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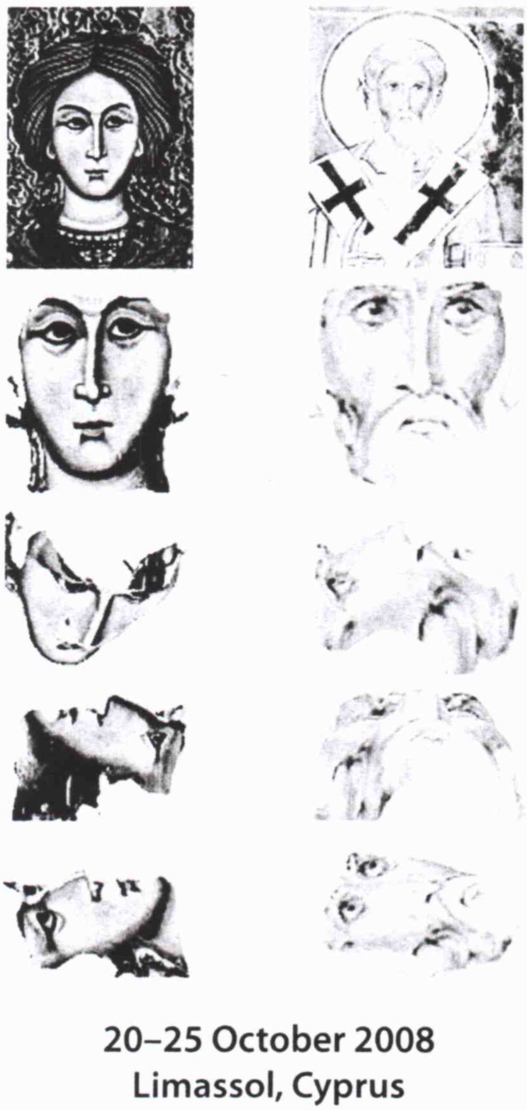

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SHARING 3D ARCHAEOLOGICAL DATA: TOOLS AND SEMANTIC APPROACHES

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ABSTRACT:

Archaeological documentation is the core process of archeological investigation on the field. Digital evolution has dramatically increased the quality and quantity of archaeological documentation, as far as digital photos and drawings produced with CAD techniques are concerned. Composite computational information systems using different platforms, software and, mainly, conceptual data representations have been implemented to manage this great quantity of information.
The availability of new technologies for 3D data acquisition is modifying the paradigm of 3D objects and consequently the work in the field; in particular, the LaserScanner 3D tool is able to gather and store information on the geometry and features of the scanned objects. In the archaeological domain, researchers are experimenting the application of this new equipment to provide complete documentation of ancient monuments (walls, buildings, caves, etc.). Recently archaeologists have started using LaserScanner 3D to survey the archaeological excavation. The availability of LaserScanner 3D during investigation in the field raises many issues: firstly, how to manage the processing of the point-clouds (Paradata); secondly, how to distribute any kind of 3D document for further analysis and research (Metadata); finally how to share this knowledge using modern tools which exploit the Semantic Web (Ontologies).
The paper deals with these issues and gives an overview on the future perspective of the archeological documentation, integrating new software like Adobe Acrobat 3D with ontological representation as CIDOC-CRM for the structured and unstructured texts and GML (with some adaptations) for the management of spatial and geographical documents.

1. INTRODUCTION

For some time, in order to check the effectiveness and efficiency of 3D acquisition tools during excavation, CISA of the University L'Orientale of Naples has been experimenting with the LaserScanner to gather 3D archaeological documentation. The tests aim at outlining the scenarios which concern the applicability of a highly precise and analytical instrument to the stratigraphical method.

Experiences carried out so far regard the creation of three-dimensional models of archaeological excavations or urban and territorial investigations. These are dealt with tests which include problems of graphical acquisition and rendering: from stratigraphical explorations to surface reconstructions, from simple architectonic survey to complex monuments.

The research program is based on the definition of a methodological pipeline specifically for digital surveying (architectonic, structural, of the surface, of the findings) which can be integrated with data gathered by others specialists.

3D LaserScanner has been utilized for the rapid creation of highly accurate geometric surveys. In some cases, the survey of archaeological structures was possible only through the employment of laser scanning technologies: resorting to traditional techniques would have required long acquisition times and less precision.

Up to now, our experimentation has concentrated on the reconstruction of geometries and surfaces, allowing us to read and analyze the models and to create views, plans and sections. Besides the models are navigable at 360°, offering views that would not otherwise be possible to see. They also constitute valuable documentation of the archaeological object, which can be useful during the phase of geometric and material definition of the artifact, as well as in the preservation, monitoring and possible restoration phases.

The 3D LaserScanner, although it requires a long learning curve and currently has still elevated costs, is a technology which in the near future will be employed more extensively to document and study archaeological contexts.

The "technological" migration from an indirect digital survey that is completely unconnected from the interpretation of the remains raises two problems. The first concerns the competence and training of those who work in this field. The second concerns the need to guarantee homogeneity in the production and management of the geometrical information acquired, as far as the type of file produced (open and/or proprietary formats), the creation of the model (Paradata), and finally accessibility and reuse of the models (Metadata) are concerned.

Based on experience gathered in the field, this contribution intends to highlight certain trends in application, while pointing out the areas of "distress", which are particularly evident in the standardization of the procedures, therefore in the accessibility of the three-dimensional models.

Only an adequate circulation of these innovative digital sources can effectively favor the exploitation of informatics and its products. Already there are many experiences leading in this direction, aiming to define standards in order to guarantee the transparency of the 3D models, therefore their reproducibility.

After a brief introduction on the role of graphical documentation in the stratigraphical investigations and the synthetic description of a few case studies, this contribution will highlight the role that certain software assumes in scenarios of interoperability and reuse, software like Adobe Acrobat 3D, able to "enclose" the 3D models within normal PDF documents or modeling language for geographic systems, in particular GML and an adapted version of it called CityGML.

2. DOCUMENTING THE EXCAVATION

In the handbook on "Archaeology, Theories, Methods and Practice", Renfrew e Bahn (2006, p. 102) highlighted that a good excavation is characterized by the value of the archaeological documentation produced during the field work (drawings, plans, sections, photos, forms and reports) rather than in the extension of the investigations or in the marvel of the discoveries.

Judgment of an excavation is based on the meticulousness of the data produced in the course of the excavation, rather than on evaluating the reconstruction and/or interpretation of what has been destroyed in the course of the investigation.

Forms, photographs and drawings are the material objects of a strategy performed in the field by the archaeologist. They are the final products of a practical behavior carried out by observing an operative method and praxis.

For these characteristics the excavation can be assimilated to a standardized procedure. By agreeing with a specific workflow, this process anticipates various phases of intervention in which the connection between operations is rigorous.

Standardization not only allows to resort to a universally accepted code of regulations, representing a factor in scientific quality, but also to obtain a homogeneity in data acquisition. Forms, diaries, reports, photographs and drawings are the material witnesses to the excavation and, as such, inalienable elements within the "circumstantial evidence" paradigm.

The documentation procedure includes an articulated series of actions (material and immaterial) referring to converging activities (planning and evaluation; excavation, data treatment; communication). The nature and level of the data are generally dictated by specific and circumscribed requirements.

How does the change of methodology manifest itself, if archaeological documentation is comparable to a standardization procedure that includes the objectives and contents of the research, up to the excavation strategy and the rules used to formalize the data acquired?

Is it enough to modify one of the above mentioned elements (forms, photos and drawings) to declare that we have changed the "investigative" strategy?

The digital revolution has without a doubt radically altered the creation of those informative and testimonial which have characterized the practice of stratigraphical archaeological excavation for over half a century. We've gone from B/W photos and slides, to digital cameras reaching high levels of resolution; from simple hand drawings to sophisticated electronic equipment such as EDM, GPS, terrestrial photogrammetry and 3D LaserScanner. Finally, the excavation diaries, once written by hand, are nowadays compiled on PDAs and managed with increasingly more complex informatics systems.
Is this technological innovation sufficient to justify – as Kuhn (1978) put it – a change of paradigm?

A number of scholars, even though they understand the importance of computers, have never truly investigated the innovative role held by informatics in the field of archaeology. The most complete and exhaustive study on the function of informatics in field archaeology was undertaken by I. Hodder (2000). The scholar enumerates 4 out of 12 strategies dedicated to computers. Some strategies seem to be reproposed, according to the well-consolidated post-processualist opinion, an attitude which reduces informatics exclusively to technical tasks. Others are praised by Hodder, as computers are seen as innovative instruments.

If excavation is not a technical activity, but rather an on-going production of hypotheses and interpretations influencing the initial stratagem, sharing the documentation produced and exchanged digitally supplies, according to Hodder, continuous and rapid data transmission, providing a constant update of what is brought to light.

The uninterrupted flux of information can easily be guaranteed by the availability of data stored in a database. At the same time different types of information gathered on site (plans, drawings, object measurements, films and excavation diaries) can easily be encoded and made accessible to researchers. In Hodder's mind, data circulation represents the temporariness of the conclusions, which are always momentary. They become definite only at the conclusion of the procedure.

To guarantee constant and steady traffic of information, a certain degree of formalization is necessary. The user, in order to contextualize the records, may turn to other types of data. Stored and indexed excavation diaries are used, for example, as sources of the excavator's considerations and on his/her evaluations pertaining to the questions raised during on-site research.

According to Hodder, the dig must be filmed not only to document the main phases of the intervention on the terrain, but also of the fears, reflections and possible afterthoughts. Video recording completes the excavation diaries, supplying visible proof of the actual excavation.

In his hypotheses dedicated to informatics, Hodder highlights the technical, yet very important role that the computer has in guaranteeing data circulation, therefore the precise and rapid comparison of all the digital information available.

In our opinion it does not solely concern the managerial "improvements", according to the idea of efficiency that always accompanies the employment of computers in the archiving procedures. Massive use of informatics, even where data transmission networks are involved, not only ends up modifying the classification of finds, the interpretation of the stratigraphical units and the a posteriori reconstruction of the entire life of the area of interest, but the entire excavation progress.

Informatics isn't just a technical-operative means, but also a conceptual tool that constantly influences the researcher in the field, as it requires very standardized forms of normalization and data encoding. It is therefore a part of the excavation method.

As it isn't possible to separate the acquisition techniques from the end product of their application, we can maintain that the more widespread use of LaserScanning technologies providing graphical documentation of archaeological excavations, will determine profound alterations in excavation methodologies and procedures, just as in the geometric description of artifacts and in their subsequent analysis, classification and interpretation.

3. CASE-STUDIES

The equipment used to perform the work is produced by Zoller & Frohlich (http://www.zf-laser.com/e_index.html), a German company. The 3D scanner, Imager 5003, is a tool for short and medium range applications (minimum distance 40 cm. up to 53,5 m.), yet it guarantees elevated resolution (max. 36.000 x 15.000 pixel: horizontal by vertical) with a velocity of 500.000 pixel per second. The linear error specified by the company is less than 5 mm.

Three scanning profiles are available: Superhigh, High e Medium. At 10 meters distance the area sampling for High shoots is 6 mm, while for Superhigh it is double.

The maximum coverage of the area to scan is 360° x 310° (horizontal by vertical), needing about 6 minutes for a complete scan at High resolution. The Scanner, having an angle of 50° vertical not covered by the shoot (coinciding with the station's point of installation), generates a shadow cone, i.e. an absence of data, whose diameter varies according to the height of the tripod, generally positioned at 170 cm.

The Imager 5003 has an internal calibration system. The distance and angle calculation system is based upon the measurement of the phase. Data are acquired both in spatial coordinates x, y, z, and in reflectance values. The latter data, shown in grayscale with an interval between 0 and 255, corresponds to the material's "response" to the laser beam: thus it is possible to scan surfaces which are not illuminated.

For the post-processing phase we used the JRC 3D Reconstructor (www.reconstructor.it) an application dedicated to the process of point clouds. The JRC 3D Reconstructor is a software package used for processing laser data, 3D models and 2D images. It includes fast interactive pre-registration and automatic refinement of registration, multi-resolution meshing, flexible camera calibration and texture mapping, inspection and surveying tools (ortho-photo, cross section extraction, direct connection with AutoCAD drawing tools).

JRC 3D Reconstructor can also process Non-Structured Point clouds (point from airborne laser, from photogrammetric and topographical measurement - GPS total station), and shows some Projectors (orthographic, perspective, cylindrical, spherical) for real-time texturing. The independency from a specific sensor and the ability to re-sample the project data in various ways makes JRC 3D Reconstructor a 3D meta-processing software.

The surveys were carried out according to a consolidated pipeline which include planning the survey, the correct organization of the targets, and the subsequent merge of the scans, filtering and the elaboration of meshes (Scopigno, 2006).

We adopted a standardized and well consolidated procedure in acquiring and processing 3D data. The surveys were carried out analysing different types of archaeological monuments in order to test the laserscanning methodology in diverse conditions during excavations or fieldworks. The acquisition phase was a quite fast technical part: from one to four workdays; while the processing was a longer step in accordance with the archaeological needs, evaluations and interpretations. At the end of the first test campaign we found that the use of laserscanner had changed some attitudes and behaviours about work on field and the following data analysis. The availability of a rapid survey technology, able to gather spatial data in different environmental conditions, pushed archaeologists to acquiring more maps and drawings than in a conventional fieldwork with traditional equipments. A huge amount of processed data had therefore to be classified, archived and managed.

3.1 Pompei

Since 2004 the exploration of Insula 7, Regio IX has been underway, under the direction of Prof. F. Pesando, in order to understand both the settlement patterns of a sector of the city located outside the area commonly considered as the *Altstadt* and of the building history of single houses. So far investigation has concentrated on houses nr. 21, 23, 25 e 26, the north western corner of the block.

Research is based on documentation and on the survey of the existing housing structures. It is followed up by investigation in the field, needed to recover data regarding possible pre-existing or initial phases of occupation of the site.

The survey of the structures is particularly important because, thanks to accurate graphic documentation of the elevations, it is often possible to single out the different phases of construction of the buildings (vertical stratigraphy), which are no longer detectable at the surface or foundation level.

In September 2006, a 3D LaserScanner program to survey the façades and interiors of the housing in Insula 7 was carried out with the objective of defining a method to make the "extraction" and reading of vertical stratigraphy of the structures in elevation a semi-automatic procedure.

The first phase of the intervention focused on houses IX, 7, 19 and 21 along Vicolo di Tesmo and houses IX, 7, 22 – 23 – 25 and 26 along Via degli Augustali.

The campaign lasted a single day and affected a front of about 75 meters. The data, gathered into eleven different scenes, was acquired in "High" modality, thus guaranteeing sub-centimetre precision and with a resolution adjusted to the objective of the survey (fig. 1).

After the scans were recorded and assembled, a 3D model was created onto which several color images taken with a digital camera were rectified and projected. Some planes were subsequently generated to allow the creation of photo-orthoplan Then the phase involving vectorialization in CAD of the different building techniques was initiated.

The pertinent descriptive form, containing indications on the physical relationships between the various building techniques, will be associated to each type of masonry identified.

3.2 Wadi Gawasis

In January 2008, during a mission directed by Prof. R. Fattovich, an initial digital scan of two caverns was carried out; the laser scanner was used to guarantee the acquisition of detailed documentation of the caverns excavated in the fossil coral plateau and utilized probably as boat shelter from the beginning of the Second Millennium B.C. (Bard, Fattovich, 2007)

At the time of the intervention the caves presented problems related to statics, manifested by some collapses on the face and ruins near the entryway to cave 2, which had been buttressed with wooden reinforcements.

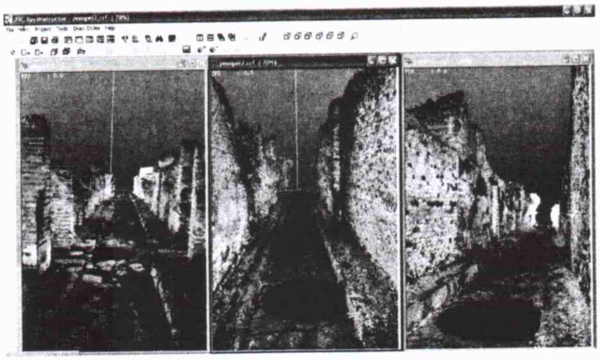

Figure 1: Pompei: three different shoots before the registration. In evidence the shadow cones.

The need to build an accurate geometric model that would constitute the basis for subsequent static monitoring of the structure, was added to the scientific need to graphically document the caverns' interiors. The survey lasted 4 days in the field and required about 4 weeks for post-elaboration in the lab.

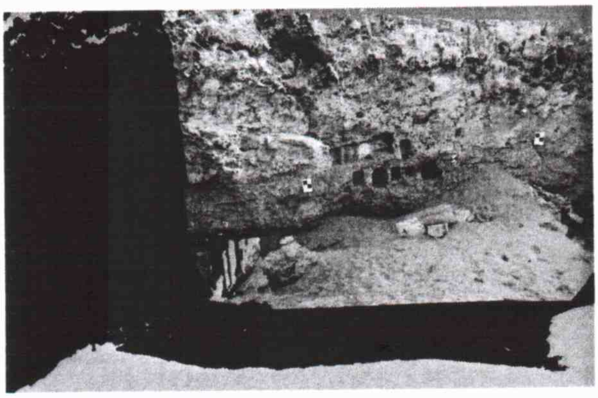

Figure 2: Wadi Gawasis: rectified Photo fitted to the point-cloud.

The survey was programmed and targets were affixed to the face of the cavern in order to allow subsequent reassembly of the scenes. Afterwards, more targets were placed on the interior walls of the caves with the same purpose. Particular care was dedicated to the placement of the intermediate targets in order to reassembly the three distinct surfaces (front, cavern 2 and cavern 3) into a single model. This allowed to rearrange and assemble all the point clouds into a single geometric reconstruction.

3D rendering of the area was later "coated" with textures taken from digital photos, opportunely calibrated and adjusted (fig. 2). The model was then used to extract important information, such as the section and plan of the cavern. At the same time the presence of deep lesions to the ceiling were detected, both in the section and in the plan.
The acquisition of new scans, expected in the next campaign expected in 2009, will allow to compare the reconstructed models and verify the progress of possible lesions, thus guaranteeing adequate monitoring of the monument's stability.

3.3 Temnos (Turkey)

At Temnos, in October 2007, during the last survey campaign performed in the framework of research activities lead by Prof. G. Ragone, a digital survey of a large portion of the terracing wall of the agora was undertaken. The tract of wall, in polygonal opera, was located on the western corner of the ancient Aeolian city.

Objective of this intervention, performed in a single day, consisted in the detailed documentation of the building techniques. Therefore a visible part of the wall of about 43 meters not covered with vegetation was chosen.

The LaserScanner was positioned about 4-5 meters from the wall, positioned on a slope slightly lower than the level of the monument, then 4 scans were acquired and elaborated

After the various scans were assembled, a mesh was created and on it were projected rectified images obtained with a digital camera. Subsequently a photo-orthoplan was created and exported to AutoCAD, where it was elaborated in order to extract the sections and to carry out the vectorial analysis of the polygonal masonry (fig. 3). The section clearly shows that the tract of wall was constructed against the earth, slightly leaning inwards to support the pressure from the terrace.

The area of our investigation is not easy to reach. It would have taken many days to perform the scans with traditional techniques. The laser scanner, on the other hand, allowed us to rapidly acquire the point clouds that were later opportunely elaborated in the lab.

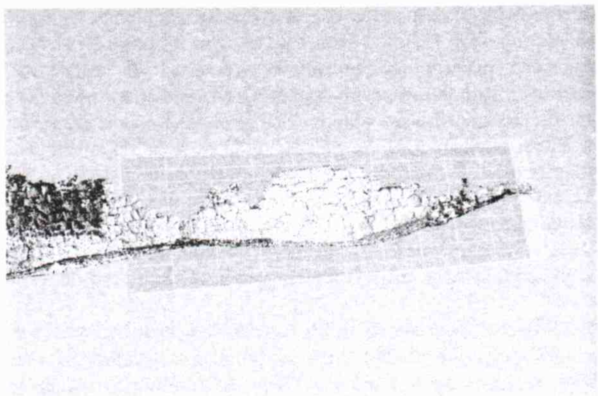

Figure 3: Temnos: the extraction of photo-orthoplan

4. USE AND REUSE OF THE 3D DATA

The availability of 3D data will determine an alteration of the investigative and archaeological excavation methodologies. Therefore the evaluation of, and attention placed upon, the techniques for acquisition and rendering of the three-dimensional models must be adapted to the complexity of the technology used in order to avoid ambiguity or – worse - inappropriate use.
The geometric basis of the digital model is an element to take into consideration. The third dimension is often not measured, but deduced from extrusion functions or reconstructions in perspective. Instead, a 3D reconstruction must be completely measured in all its components, the parts elaborated through modelling must be differentiated from those actually surveyed.

Another element must therefore be taken into consideration: the non selective property of 3D LaserScanner acquisition, along with the irrelevance of the factors of scale in graphic rendering.

All manuals on archaeological surveys, when examining indirect survey techniques, frame them mostly in a topographic kind of survey within a local or absolute reference system, although they're increasingly used to analyze and render details.

In traditional surveying (direct and indirect) the points to scan are chosen by the operator, whether he/she is an archaeologist, draftsman or architect. During acquisition he/she evaluates in a discriminating way the information to graphically record. The 3D LaserScanner memorizes all the data that the laser's optic beam can capture.

The digital master, obtained through a non-sampled acquisition of the archaeological evidence, can subsequently be elaborated: the model can be cleaned up, filtered and simplified. Only upon termination of the analysis will the spatial and physical qualities of the archaeological object be identified.

In a point cloud the concept of scale is irrelevant. The model is in itself scalable, as it is vectorial. The problem with scale presents itself only when rendering and printing the model, not when viewing it. The possibility to represent the models directly, without any kind of graphic mediation, constitutes a relevant factor in the procedures for using and reusing 3D data.

The more widely spread approach in the field of archaeology requires the description of archaeological objects almost exclusively in 2D, evidently in connection with the type of paper support on which such information is rendered. The same stratigraphical matrix, which records synchronic and diachronic events, is a simple bi-dimensional representation of the sequence of activities that the archaeologist has identified.

Recent attempts to intervene on the third dimension and on volumes (VOXEL) highlighted the geometric value of the isolated stratum in that over and under spatial relationship, which depicts the most interesting type of temporal relationships (before and after). (Cattani, Fiorini, Rondelli, 2004).

Is it possible to maintain the 3D geometrical dimension of the model without having to convert it into a two-dimensional view? Can we really make it more usable, without necessarily having to project it into a two-dimensional representation or without forcing possible users to install sophisticated and not very practical software for virtual navigation? Finally, is it possible to attribute relative semantic values to simple geometric superimpositions?

Starting from our on field experiences we tested some solutions (commercial or not) in order to store and manage all digital surveys. Our impression is that the Acrobat 3D software and the GML language could open new extraordinary scenarios for archiving and three-dimensional topological structuring of spatial data.

The functioning and the applicability of standardization and distribution of the 3D contents will be examined in the following paragraphs.

4.1. Acrobat 3d

Acrobat is a program by Adobe Systems used for creating and modifying PDF files (Portable Document Format). In the late Nineties it became the standard for the distribution of contents made up of text and images. The Adobe Reader software, freely distributed by Adobe, allows end-users to open, read and print the PDF files. PDF is a format based on a language for the description of pages, developed to represent documents autonomously from the hard- and software used to generate or manage these files.

The PDF does not include specific information, allowing it to be visualized and rendered the same way independently from the platform and/or device used to read it. This *portability* has permitted PDFs to become the *de facto* standard format, widely spread for sharing documents. In December 2007, PDF became an ISO 32000 standard.

In 2006 Adobe launched the Acrobat 3D program and in the Spring of 2007 the version v.8 was released, consenting to convert and compress CAD files into a single PDF 3D file readable with the free Reader 7.0 software. Acrobat 3D allows to create PDF documents from three-dimensional models obtained through various applications accurately maintaining the object's measurements. It is possible to visualize a model in all its aspects, having a wide choice of navigation and query functions at disposal. It won't be necessary to own CAD-like software.

Acrobat 3D supports bi-dimensional "static" models, organized in distinct informative levels, and navigable three-dimensional models: the user is able to rotate the model, measure distances, create sections, modify the illumination and rendering.

PDF is a web standard and for this characteristic it is used to distribute electronic texts. If the documents are not password-protected, they can be viewed within the browser through a special viewer; it is possible to download files in pdf format corresponding to specific requisites by adopting particular research techniques.

Documents incorporating 3D models with annotations and texts explaining the procedures used in the model's construction (Paradata) can be made available by exploiting the PDF's characteristics of portability.

Paradata (Scheuren, 2000) are a special category of observational data introduced in documentation process to more precisely determine specific features of the collecting/measuring/capturing of data. They are useful when we want to reuse manipulated data (not raw data), stored in the archives, or to have information about functioning and performance of processes generated. For this reasons Paradata may be described as a way to check and alter any process procedure evaluating costs/benefits in order to optimize the processing.

Figure 4 shows a simple example of annotation of paradata recording the software used to convert and merge the original GML model in a pdf file.

Linking Paradata with the 3D data should a positive approach to force researches to make transparent their processes according for instance the principles of LondonCharter (Beacham, Denard, Niccolucci, 2006). In the same time this special category of annotations could help other users to test and reuse the processes in order do not invent again the wheel.

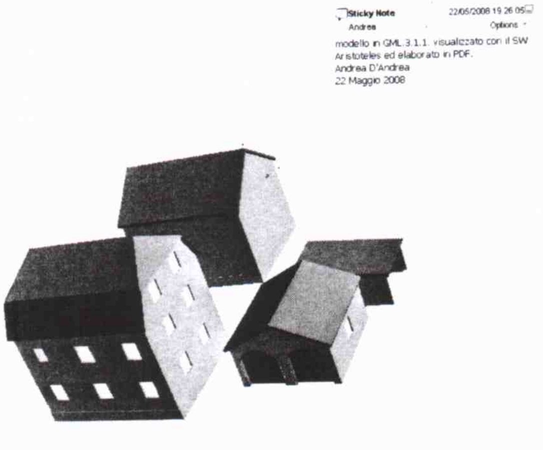

Figure 4: A pdf file: 3D model with annotations.

By annotating the processes in PDF it will be possible to search Paradata online through the traditional search engines and so understand better the generated reconstructions.

Finally, by resorting to certain functions implemented directly in the software it will be possible to use metadata, also in DublinCore format, linked both to the document and to the single 3D objects incorporated in the PDF.

The creation of 3D PDF documents will improve the interoperability between different CAD, thus stimulating forms of collaboration and *networking*. Moreover, the introduction of texts and annotations explaining the construction procedure of the 3D model would greatly clarify how to access and reuse the three-dimensional object.

Today technology promotes major integration and forms of *peer production*. However it does not yet allow a broad management of the digital models, due to the "heaviness" of certain reconstructions. The development of lighter standard formats like X3D or COLLADA may guarantee in future the full interoperability of 3D documentation based on favoring a more widespread circulation of the digital masters and the relevant digital processing.

4.2. GML and CityGML

Acrobat 3D, by integrating CAD objects codified in 2 or 3 dimensions, favors the exchange of contents and information. However, to ensure that the data is correctly reused, a means acting as exchange is not sufficient; only the 3D data can be visualized in its geometric representation.

To incorporate semantics within the model, a language in the representation of the elements having a two- or three-dimensional spatial connotation is necessary. This objective cannot be reached by turning to other domain onthologies, such as CIDOC-CRM, which have nonetheless proven to be applicable to the archaeological documentation sector (D'Andrea 2006, D'Andrea, Marchese, Zoppi 2006). The expressive potential of GML (Geography Markup Language), but most of all of one of its application-oriented profiles denominated CityGML, must be analyzed. Through appropriate modifications CityGML can be used to examine the semantic relationships of ancient monuments.

GML is an XML grammar defined by the Open Geospatial Consortium (OGC) to express geographical objects. A standard since 2007, GML is a modelling language for geographic systems and an open format used to exchange geographic information through the Internet. GML defines *feature* an entity which is distinct from a *geometric object*.

A *feature* is an object of the application representing a physical entity (a building) that might not have a geometric aspect. A feature collection is a collection of features that can itself be regarded as a feature. As a consequence a feature collection has a feature type and thus may have distinct properties of its own, in addition to the features it contains.

A *geometric object* instead defines a location or region, rather than a physical entity. This distinction between the physical and geometric representation of a spatial object differentiates GML from GIS models, where *feature* and *geometric object* are considered equivalent.

The state of a *feature* is defined by a set of properties, where each property can be thought of as a {name, type, value} triple. The number of properties a feature may have, together with their names and types, are determined by its type definition.

Other relevant elements in the organization procedure of the *feature* are the *coverage* class, representing the discrete geographic coverage of the entity in a well defined spatial-temporal domain and the concept of *observation*, which models the observation and measurement action also defined according to precise spatial-temporal coordinates. The OCG, in the formulation of their guidelines, defines *observation* as a simple class, suggesting the development of specific GML application schema applicable to scientific, technical and engineering observation and measurements, such as the 3D LaserScanner.

CityGML constitutes an application profile for GML3, oriented at the multilevel representation of informative strata such as buildings. "CityGML" is a model oriented predominantly to the codification of three-dimensional urban objects.

In the example shown in figure 5 it is possible to understand how semantics is expressed through a simplified hierarchy based on node *parent-child* linked by the relationship *is part of*.

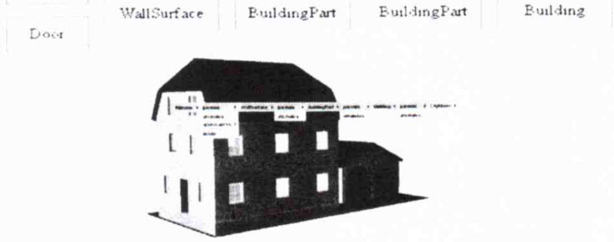

Figure 5: CityGML Schema.

Currently CityGML has been defined for the representation of urban contexts and geometries also to manage problems like traffic, pollution and for the simulation of catastrophic events (www.citygml.org).

Through appropriate modifications, the CityGML profile can be adapted to the archaeological domain for the semantic, not only geometric, representation of the constructed stratigraphical units. An ancient building is made up of a number of physical entities, such as interiors, roofs, doors, walls, floor area, foundations, furnishings, etc. Each physical entity has its own geometry and a series of attributes (dimension, chronology, building technique, etc.) which can easily be expressed, as in the example in figure 5.

The parts that are missing or that have been totally reconstructed can always be represented both geometrically with properties defining the degree of reliability and also according to fuzzy parameters (Hermon, Niccolucci, D'Andrea 2005).

The point clouds showing the ancient object's data are included in the GML grammar as *coverage*, i.e. the specific result of an *observation* which is the end product of a survey performed with a LaserScanner in a defined spatial-temporal ambit.

Representation of the stratigraphical units seems to be more complex, especially that of the negative type, as in the construction of the matrix they are the trace (or interface) of a "removal" event (natural or artificial), therefore devoid of geometry. The S.U. are always the result of an action which can be of contribution and removal; the former are generally Positive and Built Units, while the latter do not have a volume and therefore are Negative.

GML is, also in this case, the grammar used to conceptually express the S.U. Each stratum identified by digger is the trace with its own geometric properties (*geometry*) testifying an ancient event marked by an action of contribution or removal (*feature*). To highlight the chronological and functional sequence of the strata, the schema *topology_xsd* must be enriched and the physical relations which characterize the relationships between the S.U., currently circumscribed simply to the before-after and over-under sequence, should be anticipated.

There are many open-source and commercial GIS that elaborate documents written in GML (TatukGIS, OpenJump, QGIS, GVSIG and GRASS), while some programs are able to read files encoded in GML (GMLViewer). Managing documents in GMLCity is more complex, as they are viewable and correctly rendered only by specific programs such as Aristoteles and Landxplorer CityGML viewer.

Currently Reconstructor software can export point clouds in X3D and Collada format. We hope that a more coordinated action between producers and users will in the future contribute to the creation of interoperable formats like GML with the possibility to add and define properties and attributes of the recorded information.

The next step in this direction will be the integration of GML and its application profile to the CIDOC-CRM; GML could manage spatial components associated with the description of objects formalized according to CIDOC-CRM schema (Felicetti, Mara 2008). An alignment with the CIDOC has already been defined for X3D (Niccolucci, D'Andrea 2006). GML takes shape as a dominion able to express not only two-dimensional geography, but also the three-dimensional one. It is also able to record the topological relationships between *features*.

5. CONCLUSIONS

As laserscanning technologies are increasingly used to graphically document archaeological excavations, it will determine profound modifications in excavation methods and procedures, in the geometric description artifacts and in their subsequent analysis and classification.

If using new instruments to collect geometric data allows to rapidly gather highly accurate 3D information, it is very likely that the entire excavation and reconstruction procedure will gain significantly from it, in terms of quality of the data acquired and in terms of the completeness of the geometric-spatial information.

Notwithstanding this, a deep transformation of the methodology will occur not only thanks to more powerful and reliable digital technologies, but also when the product of excavation activities will be completely available to the entire scientific community. Conceptual and physical instruments already exist and are the infrastructure of the Semantic Web, dominion ontologies and standard formats. What is missing is the willingness of archaeologists, still entrenched behind circumscribed circles of knowledge, ever more restricted and auto-referential.

Until about 20 years ago, there was a limited number of discoveries and excavations and every archaeologist could, in a convenient temporal dimension, read and be informed of progress in his/her specific field of research. The extension of research, the extreme apportionment of knowledge, the appearance of a new phenomenon represented by local communities - in certain areas of particular historical interest in developing countries, excluded initially due to a sort of colonial attitude, even in the field of research – makes it difficult to keep the literature updated.

In August 2007 the Project Heathrow T5 on-line was launched, making available to users the alphanumerical and spatial data pertaining to excavations carried out at Heatrow and Stansted airports (www.framearch.co.uk). The system was developed thanks to a joint venture between Wessex Archaeology and Oxford Archaeology. The update system includes an improved version of their free GIS that allows you to explore the hard archaeological data collected during the phases of the investigations. Crucially, the raw data behind the GIS has been released in a variety of useful formats including CSV, XML, SHP and GML.

The diffusion of tools to simplify access to and reuse of the data will favor, thanks to the transmission of metadata and paradata, the creation of collaborative communities characterized by the peer production modality, the result of vast horizontal participant networking.

Achieving this objective is made possible not only because of a change in attitude, but also due to the existence of semantic and technological standards, and to a rigorous formalization of point clouds. The integration of standards, 3D representation languages and technologies constitutes a scenario from the near future.

Our tests – still partial - show how is possible integrate in an interoperable framework 3D data acquired by laserscanner and which directions should be undertaken in order to guarantee the access and the re-use of digital 3D data. This new approach for data archiving will improve the effectiveness of standard - at the moment only in the theory as regard 3D data - and could support different European digital libraries projects and international archives for spatial and geographical data.

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