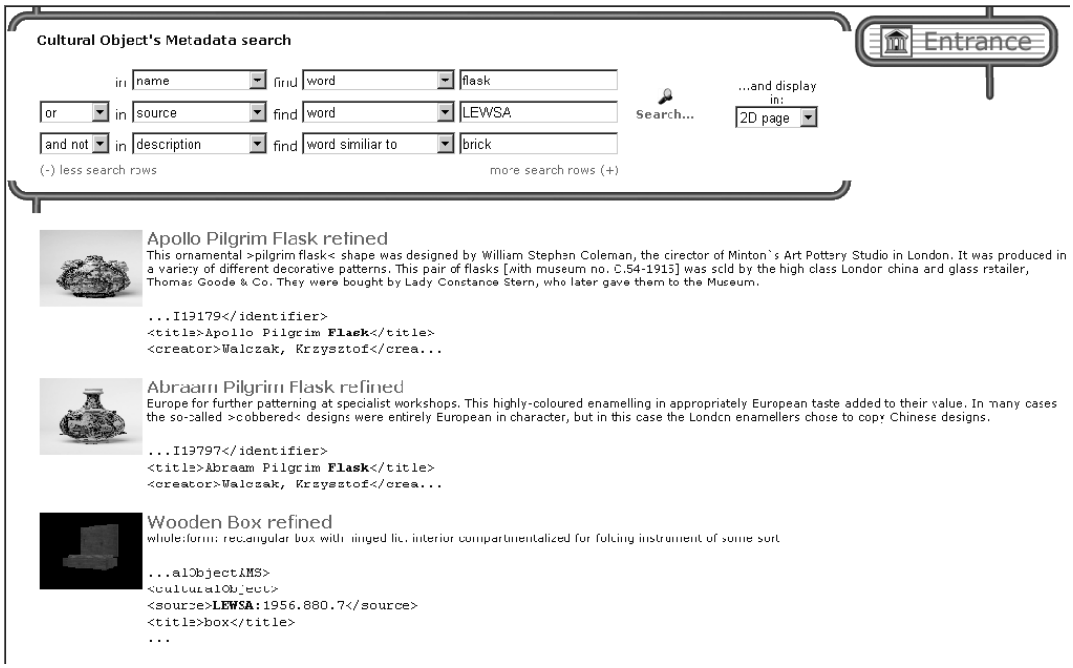

Fig. 9. Search based on metadata in a museum touch-screen interface

7.2.1 Metadata in interactive scenarios

As indicated in Sect. 5.2.5, metadata in ARCO can include not only information associated directly with objects, but also information that is necessary for presenting the objects to users. This is particularly important in presentations taking the form of interactive scenarios, when users can utilise the system not only by browsing objects but also by interacting with the contents, e.g. in quiz-like games.

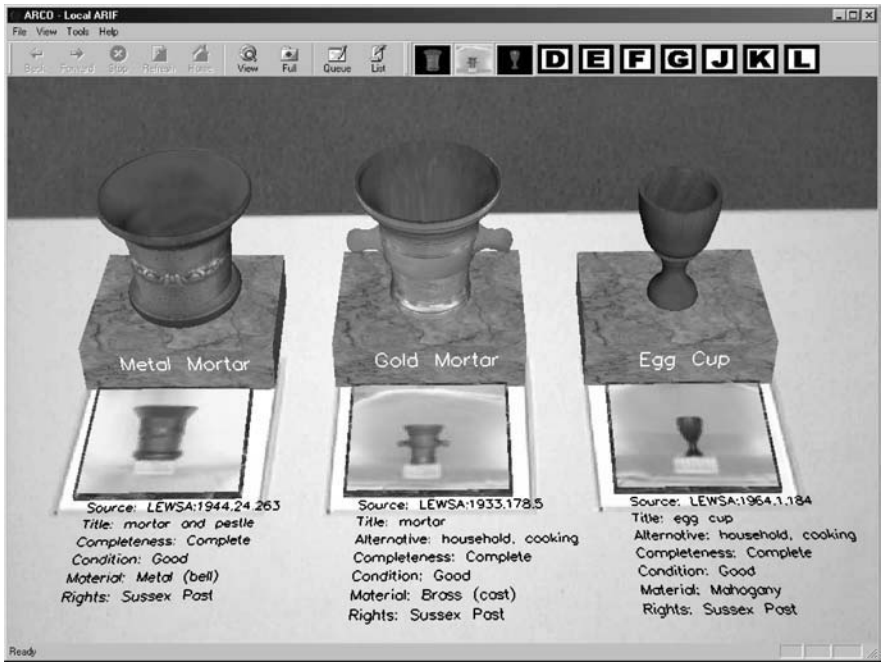

Fig. 10. Simple exhibition built in an AR environment

There can be different metadata values required for describing appearance of the same media object or cultural object in different presentations, e.g. prepared for different users or different scenarios. As a result, metadata containing such information must be associated with a media object, a cultural object and a presentation. In ARCO, this kind of metadata can be set up using the *ACMA Presentation Manager*.

Using presentation metadata, an exhibition designer can define how a cultural object should be presented within a particular scenario. For example, in a learning scenario, for each cultural object the designer can specify a list of questions with possible answers and a short description presented at the end of the scenario (Fig. 11).

Example usage of presentation metadata in a learning scenario implemented in an AR environment is illustrated in Fig. 12. A 3D model of an artefact and a question are displayed on one of the physical markers. Three possible answers are assigned to three other markers (see the bottom of Fig. 12). A user can answer the question simply by turning over one of the answer markers. Depending on whether the answer is correct or not, an appropriate response appears in the AR scene. A sound expressing approval or disapproval can also be heard.

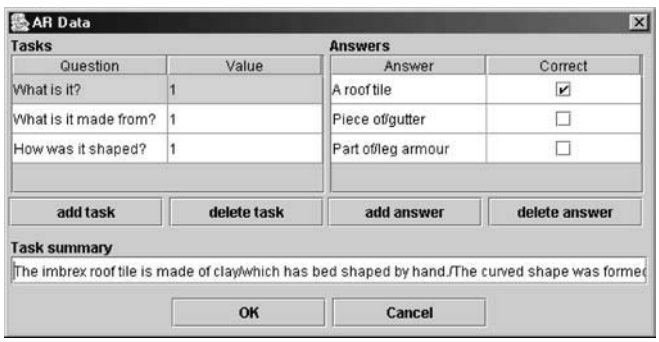

Fig. 11. Learning metadata editor in ACMA Presentation Manager

In a manner similar to that shown above, an exhibition designer can define the logic for presentation of a set of COs, i.e. actions that should be taken during the interactive scenario as a response to specific events such as user actions.

8 Evaluation and assessment

Evaluation and assessment procedures of the ARCO system, which include the AMS, have taken an iterative form akin to the spiral model [12] used in software development. We have completed three loops of this process, which comprise three museum user trials (MUT) and four prototypes. Museum users have provided very positive feedback and shown great excitement at the potential applications of the system.

Each MUT comprised tutorials, "hands-on" exercises and a questionnaire (latterly online) giving museum users opportunity to comment on all aspects of the ARCO system such as functionality, user interfaces and potential applications.

As far as the AMS is concerned, descriptive metadata were based on those being used by the pilot museum sites and therefore already correlated well with the metadata

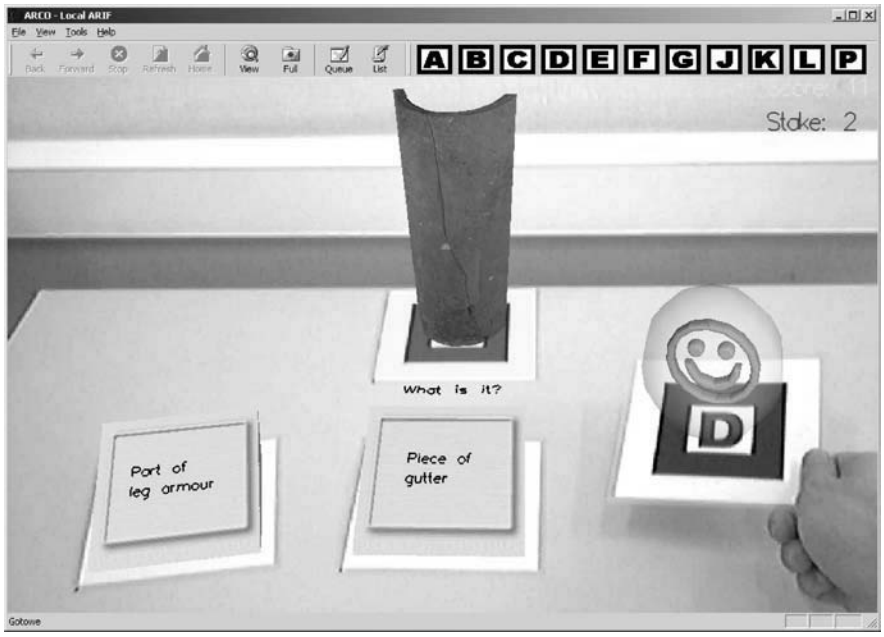

Fig. 12. Example quiz scene

in the pilot site databases. However, as the system has evolved and user requirements have been clarified, these metadata have also changed slightly from one prototype to the next. We have found that the descriptive elements chosen from SPECTRUM and DC are adequate for the objects that we have so far accumulated in the ARCO repository. But it should also be noted that the way in which the AMS is implemented within the system makes it easily extensible and modifiable.

9 Conclusions and future work

We have described the analysis and development of metadata requirements for a system that caters for the whole pipeline of processes from digital acquisition of cultural artefacts to the design and display of virtual and augmented reality environments. The system can be used to serve a didactic function and is well suited to enhancing the experience of cultural artefacts through interaction. The metadata requirements of digital representations of objects differ from those of physical artefacts in that a great deal of technical information is required to maintain and preserve them.

The data model we have described in Sect. 5.1 copes well with simple, small to medium artefacts, but could equally be extended further to deal with more complex composite objects.

Creation of repositories of digital artefacts also opens up the possibility of developing virtual learning environments (VLEs), although this would entail recording additional metadata such as that proposed for learning objects [25]. Furthermore, we envisage commercial exploitation by museums in the form of virtual loans for virtual exhibitions, which pose no threat of damage to real artefacts. This would require a sophisticated rights management model. Aggregated services based on multiple, distributed archives of digital artefacts are another possibility, but they would require the investigation of the Open Archives Protocol for metadata harvesting [33] in the context of ARCO.

With regard to operation in the heterogeneous environment of the Web, the AMS is well placed to take advantage of the CIDOC CRM (ISO/CD 21127) [14], which is emerging as an upper ontology for the cultural heritage domain. As mentioned earlier in Sect. 2, the CRM caters for high-level concepts, which need to be supplemented with application-level detail; in the case of the AMS, this role is served by SPECTRUM. A mapping of SPECTRUM to the CRM is already in existence and would form the basis for integrating disparate information from the museum, library and archive communities.

Acknowledgements. The work described in this paper was funded by the EU IST Framework V programme, Key Action III-Multimedia Content and Tools, Augmented Representation of Cultural Objects (ARCO) project IST-2000-28336.

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