AN INFORMATION SYSTEM FOR THE INTEGRATION, MANAGEMENT AND VISUALIZATION OF 3D REALITY BASED ARCHAEOLOGICAL MODELS FROM DIFFERENT OPERATORS

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ABSTRACT:

This paper describes a web-based information system designed with the aim to make available on a 3D GIS platform reality-based 3D models representing archaeological finds at an architectural scale. In wide and complex archaeological sites, different artifacts need to be modeled by different operators, using different methodologies and technologies, working in different places and times, so that the methods to build them need to be defined a-priori, widely shared and verified a-posteriori. This is the reason why it is necessary to work for the definition of widely shared standards and for a long-term preservation of 3D cultural heritage data related to archaeological sites. In order to meet these requirements, our application has been carried out using open source technologies and tools, widespread multi-platforms and standards. Entirely founded on the ICCD (Istituto Centrale per il Catalogo e la Documentazione) standards, our information system has been designed to guarantee interoperability and lead the cataloguer in data entry by simplifying and making the procedures more intuitive. Moreover, 3D modeling from real-world data is not a standardized procedure: survey and modeling methods strictly depend on the characteristics of the object, on the available technologies and on communicative aims. Our system is a purpose for solving the problem of the definition of the most appropriate methodology to adopt depending on the object and on the level of detail of its representation. The digital models of the finds are then linked to their related heterogeneous information using a semantic fragmentation and organization of elements and data.

1. INTRODUCTION

In the last years, the availability of digital instruments and the development of three dimensional digital modeling tools applied in the field of Cultural Heritage is improving the quality of digital representations and offering new possibilities in the analysis and comparison of artworks.

In this field, the introduction of the third dimension aimed at storing and managing documentation about 3D objects, offers a more intuitive way to access and manage different kinds of information. Despite this improvement, the huge quantity of heterogeneous data, gathered using different tools, is nowadays still increasing. Moreover, the lack of widely shared standards prevents the interchange of information and, as a consequence, often frustrates efforts spent towards the increasing of the quality of digital surveying and representation.

In this scenario we developed a web-based information system designed to make available on a 3D GIS platform reality-based 3D models representing archaeological finds at an architectural scale.

The digital models were conceived to be displayed in real-time with high-quality rendering and to become instruments that allow to manage, work, study and promote tourism. The models were acquired and manipulated using different techniques and digital instruments (3D laser scanners and photogrammetry).

Our case study is the Pompeii archaeological area, since our application and its framework are part of the Pompeii Information System carried out with the Pompeii project financed by ARCUS S.p.a., developed by the Scuola Normale Superiore of Pisa (SNS) together with the University of Bologna, the Special Superintendence for Archaeological heritage of Naples and Pompeii (SSBANP) and implemented by Liberologico S.r.l.

The Pompeii area is a wide and complex site, with different artefacts that are generally surveyed and modelled by different operators, working in different places and times, using different acquisition and representation techniques.

The use of different methodologies and standards doesn't facilitate the integration and interchange of information, cross analysis of data and the broadening of knowledge.

In order to address these problems, we proposed a solution that helps to collect and record the 3D models of the finds, verifying both the fidelity with accurate pre-defined quality metric standards and the responsiveness with the cataloguing and technical specifications of the Pompeii Information System (IS). This IS migrates into one platform different resources (texts, 2D and 3D images, audio and video documents, geographic information) which were previoulsy stored in various repositories and that are related to the Pompeii site and the area around Mount Vesuvius.

The application is entirely based on ICCD (Istituto Centrale per il Catalogo e la Documentazione) standards; it has been carried out using open-source technologies and widespread multi-platforms in order to guarantee interoperability and lead the cataloguer in data entry by simplifying and making the filling of the ministerial forms more intuitive.

In addition, the main system helps in the definition of the most appropriate methodology to adopt depending on the object to document and on the level of detail of its representation: the 3D

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modeling phase leads to the creation of master models that rebuild the geometry and the texturing characteristics of the find within the pre-defined metric and qualitative requirements.

Through its robust organization our system also allows:

- data entry by different cataloguers;
- qualification of 3D models in relation to the different LODs;
- quality check of data against the provided technical specifications;
- high resolution real-time visualization of models and their visual location on Google Maps;
- geo-referencing of 3D models according the Pompeii Information System geo-referencing system;
- direct input into the whole 3D GIS.

This contribution is organized as follows. It firstly briefly introduces the problem (section 1) and the related works (section 2), then it describes the design and organization of the main information system (section 3), of our integrated framework and web application (section 4), while the use of semantic digital 3D models as a common denominator between heterogeneous information and the representation of the finds is presented in section 5. In section 6 we present our conclusions and further development projects.

2. RELATED WORKS

The organization and exploration of large data sets is an important and difficult problem that can be handled using different information visualization techniques. Visual data mining and exploration have a high potential and can improve data analysis. The first example of techniques and applications in visual data exploration have been described in Keim et al. (1996). Visual data mining integrates data visualization and data mining and is closely related to computer graphics and multimedia systems (Viktor and Paquet, 2008). Although its great potentialities, the widespread adoption and use of this technology is still not easy to achieve, mainly because the results of data mining techniques are often difficult to understand.

In the last decades, the subject of data integration and combination of multiple techniques in order to allow comparative studies, virtual model documentation and visualization aimed to manage cultural heritage has been deeply investigated.

El-Hakim et al. (2005) presented a methodological approach to the fusion of different acquiring and modeling techniques using the level of detail (LOD) concept as a basis for the visualization of complex models.

An interesting example of management of multi-scale representations and their links with patrimonial information has been tested on the historical centre of Kraków and has been illustrated by Blaise et al. (2003).

While in the 1990s visualizations of archaeological sites mainly meant 3D modeling for museum presentations, nowadays photorealistic displays are also considered effective and intuitive interfaces that allow accesses to different kinds of information recorded on databases. An example of archaeological landscape exploration through VRML visualizations and access to different information was given by Gillings and Goodrich (1996). Their application was developed to make the archaeological information available on-line.

During those years, J. D. Richards (1998) provided an interesting overview on the subject of cultural heritage data management using databases.

Recently Meyer et al. (2007), while retracing the improvements of Geographical Information Systems and their important role in the relationship between GIS (which mainly have landscape applications) and Information Systems, developed an application in order to manage different types of data collected by the Service of the National Sites and Monuments of Luxemburg. Based on a web server infrastructure, this Information System allows intuitive and easy accessibility for all users and the independence from proprietary software.

Also De Luca et al. (2007) have recently developed an application that allows comparative studies starting from heterogeneous data and models using a simple and intuitive web-based interface. In this case the multiple representations of architecture buildings and their associated information have been organized around semantic models.

The organization of knowledge starting from a semantic subdivision and organization of elements and shapes, follows the shape grammar concept introduced by Stiny and Mitchell (1978) and Stiny (1975, 1980).

The first example of 3D modeling and semantic classification applied to architectural shapes was presented in Quintrand et al. (1985). Afterwards many researches concentrated on the development of classifications of architectural elements in theoretical frameworks (Tzonis and Lafaivre, 1986) and in applications of geometrical modeling (Gaiani, 1999). Recently Attene et al. (2007) developed the ShapeAnnotator, a modular system to load 3D triangular surface meshes, select the most suitable primitives to approximate sets of triangles in clusters that define the shape parts that constitute the entire model. The sub-elements can be automatically annotated in a database.

Semantic classification has also been recently used for procedural modeling of architectures (Wonka et al., 2003) and city modeling applications (Parish and Müller, 2001; Emgard and Zlatanova, 2008). These applications of procedural approaches at different scales have been taken up by Müller et al. (2006) in order to combine these two concepts to generate large and detailed urban environments using shape grammars.

These examples show the variety of problems related to visualization and data management of archaeological sites.

Our contribution has been conceived to lead scholars and cataloguers during the acquiring and modeling phases and to afford an easy tool to manage data following ministerial standards and using widespread technologies in order to spread information and knowledge.

3. THE MAIN INFORMATION SYSTEM

The Pompeii Information System has been designed and developed by SNS in collaboration with Sistemi Informativi S.r.l. Liberologico during the years 2005-2008. It is currently maintained by the SIAV (Archaeological Information System for the Geographic Area of Mount Vesuvius), an internal office of the SSBANP, and will be used both for internal purposes (cataloguing, documentation, preservation, management of archaeological heritage) and for external communication through the web portal "Vesuvian Archaeology", which is currently under development.

3.1 Contents and requirements of the system

When the project started, the main objective was to develop a web-based system using Open Source software and respecting national and international standards, capable of managing in one interoperable platform different kinds of resources pertaining to the archaeological patrimony disseminated in the

area around Mount Vesuvius, comprehending Pompeii, Herculaneum, Stabiae, Oplontis, Boscoreale and other sites.

Such resources that already were in possession of the SIAV included text, 2D and 3D images, geographic information, audio and video documents. They were previously managed by different proprietary software and were not interoperable.

Those pre-existing resources can be divided into three main categories:

- cataloguing charts, resulting from various cataloguing campaigns conducted by the SSBANP during the last twenty years. They mainly describe archaeological objects (such as paintings and mosaics) and monuments (public buildings and private houses). These charts are structured according to the Italian standard cataloguing schemes of ICCD or with schemes specially designed by the SSBANP for describing its peculiar heritage;
- geographic information: the SSBANP owned three different GIS based on the same cartographic plan (the so called R.I.C.A. map), containing various themes and related databases for the organization of different information;
- other digital resources, such as digitised images (mainly drawings and photographs of archaeological finds); charts and related digitised texts pertaining to the excavation diaries and reports by the archaeologists, etc.

Along with these already existing contents, the analysis identified a huge quantity of digital contents to be integrated in the system, resulting from various researches conducted by public and private Bodies in accord with the SSBANP, or to be created in the future.

The requirements of the system have been specified as follows:

- scalability and modularity of the system architecture, for guaranteeing durability;
- possibility of supporting various file formats;
- ability of representing complex relations between resources;
- adoption of national and international standards, to allow interoperability of resources into the system and with external systems;
- use of open source software, to permit the management and maintenance of the system during the time;
- development of a web-based system, which allows data implementation and consultation by users dislocated in various geographic places. This requirement also implies the development of an appropriate users' rights management and of an efficient workflow.

3.2 Description of the system

The system integrates the following applications:

- a cataloguing application allowing both data-entry and displaying of cataloguing charts. This application is capable of importing and exporting data in TRC text format defined by ICCD. Moreover, it can use different metadata schemas in order to support future versions of the ICCD existing schemas and other schemas that can be designed for specific kinds of resources. The application serves also for the storage of digital contents (images, video, audio, etc.) that can be updated and linked to the "multimedia entity" charts in different formats;
- a GIS application for the import, storage, organization and displaying of geographic data that can be updated using ESRI shapefile format, which guarantees the interoperability among data created using different software. GIS is strictly connected with the cataloguing application, so that geo-referenced charts can be displayed on the map;
- an OAI repository, which allows the metadata harvesting of the cataloguing charts using OAI-PMH (Open Archives Initiative–Protocol for Metadata Harvesting). Data are generated on the fly and archived in the repository after the automatic mapping of the adopted schemas into Simple Dublin Core standard and into the PICO Application Profile metadata schema, which further refines Qualified Dublin Core, developed for CulturaItalia ministerial web-portal (www.culturaitalia.it).

The system groups the authenticated users into "projects". Each user can be associated to one or more projects, and owns different "levels" (set of user rights) depending to the project.

The system interface is divided into:

- the administration area: here it is possible to create and modify users, projects and levels, and to import and export data into and from the Catalogue and the GIS;
- the search and browse area: comprehending simple search (google-like search); advanced search (cross-search through various kinds of charts); search by field (into a single kind of chart); indexes (browsing for each kind of chart) and GIS consultation (by themes);
- the data-entry area: here user can entry data into the catalogue which, according to ICCD standard, is divided into "cataloguing charts" (describing archaeological objects, monuments, sites, etc.); "authority files" (describing bibliography and authors related to the catalogued heritage) and "multimedia entity charts" (describing various kinds of digital contents, that can be updated into the system and linked to multimedia entities).
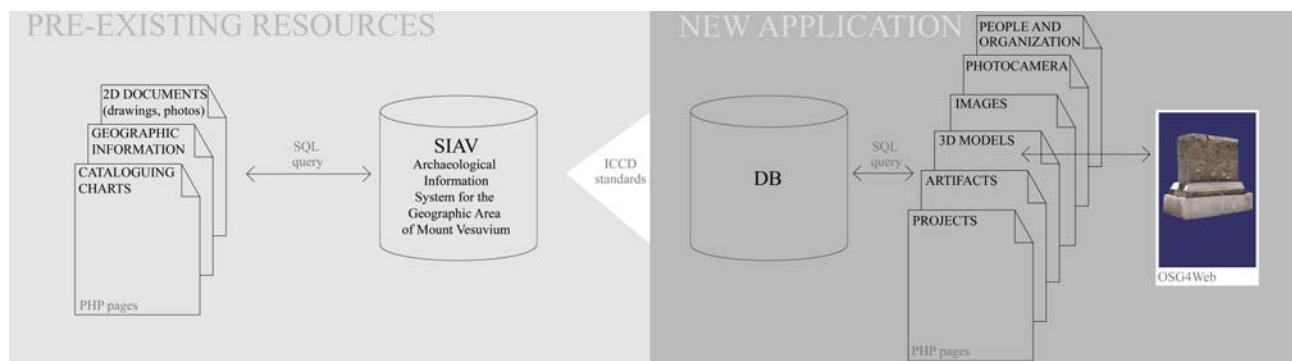

Figure 1. Relationship between the main Information System of the SAP and the new application.

3.3 System architecture

The Pompeii Information System exposes an XHTML interface compliant to the W3C's WCAG standard and has been developed using JAVA technology: Google Web Toolkit has been adopted to simplify the deployment of AJAX features.

The architecture of the system has been designed as a composition of different modules for specific features: data managing, query functionalities, XML import and export of data, repository management, data presentation and communication.

The Apache Tomcat servlet container and the MySQL DBMS have been used during development and testing stages, although virtually any J2EE container and any SQL-compliant DBMS could be employed.

Geographic information is managed through the open-source server GeoServer, certified by the Open Geospatial Consortium (OCG). The web application exposing the map data uses the open source OpenLayers JavaScript library.

Finally, the OAICat open-source software have been added in order to integrate in the System a repository framework allowing the metadata harvesting using OAI-PMH.

4. THE DEVELOPED APPLICATION

4.1 Conception and organization of the Web application

Our application has been designed considering the following fundamental prerequisites:

- the scalability and modularity of the architecture of the information system, in order to guarantee its long term preservation;
- the support of various standardized formats (for 2D and 3D files), in order to guarantee data integration;
- the simplifying of the management of complex connections between different kinds of data;
- the use of national cataloguing standards, in order to guarantee the interoperability within the system and with other applications;
- the use of open-source visualization software, in order to guarantee long term system management.

Moreover, considerations about data entry by different cataloging operators and about the visualization of information by different users led to the design of an information system which is based upon:

- a web interface, in order to allow a direct access to data regardless of the user location;
- the support in the filling of the ministerial forms following the ICCD standards adopted by the SAP;
- the geo-referencing of 3D models according to different coordinate systems;
- the simplification of the representation of data, in order to allow on-line access to the system;
- the export of data according to TRC standard (defined within the ICCD standard), in order to synchronize all operations with the cataloguing system of the SAP;
- the management of accesses, in order to provide different access privileges according to the kind of information or the different users.

The system manages data entry and visualization using the same interface. This organization leads to an immediate preview of the final display and therefore facilitates data entry.

During the cataloguing phase, the system can automatically execute repetitive tasks, such as the creation of RAW format images and thumbnails, starting from any image format.

The possibility of automatically extracting information from the EXIF field associated to digital images, allows to automatically fill the most of the fields associated to each data sheet linked to single photographs.

4.2 Technological implementation

The application is based upon open-source technologies that guarantee:

- a better long term preservation and management of data;
- the possibility to use different hardware platforms and operating system;
- low costs.

In detail, these technologies are:

- web pages programming using PHP language (www.php.net);
- database implemented by MySQL (www.mysql.com);
- DCRAW (http://cybercom.net/~dcoffin/dcraw) for the creation of RAW format photographs;
- IMAGEMAGICK (www.imagemagick.org) for the conversion of images between different formats;
- EXIFTOOL (www.sno.phy.queensu.ca/~phil/exiftool/) for the automatic extraction of EXIF tags from photographs;
- OSG4WEB (http://3d.cineca.it/storage/demo_vrome_ajax/osg4web.html) a plug-in for Mozilla Firefox and Internet Explorer that allows the visualization of 3D models.

The system can run on any web server supporting PHP and MySQL. The other above mentioned tools are optional and have been used in order to facilitate the cataloging of images.

4.2.1 Data cataloging: As already mentioned above, data entry and display use the same interface. The system manages different users (project managers, editors and simple guests) that have different reading/writing privileges. In order to simplify and make data entry more intuitive, the system provides either pull down menus or lists of pre-formatted values. These tools use AJAX to allow different database queries using the same interface that is used during the data entry phase.

As far as the cataloging process is concerned, the system requires that all data are entered using a dedicated folder on a server via FTP, or via a local network. If compared to data entry using a single file upload through the web browser, this approach allows the contemporary record of huge amount of files. This is particularly useful for the upload of heavy files such as 3D models and high resolution images. During data entry, the system can automatically provide the organization of files storing them in the final pre-defined folders.

Each archaeological find is linked to a data sheet that contains an image that represents it. In order to simplify the location and the recognition of the finds, each model is geo-referenced within GoogleMaps, using a graphic interface that sets the location simply clicking inside the satellite map of the archaeological site (Figure 2).

Beyond the geographical location of the finds on GoogleMaps, each model can be geo-referenced using different coordinate systems, such as UTM or Gauss-Boaga.

The data sheet of each find is single for each object and it can be shared between different surveying campaigns. The sheet is linked to all available data and documentation formats such as images, 3D models, textures, etc.

During the entry phase, the system can automatically create RAW format files (using DCRAW) and thumbnails using JPG format (using ImageMagick).
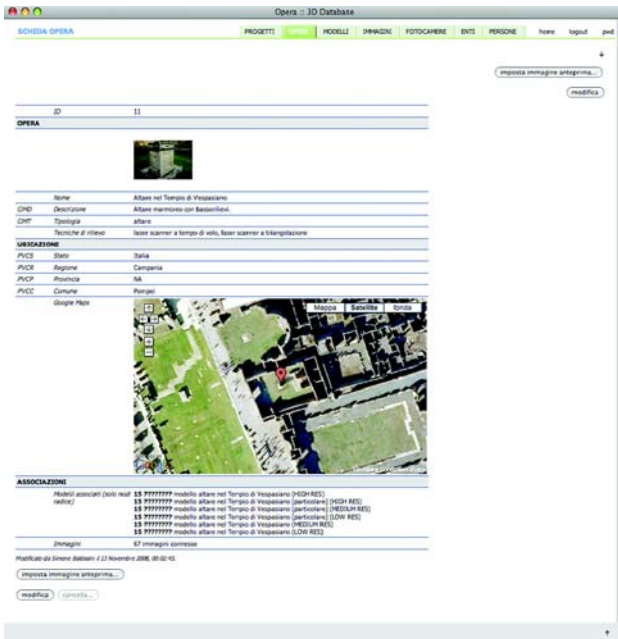
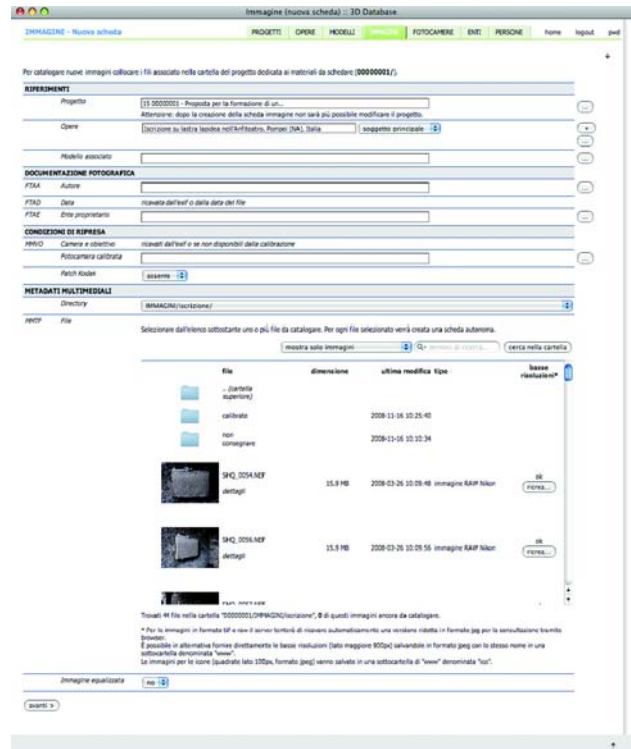Figure 2. Geo-referencing of a find within GoogleMaps.

Figure 3. Visualization of a cataloguing sheet that allows to automatically collect information about the photographs, fill the most of the fields and that automatically records the image files in different pre-defined folders.

Through the extraction of EXIF tags (using ExifTools), the system can automatically fill the most of the fields (such as the model of the camera, shooting date/time, dimensions, resolution, color space, orientation, etc.).

In order to speed the cataloguing of huge amounts of photographs, the application can automatically entry data inside folders, specifying a set of common fields only once (such as the author, the target, etc.) and automatically varying other values following the EXIF one.

This operation allows to quickly enter large amounts of data (as, for example, the surveying data used for photogrammetric modeling). Each image sheet can report the calibration data that are necessary for photogrammetric modeling (Figure 3).

The format of the 3D models that has been used within our information system is the OpenSceneGraph (www.openscenegraph.org), an open-source standard based upon OpenGL, that can be used on multiple platforms and that uses the most recent potentiality of video cards.

The entered data can be exported following the TRC standard, which is a UTF8 text format. Within these kinds of file, the first six characters of each raw represent the identifying name of the single field, followed by the colon (:) and by its value. This file allows the data to be recorded in the main information system of the SAP.

4.2.2   Data visualization: It is possible to access data using a web browser. Our system can allow both non authenticated access to public information and authenticated access to restricted area using a user-name and a password.

The visualization system is organized in different sections:
-    Projects: list of all different surveying campaigns;
-    Artifacts: list of all catalogued finds;
-    Models: list of all 3D models;
-    Images: list of all images;
-    Photo-cameras: list of all calibrated cameras used for photogrammetric surveying;
-    People and organization: list of all people and organization having different roles within the surveying and cataloguing processes.

These sections are inter-connected, so that it is possible to move from one section to another using the hyperlinks that connect the different areas.

Within each area it is possible to execute free searches in each field.

The 3D models (available in OpenSceneGraph format) can be displayed using a web browser plug-in, OSG4Web, which has been developed by CINECA (Inter University Consortium) and is still under optimization.

Within the browser window, the system shows a 3D viewer that integrates all OSG functions, such as the management of complex textures, normal mapping and levels of detail (Figure 4).
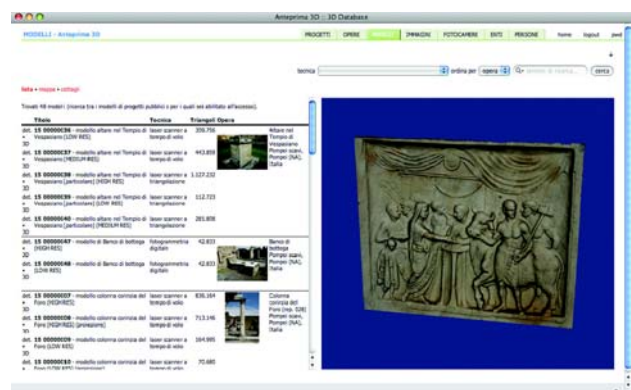

Figure 4. Visualization of 3D models (available in OpenSceneGraph format) using the OSG4Web plug-in developed by CINECA (Inter University Consortium) within the web browser.

4.2.3 3D data organization: Another aspect that characterizes our application is the organization of data and their link with the 3D models of the finds.

Within our information system, each 3D model is semantically segmented (Section 5).

This organization corresponds to the fragmentation of the find into different sub-elements. Each single sub-element can be considered as a node, which is linked to a file that can be stored separately from the other ones belonging to the same find.

Without needing a 3D file interpretation, the data-base can re-build the nodes frame and access to sub-nodes or to the entire 3D model (Figure 5).

Figure 5. Semantic fragmentation of a 3D model of a find and organization and naming of its sub-elements. Each sub-element corresponds to a single node and its linked file within the database. On the right, the node organization within the information system interface. Each row is a hyperlink that connects the sub-elements to its data sheets; on the left, the fragmentation of the 3D model and the organization of the sub-elements in groups within the modeling interface.

5. SEMANTIC 3D MODELING

An archaeological find is generally a complex artefact that can be analysed by recognizing different sub-elements that constitute it. These elements can be isolated in order to allow comparisons, cross analysis of data and to decide whether a find is constituted by original pieces or some of their sub-elements belong to other finds and should therefore be re-located.

To associate semantic to an archaeological find requires to regard the artefact as a system of knowledge. Consequently, to document an archaeological find in an exhaustive way it is particularly important to take into account the description of each sub-element.

Semantic classification becomes therefore necessary in order to organize huge amount of documentation and to provide connections between models and data.

The recognition of sub-elements corresponds with the segmentation of the 3D model of the find.

This operation requires the support of archaeologists and architects in order to recognize transitions between different elements that constitute the find. For this reason, the segmentation of the finds is not an automated procedure.

The semantic classification leads to the identification of classical orders, building functions and materials.

The naming of each single sub-element and of the classes in which they can be grouped is an important phase that strictly depends on archaeological and architectural widely shared interpretations.

Considering that each single sub-element has to be analysed regardless of its context, the name can be derived from classical orders only if specific morphological analysis can be led; in other cases the name should suggest the function or the material that constitutes it, as well as extra information, such as geo-location and numbering that uniquely indicate a single element within the entire set of finds, in order to allow more general and versatile interpretations (Figure 6).

6. CONCLUSIONS AND FUTURE WORKS

Our approach aims to facilitate the integration of various kinds of information collected by different operators and scholars in the field of Cultural Heritage in different time and locations. These requirements has led to the use of widely shared standards (as, for example, the ICCD standards), the definition of the quality of the information depending on the level of detail of the representation (described in a manual of digital survey and modeling standards and illustrated through a series of high definition reality based 3D models as examples of all topological cases that can be found in the Pompeii area) and the continuous check of the correspondence between the data and the provided technical specifications.

Our application is based upon open-source technologies, uses wide spread formats and has an intuitive interface that leads the cataloguer during data entry.

Most of the repetitive processes that don't need the intervention of an operator are completely automated, in order to speed them and avoid errors or defects.

The originality of our application comes from its high usability, robustness and low costs.

Future developments could be singled out in the definition of different visualization conditions, such as the real-time display of the 3D model of the entire find and the contemporary identification of its sub-elements within the same interface.

This possibility could allow a direct access to the information related to the single sub-elements starting from the entire model of the find and vice-versa.

Another possible development of our application could concern the definition of standards for the use of graphic materials (3D models and images) processed before the quality standards singled out within our application.

Even if 3D models and images collected before the widespread of accurate digital instruments (laser scanners, photogrammetric technologies and high definition cameras) generally offer a low metric accuracy, in some cases they could be useful to document the evolution of an archaeological site through time and could moreover be used for simple visualizations at certain pre-defined levels of detail.

FIND 243-252 — FIND NAMING: code

ENTABLATURE A 1 — Naming of MORPHOLOGICAL ENTITY:
1. classical order or building function or building material
2. site placement
3. progressive numbering

cornice

architrave

COLUMN A 1

abacus

capital

Naming of SINGLE ELEMENT:
1. classical order or building function or building material
2. site placement
3. progressive numbering

rocchio 2

THERMOPOLIUM

node organization

| COATING | DOLIUM M. | DOLIUM M. | COATING | FILLING | FILLING | FILLING | BASE |

Figure 6. Top, fragmentation and naming of sub-elements following rules derived from classical orders. Bottom, reconstruction of non visible elements that constitute a find.

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