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Geographical Presentation of Virtual Museum Exhibitions

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Abstract

In this paper we present a system, called GeoARCO, which enables presentation of virtual museum exhibitions in a geographical context. The system is partially based on the results of the European project ARCO — Augmented Representation of Cultural Objects, which has developed technology for museums enabling them to create and manage virtual museum exhibitions for use in interactive kiosk displays and on the Web. GeoARCO uses the Google Earth platform to enable presentation of digital artefacts as well as complete cultural heritage exhibitions on top of the 3D globe model. Users can browse and search available exhibitions, display current location of objects as well as historical data about the objects, such as the place where the objects were made or discovered. A user can also display detailed 3D models of artefacts, reconstructed sites or entire virtual exhibitions. The system cooperates with multiple ARCO databases run by different museums.

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1. Introduction

Recently we can observe how virtual reality and augmented reality technologies are maturing from an early experimentation phase to a practical deployment phase, where 3D VR and AR applications become more and more popular in various domains. This is partially a result of enormous progress in hardware performance — especially graphics cards, increasing availability of automatic 3D modelling tools [SKZ05], and development of standards such as VRML/X3D [Web] and MPEG-4 [Koe02] enabling platform-independent representation of interactive 3D contents. Furthermore, wide availability of 3D computer games and movies based on 3D computer graphics results in increasing familiarity of users with 3D graphics and — at the same time — is raising user expectations. Young generations of people familiar with interactive 3D games and movies based on 3D graphics look for similar experiences in other domains.

One of prominent application areas of virtual and augmented reality technologies is cultural heritage. Museums around the world hold countless artefacts that they cannot exhibit to the public due to limited space, items' fragility, or the prohibitive cost of creating and managing appropriate displays. Travelling exhibitions or those that draw on multiple collections are even more problematic because of the expenses associated with transporting and insuring priceless objects, along with museums' reluctance to part with certain treasures. Yet such exhibitions typically have the widest appeal and generate the most revenue.

Virtual reality and augmented reality technologies offer museums and other cultural heritage institutions a convenient alternative method of presenting cultural heritage resources — both existing and reconstructed. The resources can be presented in the form of highly educational and entertaining interactive scenarios.

The use of VR and AR technologies is particularly beneficial, when the digitized collections of objects are accessible remotely over the Internet. Such virtual museum exhibitions on the web enable different audiences, including the disabled and students of all ages, as well as the general public to remotely access and interact with vast numbers of objects scattered among various localities in an engaging and informative way. Such exhibitions, however, suffer from the lack of one important element — the geographical context.

In this paper, we present a system, called GeoARCO, that enables presentation of virtual museum exhibitions in the geographical context. The system is partially based on the results of the European project *ARCO — Augmented Representation of Cultural Objects* [ARC], which has developed technology for museums to enable them to create and manage virtual museum exhibitions for use in local interactive kiosk displays and on the Web. GeoARCO uses the Google Earth platform to enable localized presentation of digitised artefacts as well as complete cultural heritage exhibitions on top of the 3D globe model. Users can browse and search available exhibitions, display current location of objects as well as historical data about the objects, such as the place where the objects were made or discovered. A user can also display detailed 3D models of artefacts, reconstructed sites or entire virtual exhibitions. The system can cooperate with multiple ARCO databases run by different museums.

The rest of this paper is organized as follows. In Section 2 related works are shortly described and rationale behind our research is presented. Section 3 provides an overview of the ARCO system describing its goals and capabilities. In Section 4, the GeoARCO platform is presented in details. Section 5 provides examples of interactive GeoARCO presentations. Finally, Section 6 concludes the paper and indicates future works.

2. State of the art and rationale

In the field of cultural heritage, digital mapping and geographical data management through Geographic Information Systems (GIS) is long recognised as an important element for conservation, protection, analysis, communication and learning purposes. Recently, numerous free or commercial web-enabled GIS software packages have been developed, which have led to many successful implementations of Internet GIS-driven services and maps, such as *Electronic Cultural Atlas Initiative* [Eleb] [Elea]. With increasing graphical capabilities of personal computer systems and widening access to broadband Internet, 3D GIS visualisation applications become more and more popular, with the *Skyline* [Sky], *Google Earth* [Goob], and *NASA World Wind* [Nat] being prominent examples. Google Earth together with its 2D version — *Google Local* [Gooc] — made a breakthrough in the availability of GIS visualisation services to the broad public.

There has been a lot of effort in employing Google Earth application in the cultural heritage domain. Individuals and organisations across the world are developing collections of historical places, monuments and objects that can be visualised within Google Earth. In most cases such information has a form of static datasets, which are created once and contain a number of points on the map with descriptions, pictures and sometimes also links to corresponding web sites. The examples here are cultural heritage sites in *New Zealand and Australia* [New], *National Geographic Africa Magaflyover* [Wil] and *National Geographic ZipUSA* features [BB].

There have been also several attempts to integrate Google Earth with databases of cultural resources. In this approach the information from the database is transformed into a special XML file that can be downloaded, read by Google Earth and visualised. The Google Earth version of *UNESCO World Heritage Map* [Uni] is a good example.

Since Google Earth is able to display 3D models on top of the Earth surface, the application can be also used for visualisation of 3D reconstructions of heritage sites, especially those with archaeological or architectural focus. *Google Earth Blog* [Tay] and *Google 3D Warehouse* [Gooa] feature many of such objects grouped into several categories.

The examples presented above, although stimulating, are in fact very limited. Most of them use simple 2D web contents to present the heritage resources, which in practice restricts the presentation to textual descriptions and photographs. The systems that use 3D representation of objects or sites, try to visualize them directly embedded within the 3D GIS system (e.g., in the Google Earth). We argue that such approach is not appropriate or at least not optimal because of several problems:

1. The quality of 3D models that can be currently displayed directly within the GIS platforms is low. Introduction of the last version of Google Earth (4.0) has improved the presentation capabilities [Col], but still this is not enough for faithful representation of digitized museum artefacts or architectural designs.
2. Direct embedding of 3D objects into the GIS platform requires conversion of their digital representations into a system specific format (e.g., KML or COLLADA in case of Google Earth platform). This format cannot be used in other presentations of the contents — either local or on the web.
3. In case of digital representation of artefacts, the paramount problem is related to scale. The artefacts must be represented in a different scale than the geographical information. When looking at objects a user looses the geographical context, when looking at the geographical information, the user cannot see the objects.
4. Another problem is caused by distribution of objects. When the system tries to directly position objects in their origin (or some other related location), the objects are distributed at a large area making it difficult for users to locate the objects, navigate between them, compare objects, etc. As a result, most advantages of 3D virtual museum exhibitions are lost.
5. Presentation capabilities of popular GIS platforms (such as Google Earth) are usually limited to displaying the outside surface of objects, not enabling to visualize interiors. This may be sufficient for simple representation of shapes of buildings, but is not sufficient to represent architectural interiors, e.g. a reconstruction of a museum room. Also, the navigation capabilities are limited, e.g. not enabling to view the object from below.

6. The last — but important — problem is related to interactivity. 3D presentation of museum artefacts enables building interactive scenarios, which have the potential to significantly enrich user experience while learning about the objects or places. This is not possible (at least currently) when the objects are directly embedded within the GIS platform.

To avoid the above mentioned problems and limitations, we have decided to use a different approach. We have integrated ARCO — a system able to build high-quality, interactive, standards-compliant virtual museum exhibitions — with a popular GIS platform (Google Earth), taking the best of the two worlds. ARCO enables interesting and engaging presentation of the digitized contents, while the GIS platform displays, in a user-friendly way, all geographical information related to the digitised collections. These two subsystems can communicate with each other while a user is interacting with the presentation.

3. The ARCO system

3.1. Overview of ARCO

The recently completed European Union funded research project *ARCO — Augmented Representation of Cultural Objects* [ARC] [WCW06] has developed technology for museums to create and manage virtual exhibitions for use on the web and in interactive kiosk displays. The ARCO system comprises simple to use authoring tools, which allow exhibition designers to set up virtual exhibitions in just a few minutes. The exhibitions can be then presented both inside museums, e.g. on touch-screen displays installed inside galleries and at the same time on the Internet. The presentation is based on virtual and augmented reality technologies as an extension of standard web presentations and allows visitors to interact with the contents in an intuitive and exciting manner.

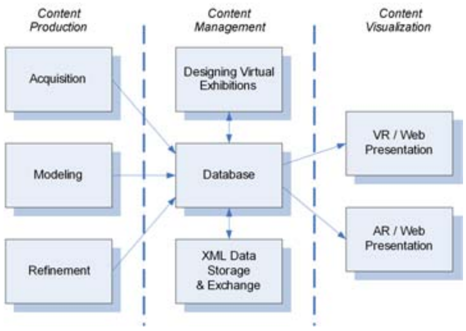

Figure 1: *Overall architecture of the ARCO system*

The overall architecture of the ARCO system is presented in Figure 1. The ARCO system consists of three main architectural components: *content production*, *content management*, and *content visualization*. The content production includes all tools and techniques used to create digital representations of museum artefacts. The digital representations are stored in a database and managed with the *ARCO Content Management Application — ACMA*. Each digitized artefact stored in the database is called a *cultural object*. Each cultural object is represented as a set of *media objects* and associated *metadata*. Examples of media objects are images, movies, 3D VRML/X3D models, QuickTime VR images, descriptions, and sounds. Metadata is structured according to *AMS — ARCO Metadata Schema* [PWM*05].

In addition to managing digitized cultural objects, the ACMA tool enables building interactive virtual exhibitions that present collections of cultural objects retrieved from the database. Using the *ACMA Presentation Manager* a user can build virtual exhibitions by creating exhibition spaces and assigning cultural objects and presentation templates to the spaces. By using advanced presentation templates, interactive presentation scenarios can be built, e.g. implementing learning scenarios associated with the cultural content. Data can also be exported from the ARCO database into an XML data format to move contents between databases and to set-up prearranged exhibitions.

The visualization of the virtual exhibitions may be performed by a standard web browser or a web-based augmented reality (AR) application. The AR application integrates a web browser and an AR browser [KB] allowing presentation of either 2D/3D web contents or AR virtual exhibitions. The classical web browser interface allows users to search and browse the database contents by the use of a well-known interface, whereas the VR and AR exhibitions let them examine virtual reconstructions of selected objects in 3D environments.

The virtual exhibitions displayed in the VR and AR interfaces are dynamically generated based on the database contents — the exhibition spaces, the presentation templates and the cultural object models. The use of different templates enables different presentation of the same content. Different forms of exhibitions can be also achieved by the creation of template instances derived from the same template but supplied with different sets of parameter values. The parameters may affect both the visual and behavioural elements of the exhibitions. The virtual exhibitions can be customized for a particular user or created in response to a user query.

ARCO uses X-VRML for creating parameterized templates of virtual exhibitions [WC02] [WC03]. X-VRML is a high-level XML-based language that adds dynamic modelling capabilities to virtual scene description standards such as VRML and X3D. The dynamic modelling technique enables the development of dynamic database-driven VR applications by building parameterized models (templates) of virtual scenes that constitute the application, and dynamic generation of instances of virtual scenes based on the models, data retrieved from a database, current values of model parameters, input provided by a user, and user privileges or preferences. In ARCO, the X-VRML templates define both the visual and the behavioural aspects of virtual exhibitions. The visualization is performed using standards such as VRML and X3D. For the behavioural aspects, high-level XML scripts are used.

The use of presentation templates enables separation of the processes of preparing contents (the cultural objects), designing the presentation form (the templates), and setting up virtual exhibitions, allowing the latter to be easily performed by users without extensive knowledge in computer science and 3D technologies. All the visualization and interaction rules necessary to build exhibitions are encoded in the templates. An exhibition designer can create an interactive exhibition by simply collecting the object models, setting their visualization and interaction parameters and creating an instance of a presentation template. The process of designing an interactive presentation can be performed by the use of a simple application connected to the database.

3.2. Designing virtual exhibitions

The structure of ARCO virtual exhibitions is determined by a hierarchy of exhibition spaces stored in the database. The exhibition spaces are conceptually similar to folders that may contain three types of elements:

- *presentation template instances*,
- *cultural object instances*, and
- *cultural object selection rules*.

A template instance is a template supplied with actual values of some of its formal parameters. A single template can have an arbitrary number of instances in different exhibition spaces, which provides high flexibility in designing virtual exhibitions because different template instances, which imply different visualization and interaction parameters, can be set for every exhibition space. Flexible assignment of parameter values to template instances makes it possible to easily combine search interfaces, customizable browsing interfaces, and fixed exhibitions.

A cultural object instance is a cultural object together with object's presentation parameter values. Again, the same object may have instances in more than one exhibition space. A cultural object selection rule is a search statement that retrieves from the database all objects that meet criteria defined in the rule. The selection is performed when a user accesses the exhibition space and thus enables building virtual exhibitions that are always up-to-date.

An exhibition designer can provide the template parameters and cultural object parameters while setting up a presentation (see Figure 2). When a user enters an exhibition space, all cultural object instances that are assigned to this particular exhibition space or retrieved by a selection rule are displayed in a way defined by the presentation template instance assigned to the same space.

The same exhibition space may be displayed differently in different environments by the use of different presentation templates. To achieve maximum flexibility with respect to different presentation methods, the concept of presentation domains has been introduced. A presentation domain is the context in which the exhibition is intended to be used (e.g., local web environment, remote web, augmented reality scene, or a GIS system). Each presentation template is associated with a list of allowed presentation domains, but each template instance corresponds to a single domain. In an exhibition space, multiple instances of templates for different domains may be created, but at most one instance for each domain. While accessing an exhibition, the browser specifies which domain should be used. Then, the appropriate instance of the template is used to dynamically produce the contents.

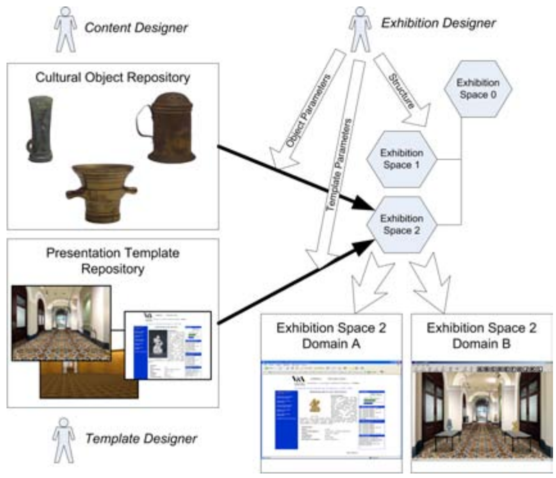

Figure 2: *ARCO — building virtual exhibitions*

In order to speed-up the process of designing exhibitions and to ensure consistency of presentation of objects organized in the exhibition spaces hierarchy, the concept of inheritance of template instances has been introduced. In this approach, if a specific exhibition space does not contain its own template instance in the indicated presentation domain, the instance contained in its parent space is used by default (recursively). This solution enables using a single template instance for the whole tree of spaces in the exhibition hierarchy and thus saving the preparation time and ensuring visual and behavioural consistency of presentation within a virtual exhibition.

4. The GeoARCO system

4.1. Overview and architecture

The GeoARCO system is an extension of ARCO enabling geographical presentation of cultural objects and virtual exhibitions. GeoARCO can be used in the same way as ARCO, but, additionally, the Google Earth client can be used to browse and display the virtual exhibitions in a geographical context.

Google Earth is a free application that allows users to browse aerial photographs of the entire planet. An important feature of this application is that on the top of the aerial photographs it can display other kinds of information, such as image layers, points of interest, lines, texts and even simple 3D models. The elements displayed on the map can contain hyperlinks, which can be opened in an integrated web browser.

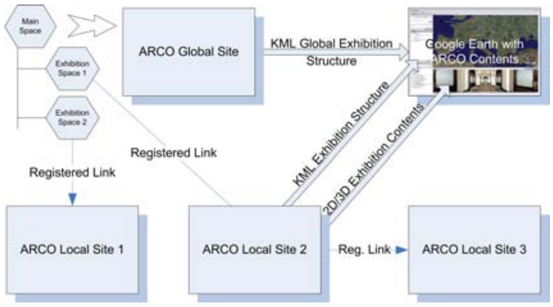

Figure 3: *Architecture of the GeoARCO system*

Figure 3 presents the overall architecture of the GeoARCO system. There are four instances of the ARCO system shown in this example. The instances may be run and maintained by different museums. Exhibition spaces in the GeoARCO system, in addition to the elements described in the previous section, can contain links to exhibitions in other instances of the ARCO system. In such a way, the ARCO instances become interconnected similarly as web servers. The process of linking is performed by an exhibition designer who may include in an exhibition space other spaces available in different museums (i.e., in other instances of ARCO).

The network of ARCO instances is flat in the sense that it does not form a fixed hierarchy. The hierarchy of spaces is dynamically defined by a hierarchy of exhibition spaces in the entry ARCO instance and the connected instances. Depending on the entry point, the same server may be used as a global site or any of the sub-sites in the dynamic hierarchy.

When a user connects to an ARCO site using the Google Earth application, based on the structure of the exhibition spaces, a hierarchy of *Places* is generated and transferred to the application in the KML format [Goo06]. The hierarchy contains the entry space, all subspaces (both local and linked from other ARCO instances) and all objects assigned to the spaces. For each item, the name and basic description are provided. Clicking on an item in the hierarchy, a user can navigate to the item's location on Earth, and display its picture and description together with additional information including links to object's 3D model and object's representations in virtual galleries (either 2D or 3D). The 3D model and virtual galleries can be displayed in the embedded browser (see Section 5).

4.2. Geographical data in ARCO

In order to properly represent geographical data related to cultural objects we have extended the XML schema of metadata used for describing cultural objects (AMS). The additional geographic information includes the coordinates of the object's origin, place where the object is currently located, place where the object has been temporarily moved and other places related to the object.

In addition to the cultural object metadata, coordinates may be also specified in the presentation parameters and assigned to either cultural objects or exhibition spaces. This feature is useful for positioning virtual exhibitions in specific places on the Earth model. Also, in some cases it is useful to position objects around an exhibition regardless their real origin or current location.

The third element that influences geographical presentation of objects and virtual exhibitions is the "belongs-to" relationship. This relationship is specified by adding cultural objects or sub-spaces to exhibition spaces in the ARCO Presentation Manager. The relationship is then represented as connecting lines on the 3D model of Earth (see Section 5).

4.3. Dynamic KML

As indicated in the Section 4.1, in GeoARCO, the Google Earth application is controlled by the use of dynamically generated KML contents. KML is a language based on XML, which allows users to define what information and how is to be presented on top of the Earth model. The GeoARCO KML descriptions are generated based on the structure of exhibition spaces and cultural objects stored in the ARCO databases.

In Figure 4, an example of a KML description of an exhibition space generated by the GeoARCO system is presented. The generated KML file contains a *Folder* node, which represents an exhibition space in the ARCO system. The *Folder* node can contain a number of *Placemark* nodes. A placemark in Google Earth is represented as an icon with a label positioned at some specific coordinates on the globe. Additional description can be attached to a placemark. In GeoARCO, the first *Placemark* represents the exhibition space itself. The remaining *Placemark* nodes represent cultural objects assigned to the exhibition space. There is one *Placemark* corresponding to a cultural object in the presented example.

Sub-spaces are represented by the *NetworkLink* nodes. A network link enables inclusion of any other KML file in the current KML file. This approach has two important advantages. Firstly, it enables to easily reflect the recursive nature

```
<kml xmlns="http://earth.google.com/kml/2.1">
  <Folder>
    <Placemark>
        <name>Art in Western Poland</name>
        <description>...</description>
        <Point>
            <coordinates>16.83688,53.05467,0</coordinates>
        </Point>
    </Placemark>
    <Placemark>
      <name>Woman with butter churn</name>
      <description>...</description>
      <Point>
        <coordinates>16.97409,51.76316,0</coordinates>
      </Point>
    </Placemark>
    <NetworkLink>
      <name>Art in Western Poland</name>
      <visibility>1</visibility>
      <Url>
        <href>http://...</href>
        <refreshMode>onInterval</refreshMode>
        <refreshInterval>60</refreshInterval>
      </Url>
    </NetworkLink>
    ...
  </Folder>
</kml>
```

Figure 4: *Example of a KML specification*

of the exhibition spaces hierarchy in the KML files. Secondly, network links enable automatic refreshing. Therefore, any changes made in the ARCO database can be automatically reflected in the Google Earth application in a short time.

To enable automatic generation of KML contents an appropriate X-VRML template has been developed. The template is assigned to a special presentation domain. The template retrieves objects and sub-spaces assigned to an exhibition space, extracts their position information and displays them in the proper places on the globe. This template may have instances in all exhibition spaces along with 2D or 3D presentation templates assigned to other domains such as WEB_LOCAL, WEB_REMOTE, AR, etc. Due to inheritance of template instances (see Section 3.2) a single template instance may be used throughout the whole hierarchy of exhibition spaces.

Figure 5 shows a fragment of the X-VRML template that is used to generate the KML description. The template consists of KML and X-VRML commands (X-VRML commands are highlighted in bold). The fragment contains a loop that retrieves the names and assembles the URL addresses of all sub-spaces of the current space and inserts them in the KML code in appropriate places. The refresh interval is a parameter that can be set once for the whole template.

```
...
<For name="i" from="0" to="{sizeOf(@lSubSpaces)-1}">
  <Set name="currSpaceId" value="{@lSubSpaces[$i]}"/>
  <Set name="spPath" value="{@aPath}domain={@domain}..."/>
  <ARCO_AFProps afId="{$currSpaceId}" propName="SPACE_NAME"
    varName="spaceName"/>
  <NetworkLink>
    <name><Insert value="{@spaceName}"/></name>
    <description/>
    <visibility>1</visibility>
    <Url>
      <href><Insert value="{@spPath}"/></href>
      <refreshMode>onInterval</refreshMode>
      <refreshInterval>
        <Insert value="{@refreshInterval}"/>
      </refreshInterval>
    </Url>
  </NetworkLink>
</For>
...
```

Figure 5: *A fragment of X-VRML template for KML*

4.4. Schemes of interaction

Several schemes of user interaction can be implemented in the system depending on the templates used for generating the KML contents, objects' descriptions, and 2D/3D virtual exhibitions.

The basic form of interaction is when a user requests detailed information about a cultural object found in the Google Earth — either selected in the exhibition space hierarchy or on the map. The possible choices are: presentation of a 3D model of the object in the embedded browser, presentation of object's description in the embedded browser, presentation of a 3D gallery with focus set on the cultural object, and presentation of the object in the AR browser — launched as a separate application.

When a user selects the whole virtual exhibition — either in the exhibition hierarchy or on the map — the system may display the exhibition in 3D, in 2D or use it as contents for the external AR browser.

A user may also request geographical information about an object when browsing a 2D or 3D virtual gallery generated by ARCO. Using links accessible in the galleries a user may select presentation of any geographical information recorded for the object in the AMS metadata, e.g. indicate origin or current location of the object.

5. Examples of presentations

Several examples of the use of GeoARCO are presented in this section. In Figure 6, a simple presentation with three gallery spaces and four cultural objects is presented. The left side of the Google Earth application contains a panel that displays the exhibition hierarchy. On the map side, virtual exhibitions and objects are displayed. Exhibition spaces are marked with a house icon, while cultural objects with a flag icon. The cultural objects are positioned on the map in their places of origin. There is also an information window (displayed as a tooltip) for each cultural object with object's description, picture and links to the 2D/3D presentations of the object and a 3D gallery containing the object.

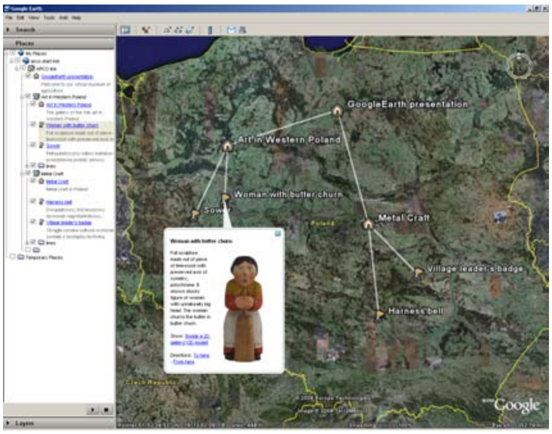

Figure 6: *Presentation of virtual exhibition spaces and objects on a map*

Figure 7 illustrates the case when a user requests detailed information about an object. In response, a 2D web page — dynamically generated based on a 2D presentation template — is displayed in the embedded browser. The page contains high quality picture of the object, full description, and selection of metadata elements. On this page a user has also access to all multimedia objects associated with the cultural object, e.g. movies, 3D models, pictures and sounds.

Figure 7: *Displaying information about a selected object*

In Figure 8, a presentation of a 3D model of the object is illustrated. The 3D model is displayed in the embedded browser on the right side. A user can freely manipulate the model to see it from all directions.

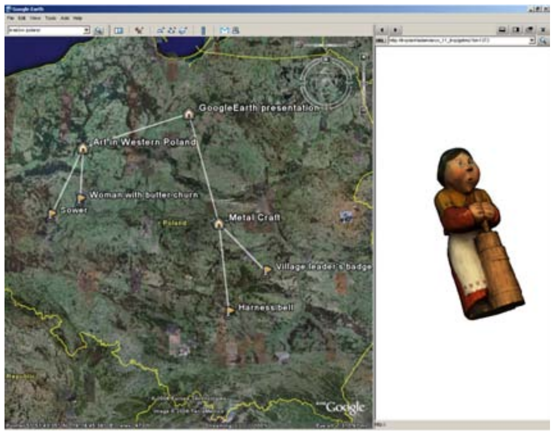

Figure 8: *Displaying a 3D model of a selected object*

In Figure 9, a complete 3D gallery containing two cultural objects is presented. The gallery is dynamically generated based on a 3D presentation template. The gallery is designed to allow users to navigate between the objects and manipulate their 3D models and display objects' metadata.

Figure 9: *Displaying a 3D virtual exhibition*

6. Conclusions and future works

The GeoARCO system presented in this paper enables museums to create high-quality, interactive virtual exhibitions that can be presented in the appropriate geographical context, thus considerably increasing their educational value. Users may browse the digital representation of the globe in the Google Earth system at the same time learning about the cultural heritage of particular regions. Users may also browse virtual galleries generated by the ARCO system and learn about origins or current locations of objects in the GIS presentation. By integrating the two advanced presentation platforms into a single interactive system, we have reached a new level of usability, that outperforms other solutions available today.

Important feature of the system is that 2D/3D cultural object representations and virtual galleries are built based on open standards and therefore can be used in other presentation modes (web, local kiosk, etc.). ARCO uses non-expensive hardware and software solutions. Even small museums with limited financial resources can afford the system. Also, the Google Earth platform is offered for free (basic version), making it accessible to all users.

We continue to develop the GeoARCO system. Future works include development of more advanced virtual exhibition templates enabling richer interaction with the Google Earth platform. Also, the KML templates may be extended to support geographical selection of objects and virtual galleries. Possibility to directly position objects on the Earth model would be desirable to simplify the use of the system. Based on the COLLADA description standard available in the newest version of the Google Earth system, we plan to build more advanced presentation elements that could be placed on the Earth model.

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