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An Ontology for 3D Cultural Objects

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Abstract

3D cultural objects are digital 3D replicas of objects having a cultural value, as models of artefacts, reconstructions of buildings, sites and landscapes. As such, they have a twofold nature, and inherit properties both from their digital nature, like the shape and texture, and from the cultural content, for instance to be used for scholarly purposes or communication to the public. In some cases, one of the natures prevails on the other. This may be the case because the object is being processed, e.g. visualized on a computer, or scrutinized by heritage scholars for review. In a few others, it is unfortunately the user's narrow-minded attitude that leads to take into account only one nature of such an object and neglect the other. It is therefore necessary to explore a way of documenting 3D cultural objects that keeps together all the relevant information, both the cultural and the digital one. In this paper we propose an ontology for such complex objects that owns the following important properties: i) it is sufficiently general to encompass very different artefacts, from pottery sherds to historical landscapes; ii) it fully complies with international standards for heritage, in this case CIDOC-CRM, of which it can be shown to be a specialization/extension; iii) it is sufficiently simple to be used and understood by heritage practitioners and professionals with moderate computer skills, and documents items in a plain, human readable and understandable way; iv) items documented as instances of this ontology can be efficiently processed for the most frequent purposes, as computer visualization, retrieval of cultural information or storage in a database; v) it is ready for compliance with other important requirements, as for instance the proposed charter on credibility known as London Charter.

Categories and Subject Descriptors (according to ACM CCS): H.3.7 [Standards]:

1. Introduction

A holistic approach to computer visual representations of heritage artefacts is being fostered by a number of scholars investigating not only how Information and Communication Technology (ICT) may enhance the visualization of such objects, adding spectacular features to cultural communication, but also the rules that modelling and visualization must follow to respect the cultural content. Such an approach is the foundation of the EU project EPOCH [EPO], which is now developing an interoperable set of tools by combining existing ones into a toolkit and a common software infrastructure. However, it is evident that such efforts requires the adoption of standards at the interfaces between different tools and at the beginning and end of the production chain. Therefore, standards for 3D objects are currently investigated, in order to optimize technology and guarantee the cultural validity of outcomes. These two facets of cultural objects must march together, indissolubly tied also as far as data are concerned. In both regards standards do exist.

Technology offers a variety of *de facto* or *de jure* possibilities, presently being investigated by the project, while for the cultural side CIDOC-CRM [CRM] is the necessary choice. As it is well known, CICOC-CRM is an International ISO Standard (ISO 21127:2006) under publication as of 06/06/06. It "establishes guidelines for the exchange of information between cultural heritage institutions. In simple terms this can be defined as the curated knowledge of museums. [. . .] ISO 21127:2006 is specifically intended to cover contextual information (i.e. the historical, geographical, and theoretical background that gives museum collections much of their cultural significance and value)." [ISO06]. CIDOC-CRM current version is 4.2.

At this point, there is the need of a container to host the different descriptors of the 3D cultural object, the digital replica of a cultural artefact reproducing a man-made object or a complex of such objects and natural ones. The definition of "real" cultural objects, as compared to "digital" cultural objects, is beyond the limits of the present paper. However, it assumed that CIDOC-CRM is a "good" way to describe them, i.e. it satisfactorily manages the necessities of documentation of the cultural heritage domain. Therefore we will assume that the objects originating the digital replicas we are going to consider here are (well) described using CIDOC-CRM. Calling them cultural objects is just shorthand and it just implicitly means that whatever the definition of cultural heritage objects one has in mind, CIDOC-CRM is an ontology describing the things that belong to it.

It has been recently noted that just documenting the cultural object and the associated digital object is not sufficient to guarantee credibility to the latter. Draft guidelines to document such derivation process, the so-called "London Charter", are in progress [BDN06]. In our opinion, this documentation is the third facet of the digital cultural object description, and is the glue that keeps together the other two. In fact, many digital objects (DO) may be associated to the same cultural object (CO) using different replication processes (RP), as scanning, modelling and so on, and only triplets (CO, DO, RP) are unique: RP: CO $\mapsto$ *DO*. By the way, unless random factors are deliberately introduced — in this context, in a rather unjustified way — the description of RP guarantees in principle that the derivation may be repeated. In practice this may be limited by external factors such as, for example, environment illumination in scanning, although this is true for any scientific experiment and repeatability is generally only theoretical.

Another factor adds to the difficulty of keeping the above descriptions together by attempting to reconcile the respective different ontologies. According to [HPS04], "a reason for expecting continuing diversity is that an ontology is often aligned with a particular perspective on the world." In our case, there are two perspectives, the cultural one (which cares little of the way the object is digitalized, as long as some validity rules are respected) and the technological one (which pays attention to the technology but needs guidance as far as embedded "cultural" content is concerned). Such perspectives correspond to two different communities, heritage professionals and computer experts; reconciliation comes from the necessity of interacting on a common goal, for example communicating heritage availing of computer graphics.

In fact, both parties often state that the "other" feature is beyond their scope. For instance, [Doe01] describes a comparison of OpenGis with CIDOC-CRM and, when technical details are involved, rightfully states that "this is out of the scope of the CRM." In a similar way, technical 3D standards as X3D [X3Da] or Collada [Col] have little room, if any, for incorporating information concerning the"original" being modelled.

Therefore, the optimal solution would be to enable each party to keep their own ontology and related perspective of the world, and to provide tools to combine the different ontologies into a more general one, that can be "flattened" back into generalisations of the original ontologies, minimally extended with a container for off-topic information; a simpler task, if the original ontologies already have a container for it. In other words, the mechanism we propose is such to allow each party to deal with familiar concepts, with perhaps just a small extension, where all the non-pertinent stuff is stored: that is, heritage professionals are enabled to manage information with CIDOC-CRM and accept that there is a class where the digital information is stored; technology professionals will have a place in the standard they use for storing cultural information which may be irrelevant for processing.

The difficulty of this approach is that it must be provided a mechanism for collapsing the information which is irrelevant for a particular perspective while expanding the one which is, on the contrary, relevant, from a background where both pacifically coexist.

This is what we will try to do in the present paper.

Since the methodology for the documentation of the production process is still in its infancy, we will limit to the other two facets, i.e. we will consider the ontology of Cultural Objects (CIDOC-CRM), which concerns the CO; and the ontology of 3D objects (in particular, X3D, for reasons to be clarified below), which concerns the DO, considering only very simple information relating to the RP to be stored wherever appropriate.

2. Previous work: combining the CRM with MPEG

Previous work in this direction has been undertaken by Jane Hunter in [Hun02]. In this paper the author describes an approach which combines the domain-specific aspects of MPEG-7 and CIDOC-CRM into a single ontology, in order to describe and manage multimedia in museums. She also gives the complete description of an example concerning an ethnographic film taken between 1901 and 1912, and digitized in 1999 for preservation purposes.

Although listing a number of Museum Multimedia Types, the author's focus is video-audio documentation of intangible heritage. In this case the digital object is not a replica, but more precisely a substitute. Incidentally, also in this case a description of the production process would have been substantial: did the movie film aboriginal dances taking place independently, or the director arranged people to perform dancing in front of the camera? Did the digital copy include all of the original movie, or some parts were lost?

Hunter's paper then describes a combined ontology in which CIDOC-CRM is extended to include MPEG-7 classes, attached to CIDC-CRM where they fit better.

Some information is present in both ontologies, and may be directly mapped. Other is better managed by one of the two merging ontologies. The attachment point for the MPEG-7 class hierarchy is CIDOC-CRM class E73.InformationObject, which is enriched by adding appropriate subclasses.

Although paving the way for the model we will discuss in this paper, and being a very good application of the capacity of CIDOC-CRM to manage unforeseen conditions, Hunter's approach cannot satisfactorily manage the problems we are dealing with here. Her examples are in fact the physical carrier of cultural information which is stored nowhere else and are autonomous; digital replicas are on the contrary cultural nonsense, or just computer graphics exercises, out of the heritage context in which they originated.

3. Is a bell beaker a Bell Beaker?

To further proceed in the definition of a harmonized ontology for 3D objects, we will consider a bell beaker like the one reproduced in figure 1. These objects are typical of the Bell Beaker culture, an archaeological culture spread in Europe and dating from 2800 to 1900 BC. In other terms, these objects are associated with a complex of time periods, regions and practices. They are supposed to have been used for drinking beer, or mead, possibly in ceremonies, and are usually part of a prestige package in grave goods.

The one depicted below comes from the Wiltshire Heritage Museum in UK. It is a European Bell Beaker dating before 2500 BC found complete and intact in West Kennet Long Barrow near Avebury. This is perhaps the best-known beaker from the British Isles.

Figure 1: *A Bell Beaker from the Wiltshire Museum.*

Now, assuming the above (or, better, the file from which the image originated) is a faithful reproduction of the Bell Beaker kept in the museum, what makes it a digital cultural object? It is in fact the statement given above, relating it to the real Bell Beaker of the museum. In other words, it is this relation that turns a computer file — the bell beaker — into a digital cultural object — the Bell Beaker digital replica. Is the latter a cultural object by itself? In general no, unless we want to consider it as artwork, what is certainly not the case for Figure 1. This might the case, for instance, of the well-known Picasso's painting *Las Meninas*, a set of variations after the homonymous painting by Velazquez. So, using an ontology as CIDOC-CRM, conceived for cultural heritage, to document it might appear inappropriate, and an overarching technological standard as MPEG-21 might seem to work better. This is not the case, unless there is a way for embedding in it the cultural information in a simple and elegant way — and current standards do not envisage such opportunity. A possibility would be to extend existing technological standards, for example creating a "cultural profile" in X3D with appropriate extensions as suggested in [Nic06]. Although possible, this would create yet another "standard" of difficult maintenance. Even if inspired by an accepted standard as CIDOC-CRM, who would guarantee that any future change in the latter would be implemented in such extensions? So the only way to proceed is to incorporate into CIDOC-CRM extensions taken from technological standards, but providing automatic mechanisms for update when future versions of the technological standards are made available.

4. Not extending, but embedding

The process of extension is sometimes considered as the addition of new features to an existing system. This is in fact shorthand for a more complex process:

1. Start from an ontology O
2. Define a new ontology O_1 which has a subset O_2 which is isomorphic to O
3. Identify O_2 with O.

If the process is static, the two ontologies O and O_1 will diverge after extension. New versions of O will likely be no more isomorphic to O_2. If the process is dynamic, any change on O will reflect on O_1 in such a way that O_2 will continue to be isomorphic with the new O.

The Web Ontology language OWL [OWL04] provides such a mechanism for dynamic extension. It is the include-style owl:imports construct that together with namespace declaration allows using concepts (classes) from any existing ontology. Appropriate usage of the property owl:equivalentClass eliminates duplicates.

A (partial) description of CIDOC-CRM in OWL has been given in [Bal05] basing on previous work in RDFS and DAML+OIL . It refers to version 3.4.9 and although accessible over the Internet at the designated URI, it is not likely to be maintained, or at least subsequent version will be possibly stored elsewhere, according to the convention apparently used for the URI. An URI system like the one used by W3C, storing the latest version always in the same

URI would better help updating imports. Also, a more significant name than “index.html” would be more appropriate, and perhaps an “.rdfs” file extension would help managing it with ontology tools. However, it suffices for the goals of the present paper.

The EU project DELOS, an IST Network of Excellence on Digital Libraries, has developed an OWL description of the X3D ISO standard [CK06] named OntologyX3D. Although possible for other standards, we will develop the full construction for X3D only, because it is an ISO Standard and has an ontology description, whereas Collada, a potential competitor, has no such facility. For the sake of simplicity in explanation, we will add a universal class named Scene (corresponding to the root element of the X3D Schema) and assume that the ontology is modified accordingly. This addition is perfectly legal and in fact it can be done with no adverse consequence.

So the bricks for building the 3D Cultural Objects Ontology are there, and it remains only to build it up.

5. Building a simple 3D-CO Ontology

5.1. Embedding the parent ontologies

The initial step consist in the definition of the new ontology as deriving from the two parent ones. Firstly, let us define some entities to store the URIs of the parent ontologies:

```
<!DOCTYPE rdf:RDF [
 <!ENTITY cidoc
  "http://cidoc.ics.forth.gr/OWL/crm3.4.9#">
 <!ENTITY ontox3d
  "http://sargos.ced.tuc.gr/OntologyX3D#">
 <!ENTITY owl
  "http://www.w3.org/2002/07/owl#">
 <!ENTITY rdf
  "http://www.w3.org/1999/02/22-rdf-syntax-
ns#">
 <!ENTITY rdfs
  "http://www.w3.org/2000/01/rdf-schema#">
 <!ENTITY xsd
  "http://www.w3.org/2001/XMLSchema#">
 <!ENTITY co
  "http://www.3d-co.org/current#">
]>
```

The first two entities `&cidoc;` and `&ontox3d;` provide shorthand for the respective URIs. Other entities have been added to the DTD to facilitate reading the code in the sequel; they are the standard ones for OWL, RDF, RDFS and XML Schemas. The last entity is a dummy reference to an hypothetical resource (actually *non-existent*) destined to host the 3D-CO ontology under definition.

Then let us include all the relevant namespaces in the OWL header:

```
<rdf:RDF
  xmlns     = "&co;"
  xml:base  = "&co;"
  xmlns:cidoc = "&cidoc;"
  xmlns:ontox3d = "&ontox3d;"
  xmlns:owl = "&owl;"
  xmlns:rdf = "&rdf;"
  xmlns:rdfs = "&rdfs;"
  xmlns:xsd = "&xsd;"
>
```

Now it remains only to import into the 3D-CO ontology the two parent ones:

```
<owl:Ontology rdf:about="">
 <rdfs:comment>
    This is the Ontology
    for 3D Cultural Objects,
    to be used to document
    3D replicas of objects
    with cultural value
 </rdfs:comment>
 <owl:imports rdf:resource="&cidoc"/>
 <owl:imports rdf:resource="&ontox3d"/>
 <rdfs:label>
    3D Cultural Object Ontology
 </rdfs:label>
</owl:Ontology>
```

So far, so good. Now it remains the second part of the task, that is identifying common features and attaching the universal class of OntologyX3D somewhere into CIDOC-CRM

5.2. Identifying common features

The CIDOC-CRM entity `E73.Information Object` is the attachment point for the OntologyX3D superclass Scene. However, since the latter is a particular type of Information Object it probably fits better with the subclass `E36.Visual_Item`:

```
<owl:Class rdf:about="#Model3D">
  <owl:equivalentClass
   rdf:resource="&cidoc;
    E36.Visual_Item"/>
  <owl:equivalentClass
   Rdf:resource="ontox3d;
    Scene"/>
</owl:Class>
```

The above equivalence, established towards CIDOC-CRM classes, projects onto properties, inducing the creation of properties equivalent to those in CIDOC-CRM that relate the visualization to its subject. So `P138.represents` has an homonymous equivalent in 3D-CO, which can be defined within 3D-CO and then associated to `P138` using `owl:equivalentProperty`, or simply quoted as `&cidoc;P138F.represent`.

Here is the resulting ontology as yet obtained.

```
<!DOCTYPE rdf:RDF [
 <!ENTITY cidoc
```

```
  "http://cidoc.ics.forth.gr/OWL/crm3.4.9#">
 <!ENTITY ontox3d
  "http://sargos.ced.tuc.gr/OntologyX3D#">
 <!ENTITY owl
  "http://www.w3.org/2002/07/owl#">
 <!ENTITY rdf
  "http://www.w3.org/1999/02/22-rdf-syntax-
ns#">
 <!ENTITY rdfs
  "http://www.w3.org/2000/01/rdf-schema#">
 <!ENTITY xsd
  "http://www.w3.org/2001/XMLSchema#">
 <!ENTITY co
  "http://www.3d-co.org/current#">
 ]>
<rdf:RDF
  xmlns     = "&co;"
  xml:base  = "&co;"
  xmlns:cidoc = "&cidoc;"
  xmlns:ontox3d = "&ontox3d;"
  xmlns:owl = "&owl;"
  xmlns:rdf = "&rdf;"
  xmlns:rdfs = "&rdfs;"
  xmlns:xsd = "&xsd;"
>
<owl:Ontology rdf:about="">
 <rdfs:comment>
    This is the Ontology
    for 3D Cultural Objects,
    to be used to document
    3D replicas of objects
    with cultural value
 </rdfs:comment>
 <owl:imports rdf:resource="&cidoc"/>
 <owl:imports rdf:resource="&ontox3d"/>
 <rdfs:label>
    3D Cultural Object Ontology
 </rdfs:label>
</owl:Ontology>
<owl:Class rdf:about="#Model3D">
  <owl:equivalentClass
   rdf:resource="&cidoc;
    E36.Visual_Item"/>
  <owl:equivalentClass
   Rdf:resource="ontox3d;
    Scene"/>
</owl:Class>
</rdf:RDF>
```

One might also wish to be more precise and extend CIDOC-CRM with a new class `3D Model`, at the same hierarchy level of `E37.Mark` and `E38.Image` and, like them, a subclass of `E36.Visual_Item`. This option does not alter the substance of our discourse. It can, on the contrary, improve our results. To this goal, let us introduce a subclass of the new ontology, subclass of VisualItem, named Model3D to avoid issues arising with a number as first letter. In this case, it is `co:VisualItem` which is equivalent to `cidoc:E36.Visual_Item`, and X3D is attached one level below — still to `Model3D`, but this has been moved to a lower hierarchy level.

The excerpt of the OWL description is therefore the following:

```
<owl:Class rdf:about="#VisualItem">
  <owl:equivalentClass
   rdf:resource="&cidoc;
    E36.Visual_Item"/>
</owl:Class>
<owl:Class rdf:about="#Model3D">
<rdfs:subClassOf rdf:resource =
     "#VisualItem"/>
  <owl:equivalentClass
   Rdf:resource="ontox3d;
    Scene"/>
</owl:Class>
```

Figure 2 illustrates the above merging process. The leftmost box represents the 3D-CO:VisualItem class, which is equivalent to CIDOC-CRM:E36. The mapping brings into 3D-CO all other CIDOC-CRM classes, including, for example, `E37.Mark` and `E38.Image`. In 3D-CO we define a new class, `3D-CO:Model3D` as a subclass of `3D-CO:VisualItem`. The existing one-to-one correspondence of a subset of 3D-CO and CIDOC-CRM is so preserved. The new class `3D-CO:Model3D` is defined as equivalent to `Scene`, the root of X3D, i.e. `OntologyX3D:Scene`. Further `OntologyX3D` classes are mapped into 3D-CO as subclasses of Model3D.

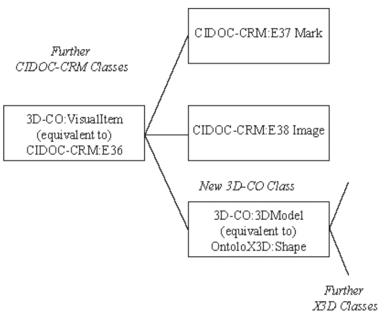

Figure 2: *Diagram of the 3D Model extension.*

The above mechanism suggests further possibilities. For example, another new class 2DVectorModel might be added as well, and the root of an SVG ontology made equivalent to it. As it is well known, SVG is the W3C vector graphic standard whose description is available at [SVGa]. An OWL description of the underlying ontology may be found at [SVGb]. We will not explore further this option, which does not substantially differ from the X3D extension described above.

6. The advantages of merging

The newly defined 3D-CO ontology has several advantages with regard to any newly defined one:

1. It inherits from CIDOC-CRM the generality of scope: as long as it is accepted that CIDOC-CRM may deal with any cultural object, also 3D-CO can.
2. The definition is concise and easy maintainable, because changes in the parent ontologies are automatically taken into account by the URI reference mechanism.
3. The definition is easily accepted by the different communities that recognise themselves in one of the parent ontologies. To them it says: "As far as your domain is concerned, business as usual, except that there is a place where all the heterogeneous stuff is stored."
4. It allows for specialization of terms without intervening on the original ontologies. In other words, if for example a particular application needs the concept of sherd as a particular case of CIDOC-CRM `E22.Man-Made_Object`, it can be introduced in the 3D-CO without loss of compatibility, using the `rdfs:subClassOf` construct as follows:

```
<owl:Class rdf:about="#Artefact">
  <owl:equivalentClass
    rdf:resource="&cidoc;
    E22.Man-Made_Object"/>
</owl:Class>
 <owl:Class rdf:ID="Sherd">
   <rdfs:subClassOf rdf:resource =
     "#Artefact"/>
</owl:Class>
```

This trick may be used to introduce a definition that specializes a concept (Sherd as specialization of Man-Mad Object), or just make its denomination more user-friendly (Artefact).

On the other hand, this approach has disadvantages, mainly consisting in possible inconsistencies deriving from new version of the merged ("parent") ontologies. For example, imagine that a future release of CIDOC-CRM changes the denomination of E36 from Visual Item to, say, Visualization Stuff. The equivalence linkage between 3D-CO and CIDOC-CRM would hence be broken because of a formal — but not substantial — change in the parent ontology.

This is unavoidable with the OWL mechanism of mapping, and is difficult to avoid anyway. Although the embedding takes into account any update in the original, there are some critical points where change may cause disruption. This can perhaps be managed on the source side, by creating a mechanism similar to RSS, which is automatically checked and sends an alert to the children ontology administrator, subscribed to such a service, when such a potentially disruptive event takes place; or on the destination side, by checking automatically that as yet no change intervened in the version, and alerting the administrator when it happens.

Figure 3 provides a schematized representation of the process developed so far. Each cell represents a class, and different planes correspond to different ontologies. The arrow shows the correspondence as envisaged in the first option described above, that is the equivalence between X3D Scene, CIDOC-CRM `E26.Visual_Item` and 3D-CO `Model3D`.

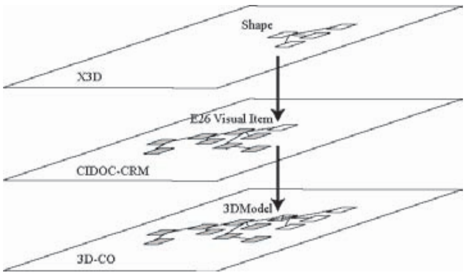

Figure 3: *Diagram of the ontology mapping.*

Figure 3 illustrates the subset of 3D-CO (represented by grey cells) that are isomorphic (one-to-one corresponding) to CIDOC-CRM.

7. Examples

7.1. Porsenna's Mausoleum

We will now show how the 3D-CO may be used to store information concerning the 3D Model of the Mausoleum of Porsenna. This is a lost Etruscan monument, of which only a description remains. This description has been used to create an X3D model, and the latter has become a testbed for different applications, see for example [Nic06], where the complete X3D description can be found.

For this example we will assume that there is a 3D-CO DTD, named CO, at the fictitious URI `www.3d-co.org`. This DTD results from the merge of the CIDOC-CRM DTD, available at the CIDOC-CRM site [CRM], and the X3D DTD, available at the X3D site [X3Db]. Thus it includes all the CIDOC-CRM entities and the X3D entities, plus any new one defined here.

For space reasons, we will not enter into further details concerning these merged DTDs, and will omit a large (and inessential) part of the description. Equivalent entities will of course be present one time only.

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<?xml-stylesheet type="text/xsl"
  href="3D-CO.xsl"?>
<!DOCTYPE CO SYSTEM
  "http://www.3d-co.org/DTD/3d-co.dtd">
<CO>
<CRM_Entity>3D Model 4321
 <in_class>Model3D</in_class>
 <is_identified_by> Object_ID 4321
  <in_class>
    E42_Object_Identifier
  </in_class>
```

```
 </is_identified_by>
 <has_title>
   Porsenna's Mausoleum
   <in_class>E35_Title</in_class>
 </has_title>
 <has_type>
   3D Model
   <in_class>E55_Type</in_class>
 </has_type>
...
<!- more CIDOC-CRM stuff if necessary->
<Model3D>
<!- this is the equivalent of Scene->
<!- X3D starts here ->
<Background
 groundAngle='1.309, 1.571'
 groundColor='0.1 0.1 0,
              0.4 0.25 0.2,
      0.6 0.6 0.6'
 skyAngle='1.309, 1.571'
 skyColor='0 0.2 0.7,
           0 0.5 1,
   1 1 1'/>
<ProtoDeclare name='pyramid'>
 <ProtoInterface>
  <field name='transparencyValue'
    type='SFFloat'
    value='0.0'
    accessType='inputOutput'/>
  <field name='translationValue'
    type='SFVec3f'
    value='0 100 0'
    accessType='inputOutput'/>
  <field name='scaleValue'
    type='SFVec3f'
    value='1 1 1'
    accessType='inputOutput'/>
 </ProtoInterface>
...
<!-more X3D stuff->
</Model3D>
</CRMEntity>
</CO>
```

7.2. The Bell Beaker

A similar process can be carried out with the drawing in figure 1, the bell beaker, in such a way that it is acknowledged as a Bell Beaker. Again we will assume that there is a 3D-CO DTD at the fictitious URI `www.3d-co.org`, resulting from the merge of the CIDOC-CRM DTD and the SVG DTD, available at the SVG site [SVGa].

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<?xml-stylesheet type="text/xsl"
    href="3D-CO.xsl"?>
<!DOCTYPE CO SYSTEM
  "http://www.3d-co.org/DTD/3d-co.dtd">
<CO>
<CRM_Entity>Drawing 1234
 <in_class>Model2D</in_class>
 <is_identified_by> Object_ID 1234
  <in_class>
    E42_Object_Identifier
  </in_class>
 </is_identified_by>
 <has_title>
   Wiltshire Bell Beaker
   <in_class>E35_Title</in_class>
 </has_title>
 <has_type>
   B/W Drawing
   <in_class>E55_Type</in_class>
 </has_type>
 <represents>Object 9999</represents>
...
<!-more CIDOC-CRM stuff if necessary->
<!-9999 is the original Beaker->
<2DVectorModel>
<!-this is the equivalent of entity SVG->
 <has_width>523.565pt</has_width>
 <has_height>536.28pt</has_height>
 <has_viewBox>"0 0 523 536"</has_viewBox>"
  <g id="Layer_x0020_1">
    <path d="... ">
...
<!-more SVG here->
  </g>
 </2DVectorModel>
</CRMEntity>
</CO>
```

In conclusion, it is possible to create an XML integrated description of the object, keeping together both the CIDOC-CRM data — and above all the link to the original object — and the graphic data, using for the latter the most appropriate description, in our example X3D or SVG. The creation of joint DTDs is straightforward since merging operations using XML namespaces is rather common.

8. Conclusions and future work

The approach used in this paper has shown to be very promising. Its advantages have already been described, but there are many more. For instance, it is possible to store together integrated descriptions of cultural objects with 2D or 3D models, availing of internationally accepted standards, into an XML native database.

It must be noted that the exercise presented here is mainly a proof-of-concept. For example, we need to rely on resources stored in sites sometimes unavailable — to test the code it has been necessary to copy them on our server and access them from there. The CIDOC-CRM ontology refers to a previous version of the standard, and the server hosting the X3D ontology is often down. To make all this practical, provisions should be taken to guarantee safe access to resources and frequent updates — in one word, maintenance. On the other hand, the examples presented in chapter 7 show that practical applications are viable.

From the above XML encoding, domain specific descriptions may be easily extracted: writing an XSLT to extract the cultural (or graphical) information is a straightforward task.

Future work will concern the update of CIDOC-CRM OWL description, full integration of graphical standards into 3D-CO and making the resulting ontology available on-line.

Finally, an extensive number of test cases need to be fully carried out: usually problems arise from practice even when the theory looks effective and terse as in the present work.

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