Archeologia e Calcolatori
12, 2001, 245-273

DOCUMENTING AND VALIDATING VIRTUAL ARCHAEOLOGY

1. Introduction

The term *Virtual Archaeology* can be traced to a paper presented by Paul Reilly at the 1990 CAA conference (Reilly 1991). His view centred on excavation recording and the possibilities of virtual re-excavation using technologies such as hypertext, multimedia and three-dimensional solid modelling. Subsequently, the field has widened to cover the application of visualization and presentation methods to the "reconstruction" of past environments, including buildings, landscapes and artefacts. Forte, who has done much to popularise the term (e.g. Forte 1997; Forte, Siliotti 1997) suggests that «…virtual archaeology can be defined as digital reconstructive archaeology, computational epistemology applied to the reconstruction of three-dimensional archaeological ecosystems, therefore, cognitive ecology» (Forte 2000, 247). Today, Virtual Archaeology encompasses not only 3D modelling and visualization, but also 'auralization' using acoustic models (e.g. Pope, Chalmers 2000; Campos *et al.* forthcoming).

Concerns have often been expressed about the methods employed, the reliability of content and the motivations behind many Virtual Archaeology projects. Miller and Richards (1995) identified the growth of the 'heritage industry' and industrial sponsorship as motivational factors that took control out of the hands of archaeologists. Projects often served as «…vehicles for demonstrating advanced graphics techniques with any archaeological considerations playing a less important role» (Ryan 1996, 107). Such influences often led to an inappropriate and misguided pursuit of 'realism' with little or no concern for the inherent uncertainty of the data sources.

The early stages of adoption of new technologies inevitably suffer from an imbalance in favour of projects that do more to demonstrate the technologies than to address real problems in the application domain. However, ongoing developments in hardware, in visualization software (e.g. in Virtual Reality, 3D modelling and some aspects of GIS) and in communications (e.g. the World Wide Web as a vehicle for distributed hypermedia) combined with the compelling nature of images and video, and a desire for 'spectacular' presentations in museums and the broadcast media, together ensure that many of these problems continue to affect Virtual Archaeology today.

Despite Reilly's original vision, the most widespread uses of Virtual Archaeology have been in the presentation and dissemination of archaeological *results*, with applications to the archaeological *process* trailing far behind. As Barceló (this volume) notes «Virtual Archaeology means much more than "shape" reconstruction" and "Virtual archaeology should go beyond "picturesque" reconstruction». Elsewhere, he has suggested that the techniques should be viewed not «…as a way of doing reconstructions, but as a simulation of archaeological reasoning» (BARCELÓ 2000, 9). Similarly, GILLINGS (2000, 59) has challenged the predominant use of Virtual Archaeology in producing «…little more than ingenious 'end-products'…» and stressed the need to develop methods that integrate its use at all stages of the archaeological process.

A key role that visualization methods can bring to the archaeological process is in providing interfaces to data sources that help to identify uncertainty and enable the exploration of alternative interpretations. Alternative representations or dynamic models, such as that described by ROBERTS and RYAN (1997), are readily achieved using standard techniques. Such an approach can also enhance the educational and dissemination objectives of public presentations. Although there is no fundamental reason why these should, like their static antecedents, offer only a single, apparently authoritative, view of their represented past, this capability has yet to be widely exploited. MILLER and RICHARDS (1995, 20) were unable to identify «…any examples where alternative reconstructions have actually been published…». More recently, FORTE (2000, 249) observed that «Noticeable gaps are represented by the fact that the models are not "transparent" in respect to the initial information… and by the use of the peremptory <u>single reconstruction</u> without offering alternatives…». In both professional and public applications there is a need to approach Virtual Archaeology as a means to producing tools that aid understanding.

Part of that understanding can only come from exposing the sources and methods, both archaeological and technical, behind the visualization, «In fact the model must be "transparent" – that is, contain reconstructive hierarchies of the modelling and original data, so as to verify the whole process of virtual reconstruction» (FORTE 2000, 252). Whilst we readily employ such devices as quotation and citation to this end in written text, and *ad hoc* solutions may be found in some educational multimedia, little effort has been devoted to exploring standard and portable means for validating and authenticating Virtual Archaeology. As MILLER and RICHARDS (1995, 20) observed, «Worryingly, there is little, if any, quality control for computer graphics and they are not subject to the same intense peer review as scientific papers». The problem is compounded by the use of "reconstructions" in the broadcast media, where there is often little, if any, indication of archaeological input to their production.

In a notable exception to this apparent lack of concern, FRISCHER *et al.* (2000, 158) emphasise the documentation of the model creation process and the archiving of model components to create «…digital libraries… supported by written files recording the research sources, analogues, and experts consulted for each modelling decision, and for each visual and material source». A key element of their approach is the "certification" of models by a Scientific Committee whose members are involved in all aspects of the process.

A more typical approach to exposing background information is seen in the NuME system (Bonfigli, Guidazzoli 2000). Here, regular HTML description files prepared by a historian are associated with each VRML building model and can be consulted by the user. Whilst this goes some way to addressing the problems, it is essentially an *ad hoc* solution that requires rigorous quality control to ensure a uniform standard within a project. More importantly, whilst many such projects may show exemplary *internal* standards of documentation, there is no way of ensuring a consistent quality between projects.

In a paper proposing the formation of an organisation[1] dedicated to addressing these issues, Frischer *et al.* (forthcoming) discuss the «…added value of scientific credibility and authentication» and argue for the development of a philology, even an *apparatus criticus* for 'Cultural Virtual Reality'. In essence, they argue for a metadata standard to support validation and authentication. Whilst their arguments are directed specifically at VR, they are equally relevant to the broader area of Virtual Archaeology.

A consistent metadata standard that could be applied at all levels from the outline description of a project down to the individual elements of a 3D model would offer many potential benefits, including, but not limited to:

– reliable and consistent discovery of Virtual Archaeology resources on the Internet,
– comparability of aims, methods, results and credibility of projects,
– an incentive to authors to demonstrate and support the interpretations presented,
– enabling informed and public peer review of Virtual Archaeology products, and
– the possibility of developing common visualization and presentation interfaces that offer direct access to the metadata descriptions.

In the following sections, this paper examines the suitability of existing metadata standards for such tasks and discusses how they might be extended to fulfil the validation and authentication needs of Virtual Archaeology. A case study of a system built using established visualization and presentation methods is used as an example. Several recent developments in XML-based languages for multimedia, 2D and 3D graphics are discussed, each of which has the potential to host embedded metadata and may have a significant impact on the future of Virtual Archaeology.

[1] CVRO: *The Cultural Virtual Reality Organization*, see http://www.cvro.org/

2. Virtual Archaeology metadata

Metadata is often described as data about data. It is information that helps a user or system to organise, access and use a resource. Metadata may serve various roles, including cataloguing and archiving, resource discovery, technical and content description. For an introduction with an archaeological orientation, see Miller (1999).

Cataloguing and archival roles are often combined with resource discovery. For example, a library catalogue typically contains information that helps librarians to manage their collections, such as accession dates and the identity of the donor or supplier. Other information, such as author names, titles, subject classification and location also serve as resource discovery information for library users. Metadata has long been used in computer-based information systems. The data dictionaries and 'system catalogues' in database management systems provide both the information necessary for the system to locate individual items and structural and semantic information to aid users in understanding the contents of the database.

To be useful, metadata must comply with a standard that provides a common descriptive format for diverse resources. The Dublin Core[2] is an example of a simple metadata framework for the outline description of a wide range of resource types. It comprises fifteen basic elements: title, creator, subject, description, publisher, contributor, date, type, format, identifier, source, language, relation, coverage (spatial and temporal) and rights. These elements are sufficient for simple resource discovery tasks, but even in the proposed qualified form[3] (e.g. date.created, date.modified), they are not intended for detailed descriptions of complex resources. There are, however, many specialised metadata schemes for describing more complex resources. For example, the FGDC[4] spatial metadata standard has sufficient scope to cover the smallest details of almost any variety of spatial data. In the multimedia field, the various MPEG[5] standards address both technical specifications and content description.

Interoperability between different data sources can be achieved by allowing the user to pose queries in terms of these metadata descriptions. The Archaeology Data Service[6] at the University of York, UK, has been instrumental in promoting and exploiting the use of Dublin Core metadata to de-

[2] See DC, *Dublin Core Metadata Initiative*, http://dublincore.org/

[3] See *Dublin Core Qualifiers*, http://dublincore.org/documents/dcmes-qualifiers

[4] The Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998), see http://www.fgdc.gov/metadata/metadata.html

[5] See *The MPEG Home Page*, http://www.cselt.it/mpeg/

[6] See http://ads.ahds.ac.uk/

scribe archaeological resources. The ADS catalogue currently contains about 400,000 metadata records describing resources that are either archived at York or held by other institutions. A Web interface, ArcHSearch[7], provides several ways for users to search this metadata. In a recent pilot project, the ADS and the Computing Laboratory at the University of Kent at Canterbury, UK, have implemented a system that uses these metadata descriptions to achieve interoperability between several geographically distributed data sources. In effect, the system provides a domain-specific search engine for archaeological resources. However, unlike conventional Web search engines, which only index static resources, this 'Historic Environment Portal' searches the content of dynamic metadata databases (Austin *et al.* forthcoming).

Dublin Core descriptions, such as those maintained by the ADS, are sufficient to determine that a resource deserves closer inspection, just as the author, title and abstract may be sufficient to suggest that a paper or book is worth reading. However, just as we read and examine the arguments presented in a written work and, perhaps, follow up some of its citations, we also need ways of examining the structure, content, sources and methods behind a Virtual Archaeology presentation. The next section presents a case study of a typical Virtual Archaeology presentation and then examines what is necessary to provide it with a basic metadata description.

3. Case study

Public presentations, whether on the Web, in museums or in the broadcast media, can be much more than a repackaging of earlier forms in a fashionable and spectacular medium. They do not need to be limited to telling a single story or to presenting one of many possible interpretations as an established 'truth'. Fig. 1 shows an introductory frame from a multimedia presentation, "Quest for Canterbury's lost Roman Temple", developed by the author for Canterbury Museums. One of the purposes of this system is to show museum visitors how archaeologists can often make significant inferences about the layout of a Roman town and the form of its buildings from very incomplete excavation evidence and a knowledge of comparable structures elsewhere. The presentation has been designed as the first part of a system to provide information about each of the main public building complexes in the city, although the current implementation concentrates on a postulated classical temple and its precinct. The other complexes – forum, public baths and theatre – are shown only as still images with minimal descriptive text.

The temple is thought to have been situated in a precinct adjacent to the forum and theatre complexes. A portico surrounding the precinct has

[7] See http://ads.ahds.ac.uk/catalogue

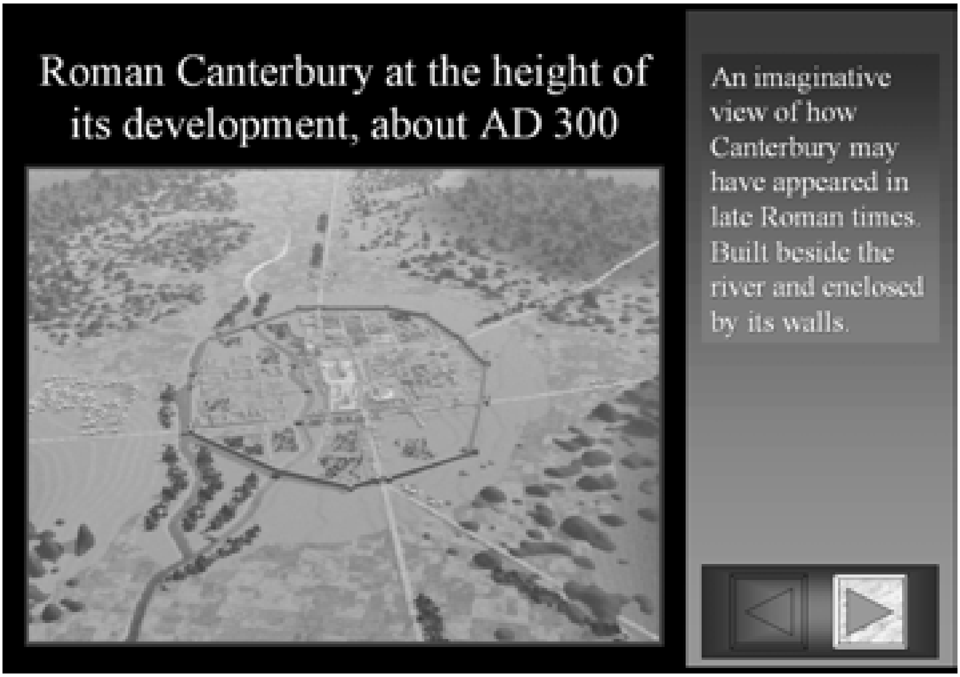

Fig. 1 – Part of the introductory sequence of the "Quest for Canterbury's Lost Roman Temple" presentation.

been located in several excavation trenches, but there have been few opportunities to explore the enclosed area. Where this has been possible, evidence of an extensive courtyard surface has been found, often cut into by post-roman structures. Materials that could come from a significant classical building have been found re-used or re-deposited in these later contexts within the precinct area, but the exact location of any temple remains unknown. However, there is anecdotal evidence to suggest that its foundations were observed, and possibly largely destroyed, during building work in the 1960s, before the establishment of a full-time excavation unit in the city.

The presentation runs on a touch-sensitive flat-panel device standing next to a display case containing finds from the area. These finds include a number of masonry fragments, mostly from one or more Corinthian columns, and a variety of marble and other stone wall-cladding materials. The presentation, therefore, seeks to breath some life into these otherwise rather dull finds that might normally be labelled only with dry statements such as "Masonry fragments, possibly from a Roman temple".

Interaction is minimal. At a few points, the user can choose which building complex to visit, or make minor changes to their route through an otherwise fixed sequence of frames. Buttons are also provided to skip backwards or forwards if the user finds the default timing too fast or too slow. The latter is more likely because the default timing is aimed at the needs of younger and potentially slower readers.

Most of the display sequence uses still images and video fly-through or walk-through sequences of complex solid models of the city in its surrounding landscape (Fig. 1) and individual buildings, together with textual annotation in a choice of three languages. Animations are used to overlay models on excavation plans and to place photographic images of the finds displayed in the adjacent case onto rendered solid model representations of Corinthian columns and capitals.

The simplicity of the system and the use of 'guided' or 'directed' sequences, rather than allowing users to roam freely around a virtual Roman Canterbury, was a deliberate design choice. Canterbury Roman Museum is small, yet it attracts large numbers of visitors and is popular with parties of children from local schools. The design of the museum itself follows a similar pattern with visitors encouraged or constrained to follow particular routes through its various rooms. The undeniable attraction of interactive displays, particularly to younger visitors, led to the requirement that the maximum duration of the display should be tightly constrained to prevent queues forming.

At an early stage of the design process, VRML was considered as a means of implementing the three-dimensional models and simple prototypes of the temple and theatre were shown at various 'open days' to give an impression of what future displays at the museum might look like. In the end, the need for directed sequences and the relatively poor image quality of most VRML renderers led to the decision to prepare all images and video sequences using a solid modelling and ray-traced rendering solution. Vue d'Esprit by e-on software[8] was used both as a modelling and rendering tool.

Source data used in the model included a DEM derived from out-of-copyright map data, and known building plans which were derived from both published and unpublished excavations undertaken by Canterbury Archaeological Trust and other groups. Many building fragments were initially drawn using various CAD programs and exported as DXF or DWG files, whilst others came from earlier projects using other modelling and rendering tools such as POV-Ray[9]. The remainder of the model was developed within Vue d'Esprit.

Despite the availability of several more sophisticated multimedia authoring packages, this system was developed using Microsoft PowerPoint, a medium more often associated with conference presentations and lecture

[8] See http://www.e-onsoftware.com

[9] See http://www.povray.org/

slides. Apart from the author's familiarity with this package, this choice was made because of PowerPoint's simplicity and adequacy for the relatively simple requirements of the display system. Indeed, the system could have been realised using almost any of the authoring packages currently available.

One of the benefits of the early VRML-based prototypes was that they were intended to be viewed using an HTML browser, with an appropriate plug-in, and so might also be published on the Web. Although the system installed in the museum employed a conventional multimedia approach, the possibility of Web-based delivery was not wholly abandoned. The same content has been used to produce several, albeit incomplete and unpublished, versions of the system as test-beds for more recent approaches. One of these is discussed later.

The image in Fig. 1 is a frame from the beginning of an initial video sequence that flies in from an aerial view to land in the centre of the town. The 3D model of Roman Canterbury and its surrounding landscape is based, where possible, on archaeological and environmental evidence. However, in a model of this size, there are large areas for which no such evidence is available and in these the model elements are no more than informed speculation. Even where evidence from archaeological excavations is available, it is invariably partial. Excavations rarely recover complete building plans and structures rarely survive above floor level and are often represented only by robber trenches.

The model represents a composite of much of what is known of Canterbury during the first four centuries AD. It is intended to convey an impression of the town's appearance during much of this period, rather than to be a strictly accurate model of any particular date. The date of 300 in the title was chosen as a compromise to allow the late-3rd century walls to be included, even though the building complexes that are the main focus of the presentation are mostly of 2nd century origin. Indeed, some earlier buildings in the model may have gone out of use and have been demolished or replaced by later structures by this date. Most of the circuit of Canterbury's medieval walls remain standing today, although large sections are more recent rebuilds, and these are founded on the earlier Roman walls. These walls are, therefore, an important local landmark and their inclusion in the model helps viewers to orient themselves.

This model and the system by which it is presented to museum visitors are quite typical of current uses of Virtual Archaeology for public presentation. The presentation is a little unusual in that it seeks to convey an understanding of the incomplete nature of the archaeological evidence and the resulting uncertainty inherent in its interpretation. Other than this, however, it offers much the same benefits and suffers many of the same limitations as most similar systems in current use.

```
<?xml version="1.0" ?>
<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:dc="http://purl.org/dc/elements/1.1/">
  <rdf:Description rdf:about=
      "http://www.cs.ukc.ac.uk/people/staff/nsr/va/crt.ppt" >
    <dc:Title>Quest for Canterbury's lost Roman Temple</dc:Title>
    <dc:Language>en</dc:Language>
    <dc:Description>
      A multimedia presentation for Canterbury Museums
    </dc:Description>
    <dc:Date>2001-02-21</dc:Date>
    <dc:Type>interactive resource</dc:Type>
    <dc:Format>application/vnd.ms-powerpoint</dc:Format>
    <dc:Subject>roman</dc:Subject>
    <dc:Subject>temple</dc:Subject>
    <dc:Subject>archaeology</dc:Subject>
    <dc:Subject>excavation</dc:Subject>
    <dc:Subject>interpretation</dc:Subject>
    <dc:Creator
      rdf:resource="http://www.cs.ukc.ac.uk/people/staff/nsr/nsr.rdf"/>
    <dc:Publisher rdf:resource="http://www.cs.ukc.ac.uk/"/>
    <dc:Coverage>Spatial: Canterbury, Kent, UK.</dc:Coverage>
    <dc:Coverage>Temporal: Roman, C2/3 AD.</dc:Coverage>
    <dc:Rights>Museum display: Copyright Canterbury Museums 2001</dc:Rights>
    <dc:Rights>
      Original plans and excavation data:
      Copyright Canterbury Archaeological Trust 1980-2001
    </dc:Rights>
    <dc:Rights>Computer models: Copyright Nick Ryan 1998-2001</dc:Rights>
  </rdf:Description>
</rdf:RDF>
```

Fig. 2 – Example Dublin Core metadata in RDF format for the "Quest for Canterbury's Lost Roman Temple" presentation.

3.1 *Metadata description*

An outline metadata description of this presentation based on the Dublin Core element set is shown in Fig. 2. Although DC metadata can be represented by a variety of notations, this example is presented using the Resource Description Framework (RDF)[10] encoded in the eXtensible Markup Language (XML)[11]. This combination is widely used as RDF has become established as the preferred method of representing metadata in many of the growing number of XML-based languages.

As with any well-formed XML document, this example begins with an XML declaration and contains a single document root element, in this case *rdf:RDF*. The RDF/XML syntax makes use of XML namespaces[12] to associate each property with the schema in which it is defined. The names used for these namespaces are defined in the opening *RDF* element. The URI in a namespace declaration serves as an identifier and need not point to any real

[10] See *Resource Description Framework (RDF)*, http://www.w3.org/RDF/
[11] See *Extensible Markup Language (XML)*, http://www.w3.org/XML/
[12] See, *Namespaces in XML,* http://www.w3.org/TR/REC-xml-names/

web address. However, in practice, it will often indicate both the 'authority' responsible for maintaining the schema and point to a human-readable description of the elements. The first namespace declaration:

```
xmlns:rdf=http://www.w3.org/1999/02/22-rdf-syntax-ns#
```

links the name 'rdf' to the RDF syntax specification. Next comes the declaration for the Dublin Core namespace, 'dc'[13]:

```
xmlns:dc="http://purl.org/dc/elements/1.1"
```

In this way, subsequent elements such as *rdf:Description* are interpreted as the *Description* element defined in the RDF syntax, and *dc:Date* as the *Date* element of the Dublin Core schema. Elements from other metadata schemas could be added to this description simply by including their appropriate namespace declaration.

RDF provides a model for expressing machine-readable metadata as simple statements in the form:

Subject (a resource) – Predicate (a property name) – Object (a literal property value)

A collection of statements about a particular subject is enclosed in a *rdf:Description* element. The subject is the resource indicated by the URI in the *rdf:about* attribute. The elements nested within the *Description* supply the pairs of Predicates and Objects. For example, the *dc:Format* element indicates that the resource *has* a DC Format with the value 'application/vnd.ms-powerpoint', the MIME type name for a PowerPoint file.

If the property value is an external resource, it is represented by a *rdf:resource* attribute, for example:

```
<dc:Creator rdf:resource="http://www.cs.ukc.ac.uk/people/staff/nsr/nsr.rdf"/>
<dc:Publisher rdf:resource="http://www.cs.ukc.ac.uk/"/>
```

Details such as personal or institution names, e-mail and postal addresses, and phone numbers could have been included in this metadata record, but here the *rdf:resource* attribute is used to indicate URLs where such information can be found. The first example points to a separate RDF record and the second to a conventional institutional home page. This linking method could also have been used to provide a link to a more extensive textual description, such as that in the preceding section, instead of the minimal information provided here in the *dc:Description* field, e.g.

```
<dc:Description rdf:resource="http://www.cs.ukc.ac.uk/people/staff/nsr/va/crt.html"/>
```

This simple example illustrates only a subset of Dublin Core elements and a small fraction of the RDF syntax. For basic archival or resource discovery needs, further details could be added, including a more extensive description and more subject keywords. Further enhancements could be made by using the Dublin Core Qualifiers which include both element refinements

[13] The use of the *dc* namespace follows that given in Beckett *et al.* 2001.

and specification of encoding schemes. Qualified DC requires an additional namespace declaration, e.g.:

```
xmlns:dcq="http://dublincore.org/2000/03/13/dcq#"
```

Given this, it would then be possible to refine the semantics of the *Date* field using the *Created* or *Modified* element qualifiers:

```
<dcq:Created>2001-02-21</dcq:Created>
```

or, including a specified encoding scheme (W3C-DTF)[14]:

```
<dcq:Created>
 <dcq:W3C-DTF>2001-02-21T14:23:01Z</dcq:W3C-DTF>
</dcq:Created>
```

More detailed and, preferably, machine usable, spatial and temporal coverage could also be added by using the *dcq:Spatial* and *dcq:Temporal* element refinements and their associated encoding schemes. These enable locations to be specified as points, bounding boxes or geographic names, and time as dates or periods[15]. However, the currently recognised qualifiers do not cover an adequate range for many archaeological and historical applications.

This outline metadata record has been presented as a stand-alone RDF/XML document. It is distinct from, and acts as a surrogate for, the resource that it describes. Such content might be maintained as separate files or generated automatically from a database, and used to serve many archival and resource discovery purposes. Alternatively, where the format of the original resource is suitable, the RDF description might also be embedded within the resource itself (see the section 'XML-based visualization formats', below). Most file formats used for multimedia presentations and their component parts (images, audio, video, text, etc.) lack this capability. For example, although the PowerPoint presentation discussed in the above case study does contain some metadata, it is not accessible by open and general-purpose methods. Such resources must necessarily be described by separate metadata records.

3.2 *Describing the components of a complex resource*

So far, the example metadata describes the resource as a whole with no details about its component parts. Refined forms of the DC Relation element may be used to provide links to the individual parts of the presentation such as the video sequences or even the 3D model. For example the DC Relation element has a qualified form 'hasPart' that can be used for this purpose:

```
<dcq:hasPart rdf:resource="http://…"/>
```

[14] W3CDTF corresponds to ISO 8601, see W3C Note: Date and Time Formats, http://www.w3c.org/TR/NOTE-datetime/

[15] For details, see *Dublin Core Qualifiers*, http://dublincore.org/documents/dcmes-qualifiers and associated references.

RDF provides several collection elements that can be used to group related elements together. For example, as an alternative to the multiple *dc:Subject* elements in Fig. 2, the keywords could have been grouped into a single unordered list using an *rdf:Bag*, with each component appearing as a list element, *rdf:li*:

```
<dc:Subject>
  <rdf:Bag>
    <rdf:li>roman</rdf:li>
    <rdf:li>temple</rdf:li>
    <!-- etc. -->
  </rdf:Bag>
</dc:Subject>
```

These two representations are equivalent because DC elements are repeatable but unordered. There is no requirement for applications to maintain the order in which elements occur in a record. For a multimedia presentation, it may be desirable to express the order in which the components appear as part of the metadata. For this, the *rdf:Seq* ordered collection element can be used:

```
<dc:Relation>
  <rdf:Seq>
    <rdf:li>
      <dcq:hasPart rdf:resource="http://…" />
    </rdf:li >
    <rdf:li >
      <dcq:hasPart rdf:resource="http://…" />
    </rdf:li >
    <!-- etc. -->
  </rdf:Seq>
</dc:Relation>
```

However, there is a serious limitation in this use of the Relation refinement *dcq:hasPart* as it does not provide an access path to the metadata describing the component. The related resource in any DC Relation field is the object itself, not an associated metadata description. If, as is the case with most media formats, this resource does not contain its own embedded RDF metadata, there will be no path that can be followed from the resource to its metadata. Consequently, there will be no path that an application can follow to extract metadata descriptions of the entire resource and its component parts. The same problem applies to all of the DC Relation refinements which cover other versions, alternative formats and other generic references between resources.

This problem is not insurmountable. One approach is to gather together the metadata records for each component in one place. Multiple *rdf:Description* elements can appear in a single RDF section, so that the example in Fig. 2 could be extended with separate descriptions of each component. However, the presentation might be only one of several applications using the same component parts. The parts might be archived separately with the intention that they are accessed as distinct resources, or they might be distributed over the Internet and maintained by different individuals or organisations. In such cases, the responsibility for maintaining the metadata would lie with the owner or holder of the object. Clearly, when a definitive copy is available elsewhere, it is undesirable to duplicate this metadata in each presentation or application using the object.

A possible solution to this problem is discussed later in the section entitled "A Virtual Archaeology metadata profile and schema?" First, however, several XML-based Visualization Formats are considered. These have much to offer the Virtual Archaeology community, not least, the ability to host embedded RDF metadata.

4. XML – BASED VISUALIZATION FORMATS

The Virtual Archaeology community has used a variety of proprietary and open data formats for modelling, exchange and presentation of data. However, as we have seen above, few of these have offered more than minimal support for embedded metadata. This lack of common functionality and standards has enabled us to largely ignore the need for complete and comparable documentation. Indeed, in many cases, documentation exists only as project descriptions published either as accompanying Web pages, or as papers in the archaeological computing literature.

These problems are, of course, common to all groups who wish to make their material accessible on the Web or in archives. XML and RDF have been developed in order to address the problems of information interchange and resource discovery in a modern distributed environment. Given this framework, it should come as no surprise that XML-based languages are evolving to provide open formats for modelling, exchange and presentation of data. Examples include the Synchronized Multimedia Integration Language (SMIL)[16], Scaleable Vector Graphics (SVG)[17], and eXtensible 3D (X3D)[18]. Each of these languages has much to offer the Virtual Archaeologist and they, or their successors, can be expected to become widely used in the coming years. For present purposes, however, their significance lies in their potential for hosting embedded metadata.

The following sections provide a brief introduction to these three languages. All are powerful and complex and this is not the place for a detailed

[16] *Synchronized Multimedia Integration Language (SMIL 2.0)*, W3C Recommendation, 07 August 2001, http://www.w3.org/TR/smil20.

[17] See Scalable Vector Graphics (SVG) 1.0 Specification, W3C Proposed Recommendation, 19 July, 2001, http://www.w3.org/TR/SVG.

[18] See X3D™ - Extensible 3D: New-Generation Open Web3D Standard, http://www.web3d.org/x3d/

```
<?xml version="1.0" ?>
<smil xmlns="http://www.w3.org/2001/SMIL20/Language">
  <head>
    <metadata>
      <rdf:RDF
      xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
      xmlns:dc="http://purl.org/dc/elements/1.1/">

     <!-— Metadata describing the entire resource -->
       <rdf:Description rdf:about="" >
         <dc:Title>Quest for Canterbury’s lost Roman Temple</dc:Title>
         <dc:Language>en</dc:Language>
         <dc:Description>
           A multimedia presentation for Canterbury Museums
         </dc:Description>
         <dc:Date>2001-02-21</dc:Date>
         <dc:Type>interactive resource</dc:Type>
         <dc:Format>application/smil</dc:Format>
         <dc:Subject>roman</dc:Subject>
         <dc:Subject>temple</dc:Subject>
         <dc:Subject>archaeology</dc:Subject>
         <dc:Subject>excavation</dc:Subject>
         <dc:Subject>interpretation</dc:Subject>
         <dc:Creator
           rdf:resource="http://www.cs.ukc.ac.uk/people/staff/nsr/nsr.rdf"/>
         <dc:Publisher rdf:resource="http://www.cs.ukc.ac.uk/"/>
         <dc:Coverage>Spatial: Canterbury, Kent, UK.</dc:Coverage>
         <dc:Coverage>Temporal: Roman, C2/3 AD.</dc:Coverage>
         <dc:Rights>
           Museum display: Copyright Canterbury Museums 2001</dc:Rights>
         <dc:Rights>
           Original plans and excavation data:
           Copyright Canterbury Archaeological Trust 1980-2001
         </dc:Rights>
         <dc:Rights>
           Computer models: Copyright Nick Ryan 1998-2001</dc:Rights>
       </rdf:Description>

     <!-- Metadata describing a video clip in the presentation -->
       <rdf:Description rdf:about="#fly_in">
         <dc:Title>Canterbury model, aerial fly-in</dc:Title>
         <dc:Type>video</dc:Type>
         <dc:Format>video/x-msvideo</dc:Format>
         <dc:Date>2001-02-20</dc:Date>
         <dc:Description rdf:resource=
          "http://www.cs.ukc.ac.uk/people/staff/nsr/va/desc/fly_in.html"/>
       </rdf:Description>

     <!-- Subsequent metadata describes other elements of
          the presentation including images, sound and video clips. -->
     </rdf:RDF>
    </metadata>

 <layout>
   <root-layout width="800" height="600" />
   <region id="header" top="20" left="0"
           width="600" height="100" fit="fill" />
   <region id="imgwnd" top="150" left="20"
           width="560" height="420" fit="fill" />
   <region id="txtwnd" top="0" left="600"
           width="200" height="600" />
 </layout>
</head>

<body>
```

Fig. 3 – Simplified extract from an experimental SMIL implementation of the “Quest for Canterbury’s Lost Roman Temple” presentation, including embedded metadata.

discussion of their capabilities. The examples[19] used here for illustration are minimal and concentrate on the facilities used for embedding metadata. For details of the languages themselves, readers are referred to the specifications and other materials available at the W3C and Web3D web sites.

4.1 *SMIL*

SMIL (pronounced "smile") is an XML-based language for multimedia presentations, including facilities for controlling layout, timing and synchronisation. The first version of the language provided only minimal support for embedded metadata in the form of a *<meta>* tag similar to that used in HTML but, in the current version (2.0), the treatment of metadata is much more thorough. Here, a *<metadata>* tag is provided to hold RDF statements describing the presentation and its components.

An experimental SMIL version of the Canterbury Roman Temple presentation is being developed, and a simplified part of this is shown in Fig. 3.

A SMIL document contains a single root node, *<smil>*. Within this, global information, such as the optional metadata and declarations of layout areas to be used in the presentation, are placed within the *<head>* element. This is followed by a *<body>* element containing the instructions for placing and sequencing the content.

In the example shown here, the body contains a sequence (*<seq>…</seq>*) of which only the first element is shown. This element is a parallel block (*<par>…</par>*) in which all components appear together. The first of these is an image containing header text that appears in the "header" region at the top of the display[20]. The image will remain visible until the region contents are replaced by another object (*fill="freeze"*). Next comes a sequence of an image followed by a video clip. The image is just the first frame of the video and is used to provide a static view for the first three seconds (*begin="0s" dur="3s"*) before it is replaced by the video. The third element is another image showing some explanatory text, and this appears in "txtwnd" region to the right of the display one second after the header and initial frame images. The duration of the inner sequence and the parallel block is determined by its longest component, the video clip (*dur="16s"*). After this time the presentation will continue with the next element (not shown here) in the outer sequence. Fig. 4 shows this SMIL presentation playing in RealPlayer[21].

[19] These and other more extensive examples can be found at http://www.cs.ukc.ac.uk/people/staff/nsr/va/

[20] A *<text>* element might have been used here but this is not supported by many available players, most of which provide only an incomplete implementation of SMIL 1.

[21] See http://www.real.com/player/. Other SMIL players include Soja (http://www.helio.org/products/smil/) and X-Smiles (http://www.x-smiles.org/).

The *metadata* element in this example contains several blocks of *rdf:Description* covering the entire presentation and each of its component parts. The first block describes the entire presentation, and it differs very little from that shown in Fig. 2. Because the metadata is embedded in the resource, the *rdf:about* attribute is empty (or can be omitted) to indicate that this description refers to the current resource. The only other difference is in *dc:Format* which now contains the appropriate MIME type (application/smil) for a SMIL document.

Subsequent *rdf:Description* elements describe components of the presentation. Here, a single example for a video sequence in AVI format is shown. The *rdf:about* attribute uses a 'fragment identifier' to indicate the subject of the statements that follow. The subject is an object with this identifier located somewhere within the SMIL presentation. This video appears in the *body* section below as a *video* element with the attribute *id="fly_in"*.

The problem identified earlier of the most appropriate location for component metadata arises again here. Indeed, it is arguably even more significant with XML-based formats such as SMIL. Whereas many proprietary formats embed most, if not all, of their components in a single file, each component of a SMIL presentation is an external, possibly remote, resource.

The example lacks detailed technical information that might be of use in selecting alternative versions of resources according to the capabilities of the player software or the display device. Although the SMIL 2.0 specification allows for selection of alternative media at run time, there are no formal recommendations on including relevant information in the metadata. The need is recognised, however, and the specification of the *metadata* element[22] includes examples based on an imaginary "smilmetadata" namespace, e.g.

```
<smilmetadata:Duration>60 secs</smilmetadata:Duration>
<smilmetadata:VideoCodec>MPEG2</smilmetadata:VideoCodec>
```

Similarly, examples of simple media content description are also offered, e.g.

```
<smilmetadata:ContainsShots>
  <rdf:Seq ID="ChronologicalShots">
    <rdf:li>Panorama-shot</rdf:li>
    <rdf:li>Closeup-shot</rdf:li>
  </rdf:Seq>
</smilmetadata:ContainsShots>
```

Perhaps such a namespace might be defined in the future. However, these requirements are already addressed much more completely by the MPEG-7 standard (ISO 2001)[23], and a more effective approach would be to base solutions on MPEG-7 Description Schemas.

[22] http://www.w3.org/TR/smil20/metadata.html

[23] See also, *The MPEG Home Page*, http://www.cselt.it/mpeg/

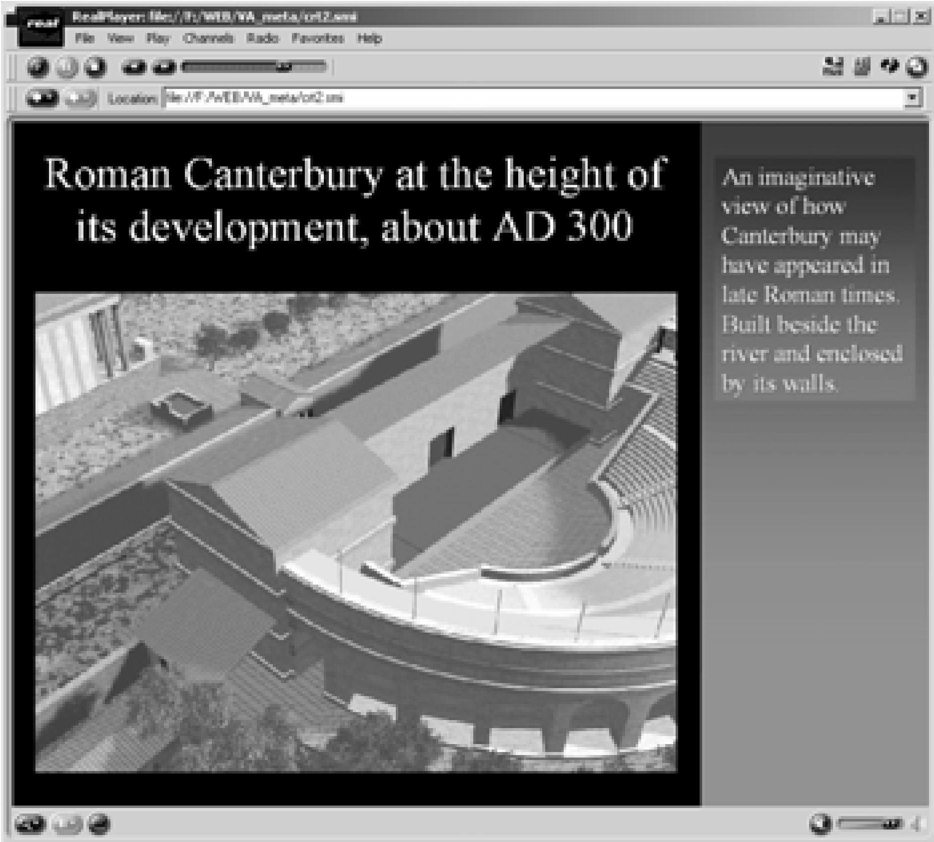

Fig. 4 – The Canterbury Roman Temple application coded in SMIL and running in RealPlayer 8™.

4.2 *SVG*

With the growth of GIS usage in archaeology has come a requirement for the presentation and visualization of spatial data. There are now many services on the Web that will return maps, aerial or satellite images, or other thematic information in response to location-based queries[24]. Most of these work by simply returning one or more 'tiles' from existing stored raster images. Archaeological and other GIS applications extend this approach by composing a raster image from multiple data layers in response to user queries (e.g. D'ANDREA, NICCOLUCCI 2001). Both raster and vector GIS data can be

[24] See, for example, http://pubweb.parc.xerox.com/map, http://www.mapquest.com, http://www.multimap.com/

```
<?xml version="1.0" encoding="UTF-8" ?>
<svg width="400" height="400">
  <desc>Sibaritide survey, October 2000</desc>
  <metadata
    <rdf:RDF
      xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
      xmlns:dc="http://purl.org/dc/elements/1.1/">
      <rdf:Description about=""
          dc:title="Intensive survey fields"
          dc:description="Field boundaries and survey units"
          dc:format="image/svg"
          dc:language="en"
          dc:creator="Nick Ryan"
          dc:contributor="Martijn van Leusen" />
    </rdf:RDF>
  </metadata>
  <g>
    <desc>border and grid</desc>
    <g fill="none" stroke="blue" stroke-width="2" >
      <rect x="0" y="0" width="398" height="398"/>
      <line x1="100" y1="0" x2="100" y2="15" />
      <!— etc. -->
    </g>
    <g fill="blue" font-size="12" >
      <desc>grid labels</desc>
      <text x="75" y="380">2637700</text>
      <!— etc. -->
    </g>
  </g>
  <g fill="none" stroke="red" stroke-width="1" >
    <desc>field boundaries</desc>
    <path d="M 104 202 L 182 191 L 177 147 L 99 162 z"/>
    <!-- more boundary paths -->
  </g>
  <!— ... -->
</svg>
```

Fig. 5 – Simplified extract from experimental SVG output presenting field survey data from a GIS.

handled in this way. Image composition is straightforward for raster data and several tools exist for 'painting' vector data onto an image. However, many existing solutions can only allow a user to pan or zoom the displayed map by the inefficient method of submitting a new query, generating a new image and reloading this in the browser. Direct delivery of vector data can help to overcome this limitation but typically this has required the user to install special-purpose browser plug-ins to handle each different format.

Scaleable Vector Graphics (SVG) is an XML-based language for describing two-dimensional vector and mixed vector and raster graphics. It also handles animation, using timing methods that are closely related to those of SMIL. Although not primarily intended for handling spatial data[25], it offers a

[25] For an XML language specifically intended for exchange and storage, rather than visualization, of spatial data, see the Geographic Markup Language (GML) http://www.opengis.net/gml/01-029/GML2.html

potential solution to the problems of delivering such data. There are indications that the CAD, GIS and presentation graphics industry is taking this development very seriously and that SVG is likely to become a widely available export format for such packages.

Fig. 5 shows a sample of SVG output generated from GIS field survey data. This example comes from the ongoing development of hand-held field survey tools described elsewhere by van Leusen and Ryan (forthcoming).

As with SMIL 2.0, SVG includes a *metadata* element intended to hold RDF metadata. The *rdf:Description* element shown here uses an alternative abbreviated syntax in which the predicate/value pairs appear as attributes rather than child elements. This syntax may be used for any non-repeating child elements. Note also the use of the SVG *desc* element to provide simple descriptions of the entire document and its component parts.

The graphical elements in Fig. 5 are much reduced from the original output and are included here only to give a taste of their appearance. The *g* element encloses groups of graphical objects such as the *rect*, *line*, *text* and *path* elements shown here. In this example, all co-ordinates are specified in screen space but, for typical spatial applications, it might be more appropriate to retain the original co-ordinates and employ the various transformations available in SVG.

SVG includes an anchor element '*a*' for XLink[26] style hyperlinks to other resources. Although many simple presentations might be stored on a Web server as a static file, most SVG documents used for Virtual Archaeology purposes are likely to be generated dynamically. For this reason, other than externally referenced raster images, most components of an SVG presentation would normally be contained in-line in the document. The issue of access to component metadata identified earlier may still arise, but is likely to cause fewer problems.

The example shown here is greatly simplified and it will be some time before an on-line version is available. However, readers can gain an impression of the capabilities of SVG in presenting GIS applications at the Web site of the French *Ministère de l'Aménagement du Territoire et de l'Environnement* where an interactive map application[27] provides information on areas of ecological interest.

4.3 *X3D*

RDF metadata descriptions in languages like SMIL and SVG provide an effective way of documenting media that represent the outputs of Virtual Archaeology processes. Each of these outputs – video, audio, text, raster im-

[26] XML Linking Language (XLink) Version 1.0, http://www.w3.org/TR/xlink/

[27] See http://www.environnement.gouv.fr/centre/Carte_interactive/SVG/carte_de_consultation.htm

```
<?xml version="1.0" encoding="utf-8"?>
<X3D xmlns="http://www.web3D.org/TaskGroups/x3d/translation/x3d-compact.dtd">
  <Header>
    <meta content="A trivial X3D example" name="title"/>
    <meta content="A red box" name="description"/>
  </Header>
  <Scene>
    <Shape>
      <Appearance>
        <Material diffuseColor="0.8 0.0 0.0" />
      </Appearance>
      <Box size="1 1 1" />
    </Shape>
  </Scene>
</X3D>
```

Fig. 6 – An example X3D document.

```
#VRML V2.0 utf8
  Shape {
    appearance Appearance {
      material Material {
        diffuseColor .8 .0 .0
      }
    }
    geometry Box {
      size 1 1 1
    }
  }
```

Fig. 7 – A VRML world corresponding to the content of the X3D document in Fig. 6.

age, vector graphics – is typically derived from a model and, so far, little has been said about documenting such models. This is arguably the most important aspect of Virtual Archaeology metadata. Links to original sources, descriptions of the methods employed and assumptions made in constructing the model surely belong with the model itself. X3D is a language with the potential to make this possible.

The X3D Graphics Working Group is developing an XML language with the geometrical and behavioural capabilities of VRML. The intention is that this language will eventually serve as the next generation of VRML. Its potential significance for Virtual Archaeology has already been recognised by CANTONE (forthcoming). Current X3D efforts are devoted to making the first form of the language directly comparable with VRML 2.0. Related profiles including the spatial extensions of GeoVRML have also received attention. Eventually, browser support for X3D is to be expected but, for the moment, XSLT[28] is used to translate X3D into VRML so that it may be displayed using current browser plug-ins.

[28] XSLT: eXtensible Stylesheet Language Transformations, see http://www.w3.org/Style/XSL/ and http://www.w3.org/TR/xslt.

An X3D document closely mirrors the structure of current VRML files. The root node <*X3D*> contains <*Header*> and <*Scene*> elements. A trivial X3D example containing a single red cube is shown in Fig. 6. The world specified by the *Scene* element corresponds directly to that described by the VRML code in Fig. 7.

At present, X3D shows no more concern for metadata than did VRML. As often happens with XML-based languages, metadata is not a primary concern in the earliest published version. This much is clear from the adoption of a simple *meta* header tag similar to that used in HTML and SMIL 1, and offering little more than the VRML *WorldInfo* node, rather than the more powerful RDF-based approach of SMIL 2 and SVG. Hopefully this omission is rectified in later versions.

However, the absence of any mention of RDF metadata from the specification is no barrier to its use. As we have seen in earlier examples, this approach to document description is reliant on XML namespaces. There is, in practice, no reason why a RDF element could not be included in an X3D document, and the *Header* would be an appropriate place for a description of the complete resource. Descriptions of the individual elements of the model could be included using separate *rdf:Description* elements as in the earlier SMIL example.

5. A Virtual Archaeology metadata profile and schema?

Earlier sections of this paper have discussed the need for a coherent approach to metadata descriptions for Virtual Archaeology, identified RDF as an appropriate vehicle for such descriptions, and examined several XML-based presentation and visualization formats in which RDF can be used. The Dublin Core provides a sound basis for descriptive metadata, but it was never intended to encompass the detailed requirements of specific application areas. This section suggests how the Virtual Archaeology community might develop a metadata profile and schema as a means to express the more extensive requirements outlined in the introduction

To maximise interoperability with other systems, it is essential that Virtual Archaeology metadata should build on, rather than replace, other standards. Heery and Patel (2000) discuss 'Application Profiles' as metadata schemas that allow the use of «…data elements drawn from one or more namespaces, combined together by implementors, and optimised for a particular local application». They discuss several examples that begin with the Dublin Core and add application-specific qualifiers and encoding schemes. According to their definition, an application profile may refine namespaces by semantic narrowing of existing elements, and specify controlled vocabularies (encoding schemes). It cannot, however, introduce new elements. To do this requires the definition of a new namespace and an undertaking to maintain its schema. From this it is clear that Virtual Archaeology needs both a metadata profile to define how existing schemas should be used, and a schema defining elements that address domain-specific requirements.

The DC Education Working Group has identified several areas of concern that overlap with the requirements discussed here[29]. These include target user groups, learning processes, standards compliance and quality. Amongst their proposals are *audience* and *standard* elements to indicate the intended audience and compliance with published standards. The *standard* element has two refinements (*identifier* and *version*) to provide more detailed information. As an alternative, a refinement of *dc:Relation*, linking to a standards document via a *conformsTo* element is also discussed in this proposal. As many virtual archaeology products have an educational objective, these elements might usefully be included in the profile, although care should be taken to ensure that, as they come from a different domain, their definitions are not too restrictive for our needs.

Technical metadata is another area where existing standards can be brought into the profile. It is clearly not the role of an archaeological community to define such standards, but it is appropriate to examine existing and emerging metadata schemas and to determine which would be best suited to conveying any technical information required by archaeological projects. The required elements might cover resource size, image resolution and quality (e.g. level of compression), video duration and encoding (identity of codec used), etc. As mentioned earlier in the discussion of SMIL, the MPEG standards would be an obvious candidate to provide elements for inclusion in the profile.

The remainder of this section addresses ways in which specificDublin Core elements would need to be refined in a Virtual Archaeology profile and schema. For convenience, the Virtual Archaeology namespace will be labelled '*va*', but the issue of the responsibility for its maintenance will be left open until the concluding section.

Creator/Publisher/Contributor

Many people and organisations may be involved in the production and dissemination of an archaeological model. For each of these, a complete description of a resource would need to include both their identity and the roles they have played in the process. In a sense, Creator and Publisher are just special cases of Contributor with broadly defined roles. Other roles are not covered by existing DC refinements so would need to be defined in the *va* namespace as new elements, element refinements, or as attributes of existing elements. These might be expressed in RDF/XML as follows:

[29] See, http://www.ischool.washington.edu/sasutton/dc-ed/Dc-ac/DC-Education.html

```
<va:Excavator>John Smith</va:Excavator>
```

or

```
<dc:Contributor>
  <va:Excavator>John Smith</va:Excavator>
</dc:Contributor>
```

or

```
<dc:Contributor va:role="Excavator">John Smith</dc:Contributor>
```

In the first case, the namespace definition should indicate that the semantics of the *Excavator* element are a refinement of *dc:Contributor*. In the second, the profile would confine the use of this element as a child of *dc:Contributor*. In the third, the profile would need to define a controlled vocabulary of permitted attribute values. Each of these methods has different merits and an early decision is needed as to which form is to be preferred.

Subject

The use of the DC Subject in the *va* profile is relatively problem free and can follow the standard recommendation to use a controlled vocabulary. Where possible, existing archaeological thesauri should be used as sources. Although the profile might include a list of recommended thesauri, this should not be considered normative, and consideration should be also given to suitable refinements to allow subject keywords to be linked with on-line thesaurus definitions.

Description

Other than the *Table of Contents* and *Abstract* refinements, the *dc:Description* definition may contain or reference almost any textual or graphical representation of the resource content. A Virtual Archaeology Profile should specify minimum standards of what should be included here. This might include statements about the purpose of the project, its intended audience and its authenticity. Alternatively, following the lead of the DC Education Working Group, more detailed statements might take the form of application-specific element definitions. Indeed, the profile might specify both a minimal form in which the information is summarised in *dc:Description*, and a detailed form in which extended information is provided by specialised elements.

Relation and Source

Relationships with other resources are key to fulfilling the requirement to support citation and allow users to follow chains of argument and information derivation. The DC Relation element has several defined qualifiers suited to linking the multiple components of Virtual Archaeology resources. These include the pairs *Is Part Of / Has Part*, and *Is Referenced By / Refer-*

ences. The Source element, which appears to be no more than a specially privileged form of relation, can also be considered here. As with the Creator, Publisher and, especially, Contributor elements, Dublin Core has no provision for further qualification of the relationship to indicate the role or purpose of inclusion, reference or derivation. Again, these elements would appear to need refinement in the *va* namespace as new elements, element refinements, or as attributes of existing elements

The problem of referencing external metadata was identified in discussing how to describe the components of a complex, possibly distributed, resource. A possible solution would be to define a new relation refinement, *va:describedBy*, to indicate a link to external metadata. For example:

```
<dcq:hasPart rdf:resource="http://…/video1.avi">
  <va:describedBy rdf:resource="http://…/video1.rdf"/>
</dcq:hasPart>
```

Alternatively, this element might be used in separate *rdf:Description* elements for each component which, instead of holding a complete metadata record, would simply act as pointers to the location where the record can be found. For example:

```
<rdf:Description rdf:about="http://…/video1.avi " >
  <va:describedBy rdf:resource="http://…/video1.rdf"/>
</rdf:Description>
```

Coverage

Refinements to the DC Coverage element are likely to prove the most complex. Despite attempts to provide a range of encoding schemes for spatial and temporal coverages, the library-centred origins of the Dublin Core are most apparent in the limited expressiveness of this element. No doubt the use of the suggested encodings, such as ISO 3166 country names[30] and the Getty Thesaurus of Geographic Names[31], will prove useful, but the handling of spatial co-ordinates requires greater flexibility. For example, the DCMI Point[32] and Box[33] encoding schemes fail to provide an adequate approach to the complex issue of encoding spatial reference systems. Given the importance of spatial referencing in many archaeological projects, it is recommended that the thorough work of groups such as the OpenGIS Consortium, including their Geographic Markup Language (GML)[34] specification should be used as a basis for refined spatial coverage elements.

[30] See http://www.din.de/gremien/nas/nabd/iso3166ma/codlstp1/index.html
[31] See http://www.getty.edu/research/tools/vocabulary/tgn/
[32] See http://dublincore.org/documents/2000/07/28/dcmi-point/
[33] See http://dublincore.org/documents/2000/07/28/dcmi-box/
[34] See http://www.opengis.net/gml/01-029/GML2.html

Similarly, work is needed on temporal coverages. The DCMI Period encoding scheme[35] offers a basic approach using the same W3C-DTF (ISO 8601) encoding as recommended for the *dc:Date* element. What it lacks is any serious attempt to address period naming schemes. Chronological period naming conventions depend on social and political histories of the region and, indeed, the intellectual histories of the scholars involved in creating the resource. For example, the terms 'roman' and 'iron age' show considerable variation in meanings in different parts of Europe, and the spatial extent of a named country or region can vary significantly through time. This is a core area of archaeological and historical expertise, and success in developing appropriate refinements may prove useful to other communities who might include the temporal elements of the *va* schema in their own metadata profiles.

Rights management

This is a complex issue particularly when it is realised that a Virtual Archaeology product may use commercially produced resources, copyrighted material, museum and other private property and the intellectual property rights of all contributing individuals and organisations must be taken into account (see, for example, Rust 1998). Arguably, this is an issue that archaeologists can hope will be standardised elsewhere. Until then, one or more rights management statements, or references to statements will probably suffice.

The remaining Dublin Core elements (Title, Date, Type, Format, Identifier and Language) are considered to be unproblematic and can be included without refinement in the *va* profile. Consideration should also be given to whether the profile should define which elements are required, recommended or optional.

6. Conclusions

The use of Virtual Archaeology is expanding rapidly, not only in the museum and archaeology professions, but also in the broadcast media, tourism and heritage industries. Many concerns have been expressed about the lack of transparency and difficulty of validating the presentations used in these contexts. This paper has examined the role of metadata in addressing these problems, and argued that appropriate documentation of projects may extend the critical apparatus that we take for granted in scientific papers into the world of distributed Virtual Archaeology.

The examples presented here have used XML and RDF. This is only one possible expression of metadata but its importance outweighs others be-

[35] See http://dublincore.org/documents/2000/07/28/dcmi-period/

cause these languages underlie many current and proposed developments in Internet technologies. XML-based languages offer many benefits. They are open and accessible, and a growing body of tools and programming interfaces make it possible to adapt their content to suit many different applications. Using XSLT, the information content of an XML document can be readily extracted or transformed into different formats according to the capabilities of the display device. A single resource might be adapted to suit a desktop PC, a handheld device, or an interactive TV (VALLIAPAN *et al.* 2001). Similarly, content may be selected and adapted to suit the interests of different users (RYAN forthcoming). Metadata describing linked resources, including alternative formats, representations and interpretations, as well as documents containing background arguments and discussions, are an essential component of such adaptable applications.

Of course, metadata-aware applications are needed to make use of all this information. Resource discovery needs are increasingly well served by archives such as the ADS but, to exploit the forms and uses of metadata envisaged here, authoring and exploratory tools are also needed. Metadata creation should be seen as an essential part of presentation authoring, and exploratory capabilities need to be included in browsers and other viewing software. Indeed, a motivation for converting the Canterbury Temple presentation to SMIL format is to provide a resource that can be used in prototype applications that enable the viewer to 'drill-down' through the layers of metadata and explore the resources behind the presentation. The primary objective is to allow specialists to follow chains of reasoning and citation, but alternative routes might also be provided to suit different levels of interest and knowledge. Initially, this approach is targeted at Web-based applications but, in principle, it can be extended to interactive TV. Eventually, we might hope to see TV program formats with the potential to present complexity and alternative views, and so address the interests of wide a range of audiences.

An outline proposal for a Virtual Archaeology Metadata Profile and Schema has been presented, based on refinements of the Dublin Core and other metadata schemas. The proposal is offered as a starting point for discussion throughout the Virtual Archaeology community. Details of element semantics, preferred syntax, and selection of appropriate controlled vocabularies all need to be discussed and decided. Almost certainly, elements and refinements not considered here will need to be added. In due course, a group effort will be needed to produce the necessary standards documentation for the Profile and Schema and, perhaps more importantly, to accept responsibility for its maintenance. Such a role is within the remit of the newly formed CVRO (FRISCHER *et al.* forthcoming), but the task extends beyond the needs of Virtual Reality. For this reason, the intended joint meeting of CVRO and the CAA Virtual Archaeology Special Interest Group (VASIG) at the 2002

CAA Conference would provide a suitable context in which to develop the proposal. There are, of course, other individuals and groups with an interest in Virtual Archaeology and input from all of these would be of value.

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ABSTRACT

The use of Virtual Archaeology is expanding rapidly, not only in the museum and archaeology professions, but also in the broadcast media, tourism and heritage industries. Many concerns have been expressed about the lack of transparency and difficulty in validating the models and presentations used in these contexts. A case study is used to illustrate the role of metadata in addressing these problems. The paper argues that appropriate metadata documentation of projects may extend the critical apparatus that we take for granted in scientific papers into the world of distributed Virtual Archaeology. Three recently introduced XML languages for multimedia (SMIL), vector graphics (SVG) and virtual reality (X3D) applications are examined with particular reference to their metadata hosting capabilities. Finally, an outline proposal for a Virtual Archaeology Metadata Profile and Schema is presented, based on refinements of the Dublin Core and other metadata schemas.