

Metadata Requirements for Digital Museum Environments

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1. Introduction

Advances in virtual and augmented reality technologies [1,2,3] 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 [4] in London has over 4 million objects in its collections, while the Sussex Archaeological Society [5] 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 has always been a critical aspect of describing and managing museum holdings; it continues 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 is defined as “structured data about data” [6], it can also be considered as information or data about resources. Its purposes are too many to list, but include: description, management, resource discovery, preservation, curation and rights management of information objects.

In section 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 sections 3 and 4. The resulting data model and metadata vocabulary are described in section 5, followed by a look at the metadata management tools in section 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 [7]. This standard is co-ordinated by the mda [36]; it was originally a standard for documentation of UK museum collections. SPECTRUM has resulted from a collaboration of over one hundred 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 [8] 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 [9].

The Art Museum Image Consortium (AMICO) [10] 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 [11] can record detailed information about the type of object that is being described.

CIDOC [12] has an international focus on the documentation interests of museums and similar organisations. The CIDOC Conceptual Reference Model (CRM) [13], 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 [14]. The aim of the project was to explore how existing information in museum collection management systems could be extracted and re-purposed 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) [15] 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 [16] is a multi-disciplinary 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 [17] 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 [18] and the NISO Technical Standard for Digital Still Images (currently draft) [19]. 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 10 '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) [16] does not deal specifically with museum archives, the Dublin Core Metadata Element Set (DCMES) [20] 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 [21] is to develop innovative technologies and expertise to help museums to 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 websites 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 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 of virtual representations, efficient storage, management and retrieval of cultural object collections, and advanced interactive visualisation of digital representations of cultural artefacts must be addressed. Metadata is 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.

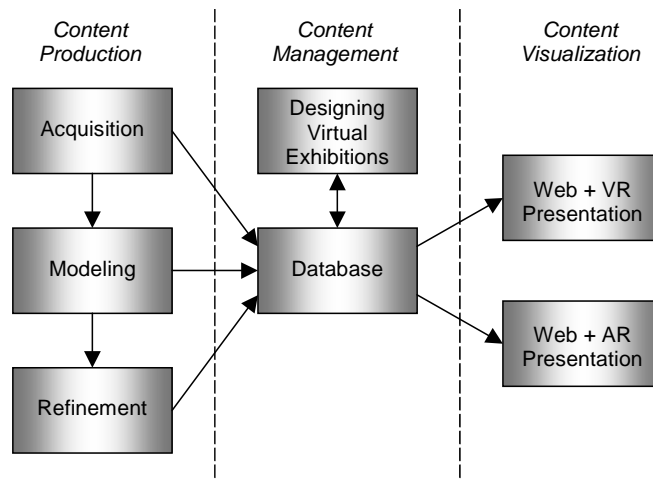


Figure 1: Overview of ARCO architecture

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 [22]. Each of these groups have differing metadata requirements:

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

A *Digital 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 section 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 not only to examine the metadata requirements for each of these processes, but also of the interactions between the processes and the necessary data exchange between various components. In Figure 2, the ARCO processes and related metadata operations are presented.

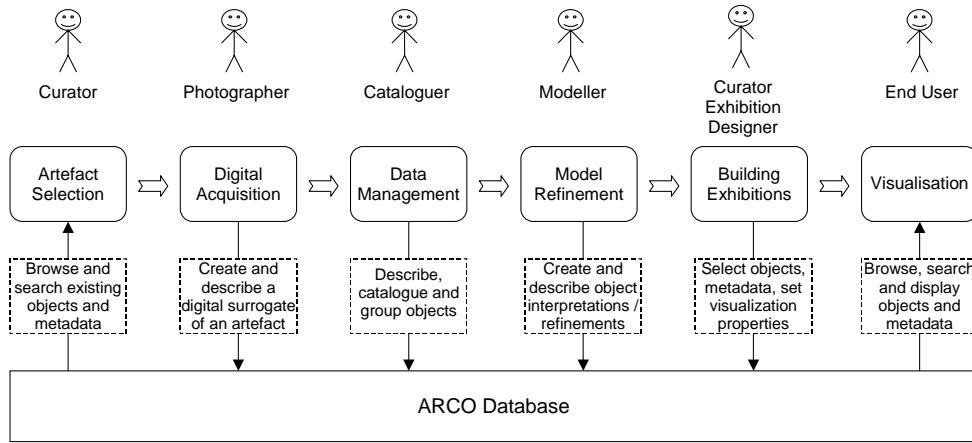


Figure 2. ARCO processes and related metadata operations

4.3 Interoperability and Standards

Interoperability has been considered at two levels: in terms of internal data exchange and in terms of openness of the system in communication with other external systems. Data exchange in ARCO is based on the W3C Recommendations, XML and XML Schemas (XSD) [23]. Semantic web technologies such as RDF [24] and OWL [25] 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 [26].

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 [27], VRML [28], OpenGL [29]); 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 [30] 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) [31], the initiatives described in section 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* [32, 33, 34]. 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 was also taken into account in developing the metadata terms associated with digital images in the 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 Figure 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 provides 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*, *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.

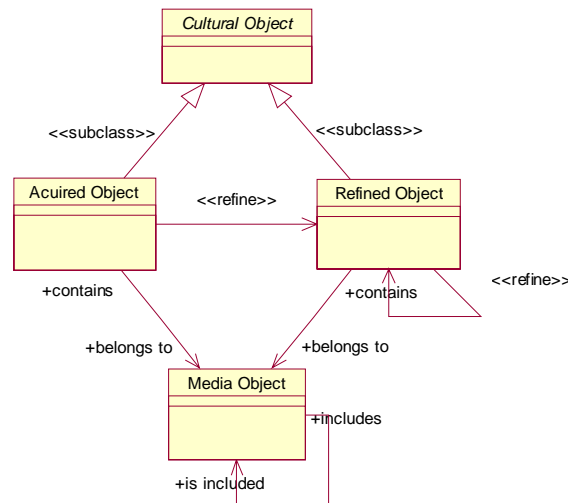


Figure 3: The ARCO Data Model

This data model loosely conforms to the definitions provided in the IFLA Functional Requirements for Bibliographic Records (FRBR) [35], 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) while 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 [37] 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 website [31]. 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 possible to gain additional information by cross-referencing the value of the *source* element with a museum's own holdings information. Curatorial metadata is recorded as being associated with CO entities in the data model described in Figure 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 [5], which is one of our pilot museum sites.

5.2.2 Technical Metadata

Technical metadata records 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 is modelled on the VAM photographic schema. Technical metadata is recorded at the level of Media Objects, see Figure 3. Some of the elements are associated directly with particular Media Objects, while other are associated with a parent-child relationship between Media Objects (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, data 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 [31]. 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” [6]. Within the ARCO project this concept is used to provide additional functionality in two ways.

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 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 visual rendering 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 Media Object in this association may be left empty meaning that the value describes visualisation of the Cultural Object. If both MO and CO are empty, the value describes the whole exhibition space.

Use of presentation metadata depends on the 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.

Type of Metadata		AMS Vocabulary Terms
Administrative		Creator, Date Created, Date Modified
Cultural Object		Source, Name, Name 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
	Simple Image	Image Size, Resolution, Compression Method, Compression Factor, Colour Depth

Media Type Specific	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
	Multi-resolution Image	Resolutions, Software, Algorithms
Presentation (examples)		Caption Text, Transform, Quiz Question, Quiz Answers, ...

Table 1: AMS vocabulary terms associated with data model entities

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 (Figure 3), administrative metadata is recorded for each of CO, AO, RO and MO.

6. Metadata Management

Management of museum collections, whether physical or digital, is reliant 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 [38, 39]. 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 Oracle9i 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 database management systems.

The choice of XML [42, 43] 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 [\[40\]](#).

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 Figure 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 modifying 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.

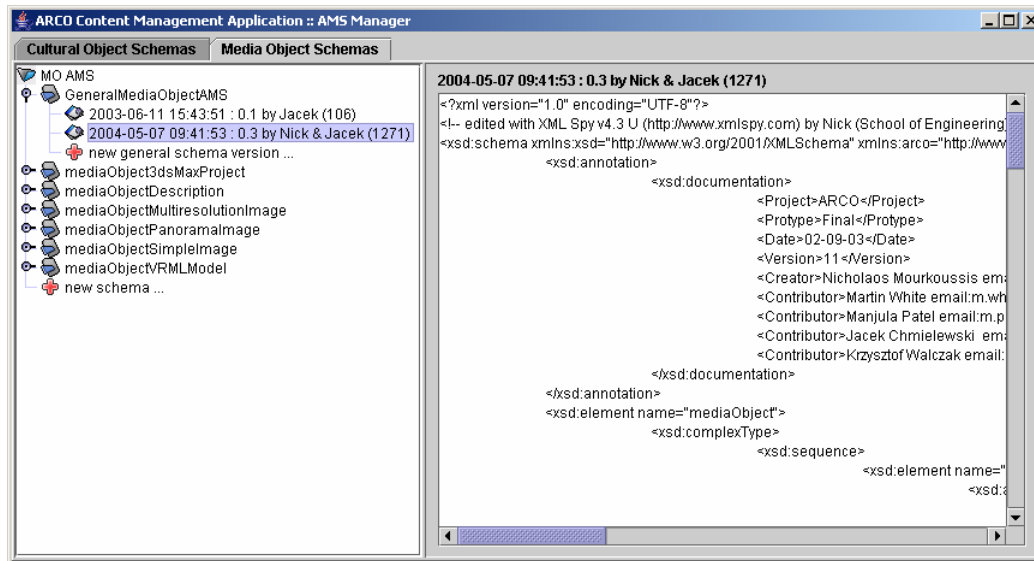


Figure 4. AMS Schema Manager

6.3 Managing AMS Records

The ACMA application provides an intuitive and easy to use metadata 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 (see Figure 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 automatically 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 (see Figure 5).

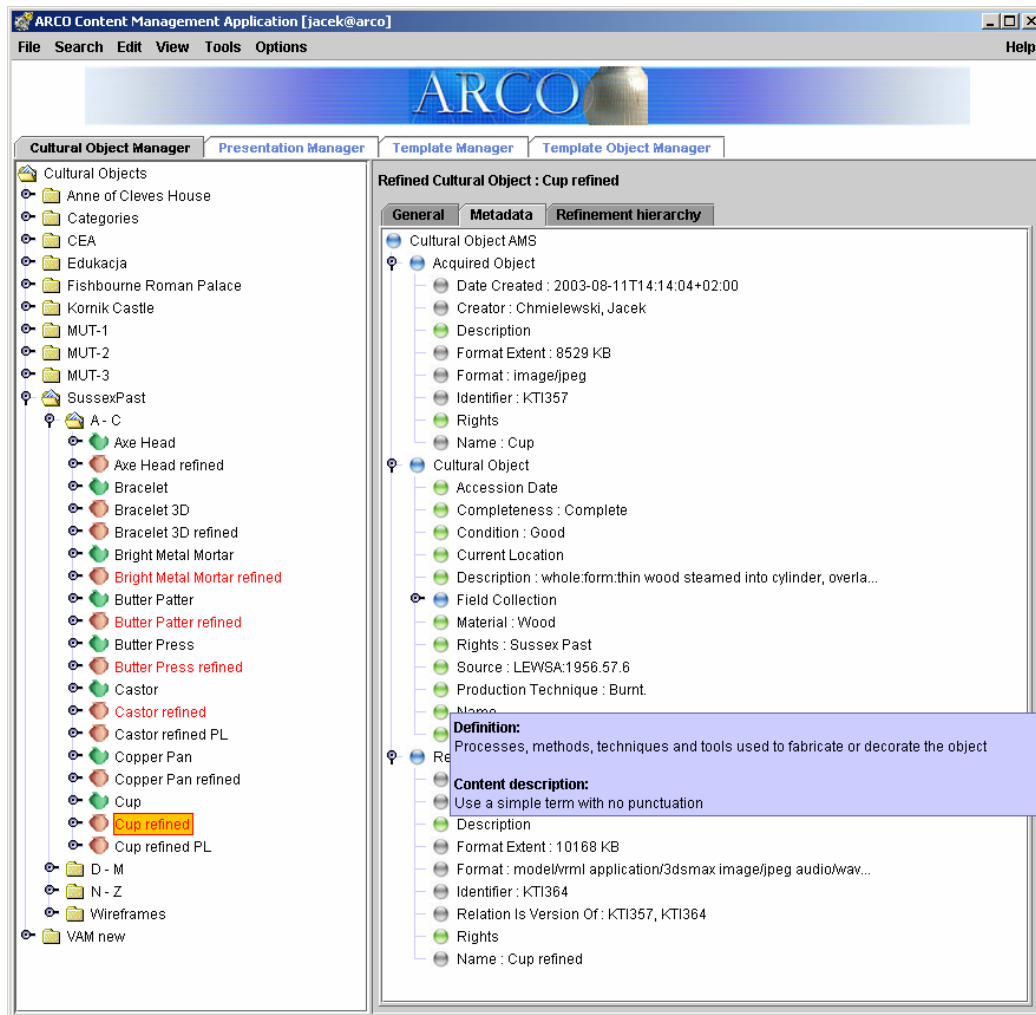


Figure 5. ARCO AMS Instance Editor: metadata tree for a Refined Object

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 (Figure 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.

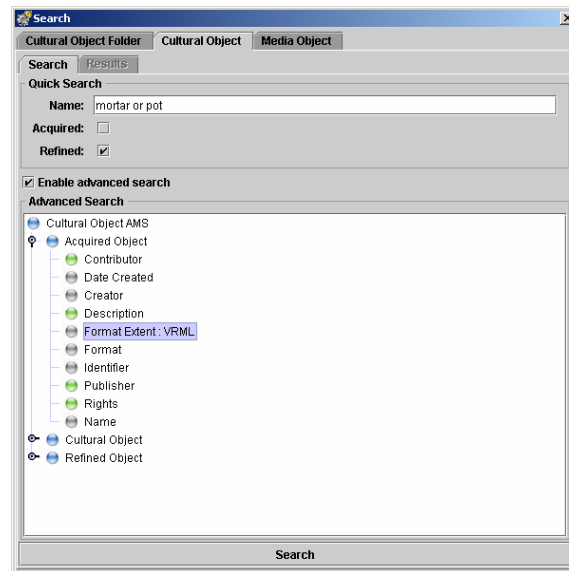


Figure 6. AMS Search window

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 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 Selector 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

visualized 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 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 with 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 [3,41]. Different templates can be used to visualize 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 which metadata terms and in what form 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 8 shows an example of metadata visualisation accessible over the Internet.

An alternative visualisation of metadata is presented in Figure 9. This presentation is designed for use on touch-screen displays installed inside a museum. Within the local presentation domain, the same COs can be visualized differently than in a presentation accessible over the Web. For example, more detailed virtual models and high-resolution images can be displayed in a local museum environment since hard-ware and network configuration can be better controlled.

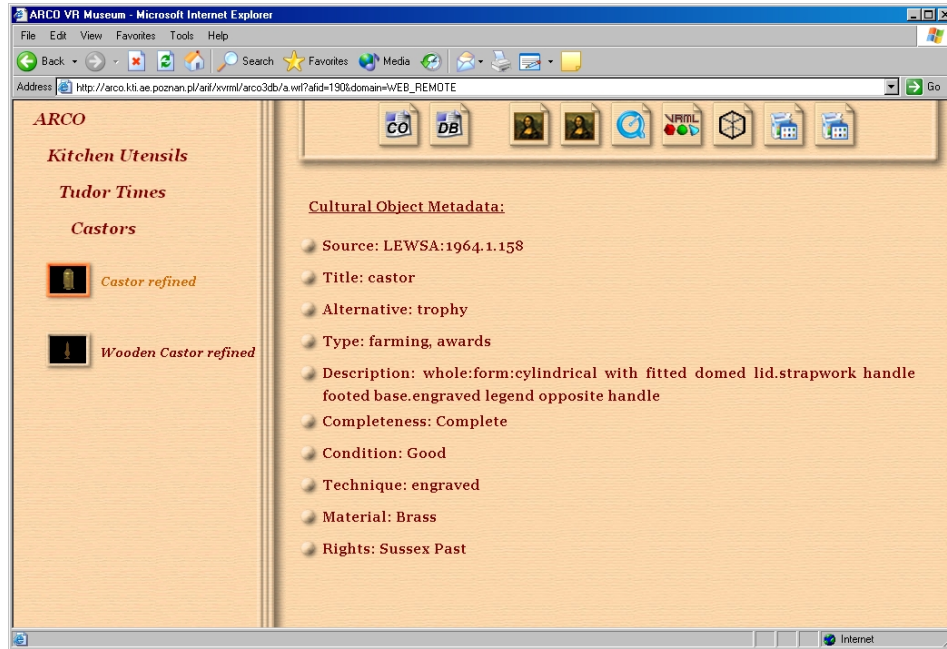


Figure 8: Metadata visualisation over the Web

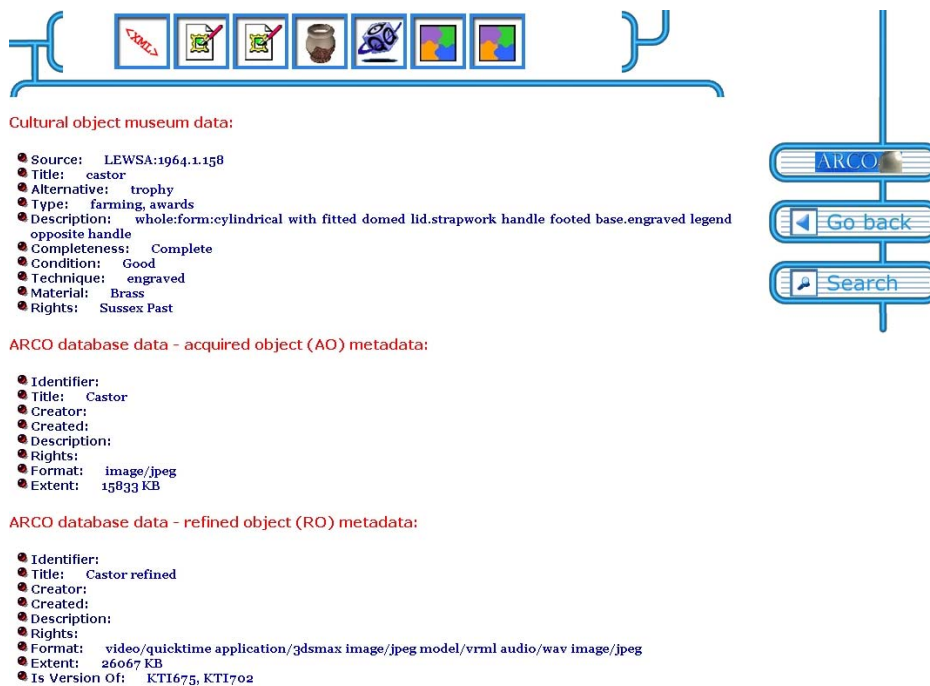


Figure 9: Metadata visualisation using a touch-screen display

Virtual exhibitions can also be visualized in the Web interface as 3D galleries, an example is depicted in Figure 10.

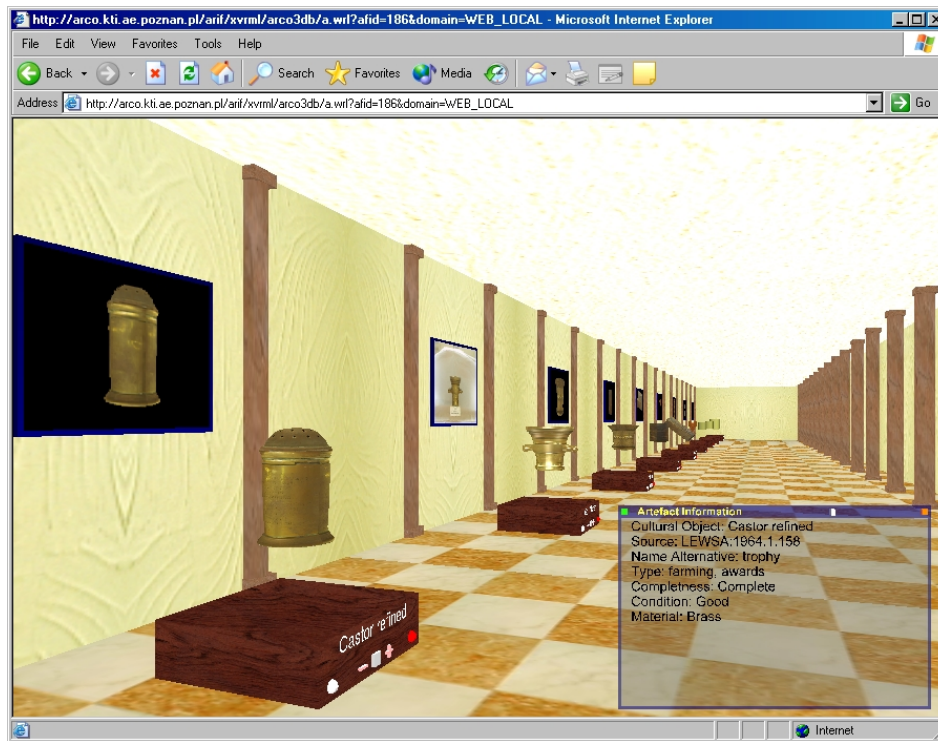


Figure 10: Metadata visualisation in a 3D virtual gallery

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, enabling end-users to quickly locate objects within the visualisation interfaces. An example on-line search form together with example results is presented in Figure 11.

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, a part of a word, a similar word or a word that sounds

alike phonetically. Boolean operators (AND, OR, AND-NOT) can be used to connect search patterns.

The screenshot shows a search interface titled "Cultural Object's Metadata search". It features a search bar with a magnifying glass icon and a button labeled "Entrance". Below the search bar, there are two rows of search criteria. The first row has "in name" and "find word" with the value "mortar". The second row has "and" and "in anywhere" with "find word" and the value "cooking". To the right of these criteria is a button labeled "more less" and a dropdown menu labeled "and display in:" with the value "2D page". Below the search bar, the text "Cultural Object Metadata search results:" is followed by "Found: 3 result(s)". Three search results are listed, each with a thumbnail image and a title: "Dark Metal Mortar", "Brass Mortar", and "Gold Mortar II". Each result includes a description and a snippet of XML metadata.

Cultural Object's Metadata search

Search...

in name find word mortar

and in anywhere find word cooking more less

and display in: 2D page

Cultural Object Metadata search results:
Found: 3 result(s).

Dark Metal Mortar
invert bell shape with wide rim flare. Heavy course moulded above base. Moulded course of foliate S-scrolls half-way up. Double ended pestle
... <source>LEWSA:1944.24.263</source>
<name>mortar and pestle</name>
<type>household, cookin...

Brass Mortar
whole:from:invert bell shape.wide flare rim.l course moulding just below rim.moulded course foot.design af stags head in oval frame repeated 4 times on sides.
... <source>LEWSA:1933.34.44</source>
<name>mortar</name>
<type>household, cooking, heraldry...

Gold Mortar II
whole:from:invert bell shape, flared rim.several courses of incised grooves.lug handles halfway up arising from wider band of coursing
... <source>LEWSA:1933.178.5</source>
<name>mortar</name>
<nameAlternative>household, cookin...

Figure 11: Search based on metadata in a museum touch-screen interface

The search results can be presented either in 2D or 3D. In case of 2D presentation, object names, descriptions and thumbnails are presented, along with emphasized fragments of the AMS metadata where the keyword has been found (see Figure 11).

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 really existed in the real environment. In ARCO, the markers are based on patterns (i.e. letters, figures) printed on square cardboard pieces [1] and on pages of a specially designed book [2]. 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 Figure 12.

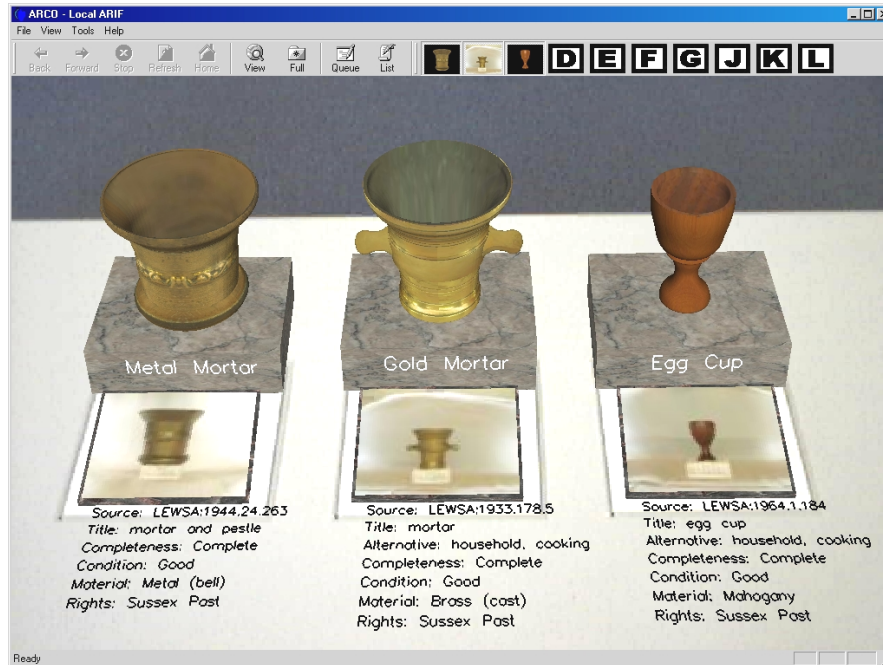


Figure 12: Simple exhibition built in an AR environment

This example 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.

Instead of using loose cardboard markers, a more natural form of interaction can be achieved by a specially designed book, such as that shown in Figure 13. Each page contains one printed marker, on top of which a virtual scene may be displayed. Users can browse a virtual exhibition by simply turning pages of the book.

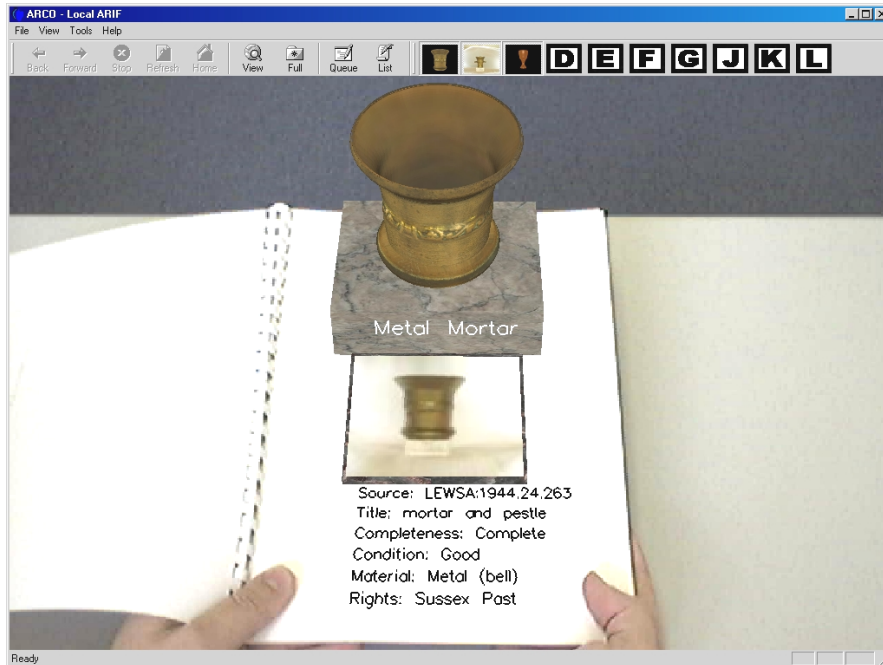


Figure 13: A book for browsing a collection of Cultural Objects

7.2.1 Metadata in Interactive Scenarios

As indicated in section 5.2.5, metadata in ARCO can include not only information associated directly with COs, 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 utilize the system not only by browsing objects, but also by interacting with the contents, e.g., in quiz-like games.

There can be different metadata values required for presentation 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, see Figure 14.

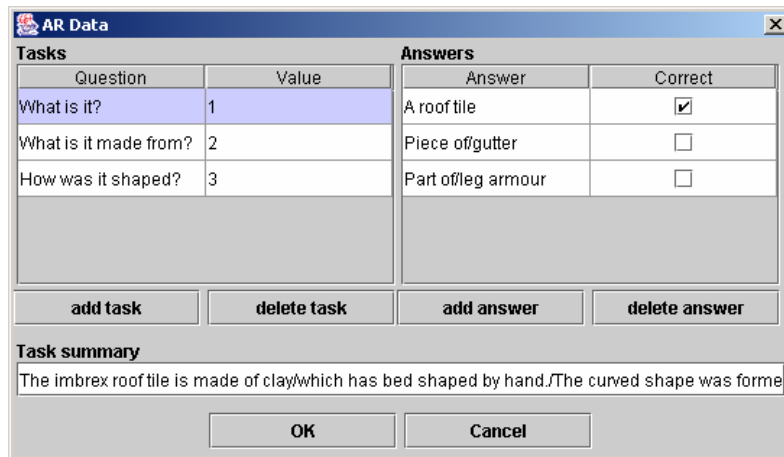


Figure 14: Learning metadata editor in ACMA Presentation Manager

Example usage of presentation metadata in a learning scenario implemented in an AR environment is illustrated in Figure 15.

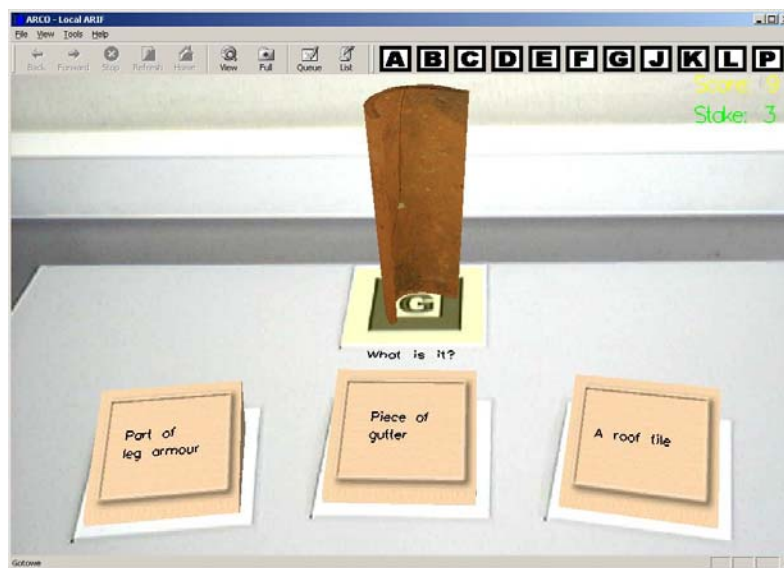


Figure 15: Example quiz scene

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 Figure 15). 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 as shown in Figure 16. A sound expressing approval or disapproval can also be added.



Figure 16: Incorrect and correct answers

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 [46] 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 was based on that being used by the pilot museum sites and therefore already correlated well with the metadata in the pilot site databases. However, as the system has evolved and user requirements have been clarified this metadata has 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 Further 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 to 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 section 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 [47]. Furthermore we can 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 would require the investigation of the Open Archives Protocol for metadata harvesting [48] 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) [13], which is emerging as an upper ontology for the cultural heritage domain. As mentioned earlier in section 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.

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