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From classical to 3D archaeology

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Abstract: This paper aims to mark some of the possible applications of the engineering CAD software in the field of archeology. The archaeological information, which is usually stored in classical format, can be digitized in 3D by using CAD software. The result of this process can be used for multiple purposes: conservation, dissemination, research, etc.

Key words: CAD, CatiaV5, digital, 3D modeling

Introduction

Archeology is the science that studies human history and prehistory through the excavation of sites and the analysis of artifacts and other physical remains [www.1, 2011], and telling us the story of the past and stories about the past.

Digital Archaeology explores the basic relationships that archaeologists have with Information and Communication Technology (ICT) and digital technology to assess the impact that such innovations have had on the very basic ways that archaeology is performed and considered (T. Evans 2006).

According to Graeme E. (www.3, 2011) (Archaeological Computing Research Group, University of Southampton) and (D. Lu, 2009) archaeological computer modeling can be summarized as:

- Mathematical – statistical analyses
- Landscape modeling – networks, geographic information systems, geophysical data
- Data modeling – models of relations, hierarchies, objects
- Artificial intelligence and expert systems
- Textual modeling – semantics and linked data
- Computer graphic modeling – simulation and representation

For 3D modeling there are minimum two big category of software which can be used in archeology: CAD (Computer-Aided Design) software used by engineering and the second alternative is software used in movies and game industry for modeling, animation, and rendering, used by artists, and graphic designers.

This paper will present some possibilities to use CAD software in the digitization of archeological information for creating virtual artifacts and virtual environments, for building visual interpretations of the excavations, buildings, pottery, and other component of the ancient world which can help to improve knowledge about the antiquity. This paper presents a series of case studies regarding the Dacian civilization (focused on the fortresses from Orăştie Mountains), developed in the framework of the project Virtual Ancient Dacia, that were realized together with a specialist from the National History Museum of Transylvania, Cluj-Napoca[1].

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All the case studies are intended to be integrated at the end of project in *Europeana*, a European Union initiative, that aims to enable people to explore the digital resources of Europe's museums (www.3, 2011).

The citadels within Orăştie Mountains have been the center of the Dacian world for over a century and a half. In an area covering ~ 200 km^2 there have been built strong fortresses with Elenistic walls, tens of temples with monumental architecture, workshops, living quarters and annexes, and systems for water catchment and distribution. Thousands of iron made objects, fabulous thesauruses uncovered during time, but also the fine pottery or the imported objects are proof of the exceptional development that this area has had in the antiquity. These vestiges form a cultural patrimony of high significance both on the national and international level: starting with 1999, the capital of the Dacian kingdom - Grădiştea de Munte – Sarmizegetusa Regia – and the surrounding citadels (Costeşti, Blidaru, Piatra-Roşie, Căpâlna, Băniţa) have been included in the UNESCO patrimony.

The systematic archeological research in the Orăştie Mountains has started in the period between the two world wars and has continued, almost uninterrupted, until the present times. During time, numerous pieces of archeological information have been gathered, which, using the modern digitization techniques, provide a new research instrument and as well as the chance to represent history in a much more accessible and exciting way (C. Daicoviciu, 1951; G. Gheorghiu, 2005; H. Daicoviciu, 1972; H. Daicoviciu, 1989).

Archaeological Information

Much of the information produced by archaeological research over the past century exists in technical, sometimes lengthy, limited-distribution reports scattered in offices across the country (P. Francis, 2010). The solution for avoiding this problem is to digitize the archaeological information and use it in electronic format within digital libraries that allow for a controlled access.

According with (A. Chalmers, 2009), the digitization of archaeological information can encompass the following fields:

- documenting the current state of existing artifacts or works of art,
- measuring, dissecting, or visualizing objects and sites to gain new insights, and
- educating students and the general public about cultural heritage.

This information can be processed using different methods that provide for its transformation in (G. Lock, 2003):

- Images – drawings, maps, pictures and images in 2D or 3D
- Texts – manuscripts, books, newspapers, letters, diaries and archive documents
- Phonograms – music and spoken text from cylinders, cassettes, vinyl or from radio shows
- Video clips – movies, news broadcasts and TV shows
- 3D models – patrimonial objects, reconstructions, etc.
- Modele 3D- obiecte de patrimoniu, reconstituiri,etc.

In the UNESCO vision, "cultural heritage is our legacy from the past, what we live with today, and what we pass on to future generations" [2], and in our opinion the digitization of archaeological information is a way to contribute to this desiderate.

Using Cad Software in Archeology

For illustrating the possibility to use CAD software in archeology the authors have choosen one of the most complex solutions: CATIA V5, wich is addressed to all manufacturing organizations; from OEMs through their supply chains, to small independent producers.

CATIA can be applied to a wide variety of industries, from aerospace, automotive, and industrial machinery, to electronics, shipbuilding, plant design, and consumer goods. Today, CATIA is used to design anything, from an airplane to jewelry and clothing [www.4].

In conjunction with ENOVIA for collaborative product lifecycle management, SIMULIA for engineering quality and DELMIA for production performance, CATIA V5 is a key component of V5 Product Lifecycle Management from Dassault Systèmes.

[2] Available: http://whc.unesco.org/en/about

In the following case studies, there can be identified two distinct uses for 3D digitization:

- the digitization of a real object
- the 3D digitization of information that already exists in electronic format

By using the solutions related to Catia V5 (3DVia, 3DViaStudio, 3D ViaComposer), all the 3D models can be transformed into formats compatible with stereoscopic projection, thus creating a virtual reality environment that offers a full experience in visualizing and interacting with the 3D models.

Modeling archeological excavation sites

Archaeological research requires the elaboration of a documentation that includes general and detailed site plans, pictures, drawings, topographical maps, etc. This data and its precisions represent a major problem when the results of the archaeological excavation need to be explained to other specialists or to those less familiar with this science: a three dimensional past is reconstituted in a two dimensional form, thus losing both important information and the reader's appeal.

A three dimensional representation of an archaeological excavation would eliminate this problem, and, moreover, it would open up new research directions. Among the advantages of applying 3D techniques to archaeology, one can mention: the visualization of successive archaeological layers, repositioning of the discovered artifacts in their original settings simulated with high fidelity, the possibility to rapidly correlate pieces of information gathered during several research campaigns, increased interactivity with the "image" of an excavation, etc. Basically, the situation in the ground before the excavation can be recreated faithfully in the virtual environment.

Information taken using the classical method from archaeological excavation sites can be used for 3D modeling of the excavation. Using surface or solid body in Catia V5, the excavation can be build at 1:1 scale with all necessary details, without any limitation from the part of software. With the help of *Material Library*, *Photo Studio* and *Real Time Rendering*, the 3D model of the excavation can be rendered with texture extracted from pictures taken on site. In figure 1 is presented an excavation made in 2010 at Gradistea de Munte (Caprareata II), modeled using 2D drawings (Fig.1b) made by archeologists on site.

The 3D digitization of archaeological digs may lead to the creation of databases with information, that could be used for establishing various correlations or for placing of the digitized objects on a GIS model in oder to help plan future digs. Other uses of digitization are to virtually recreate the initial archaeological context and allow for possible interactions with the 3D model in virtual reality environments.

Reconstructing a fortress

The proposals for reconstruction for the Dacian citadels in the Orăştie Mountains in 2D format exhibit a series of disadvantages generated by the working method which, most of the times, only offers a single perspective, making impossible the representation of certain details.

Accurate and detailed 3D model for fortress and building can be made with modules from Catia V5, even if this software with its modules is not specifically designed for architectural modeling. The advantage for 3D reconstruction in Catia is the possibility to work with assembly and subassemblies for a big model.

With the rendering facility, a picture or areal time rendered scene can be obtained at high quality.

In the figure 3b we have a classical 2D reconstruction proposed in (www.5), and in 3c a 3d reconstruction proposal made in Catia V5, at 1:1 scale with materials and a possible configuration of relief.

Modeling at 1:1 scale offers a real perspective on the proportions of the site, the possibility to model in detail any element – from the stone blocks that make up a wall and up to the objects discovered in the area, and also the possibility to present the evolution of a fortress.

Relief modeling

The relief is essential in understanding an ancient site, even more so when talking about a fortress.

Using surface modeling from the *Shape* group of modules, the actual relief can be modeled and can be used in combination with building and excavation for a better understanding of the history of the place.

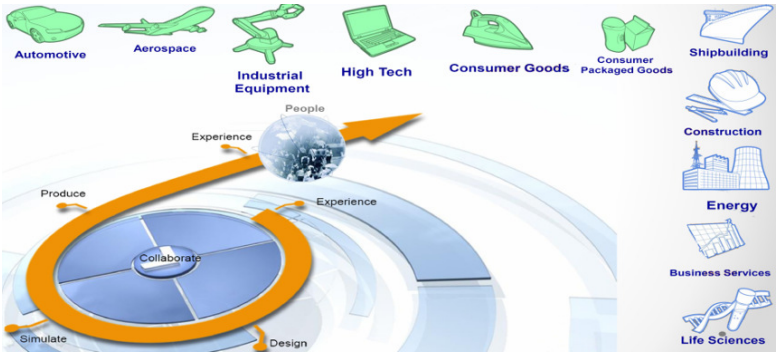

Fig. 1 - Catia V5 industry solutions

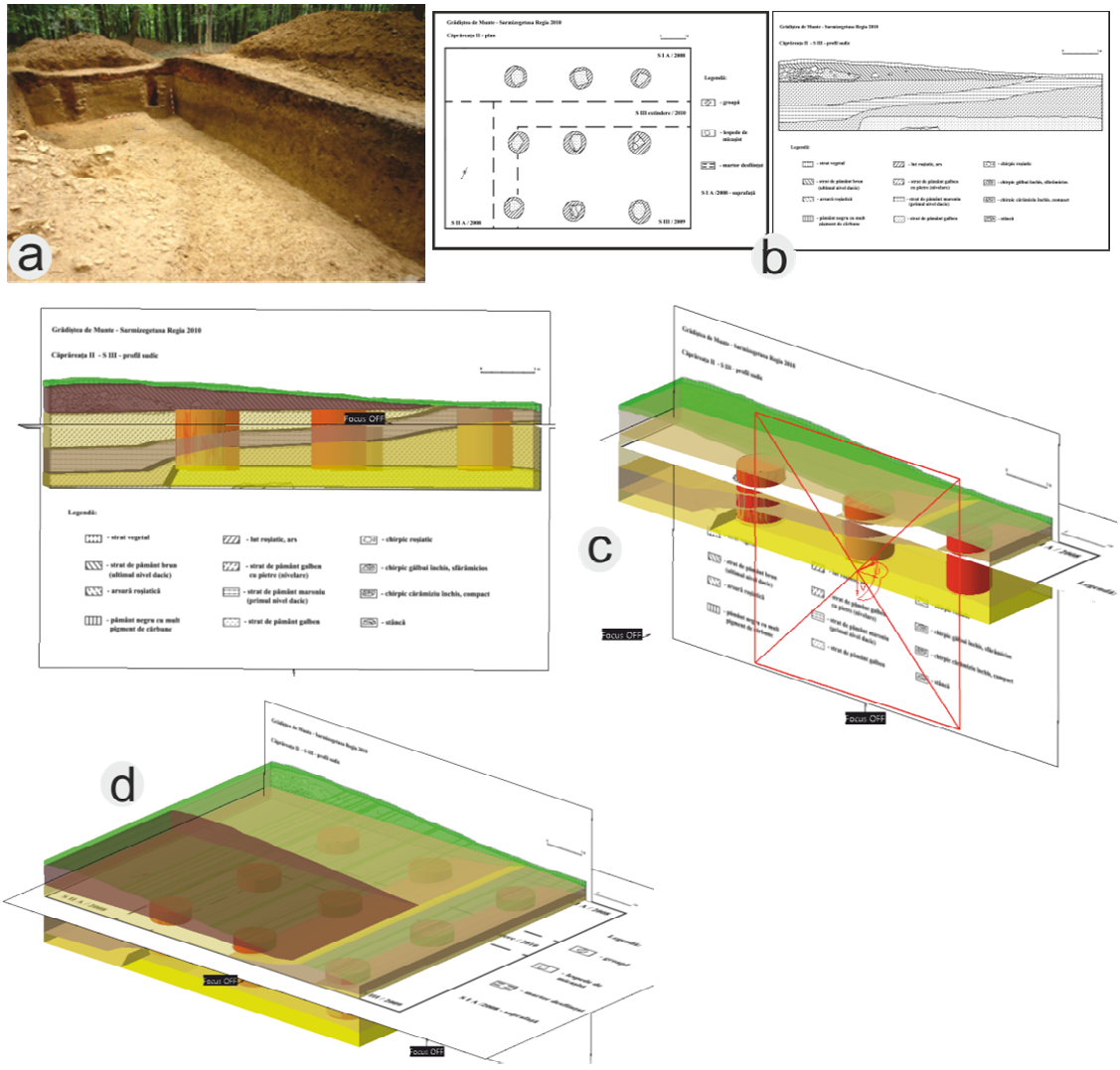

Fig. 2 - Gradistea de Munte – Site Crapareata II: a-picture taken during the excavation; b-classical archaeological documentation; c-sections through the 3D model; d-isometric vie

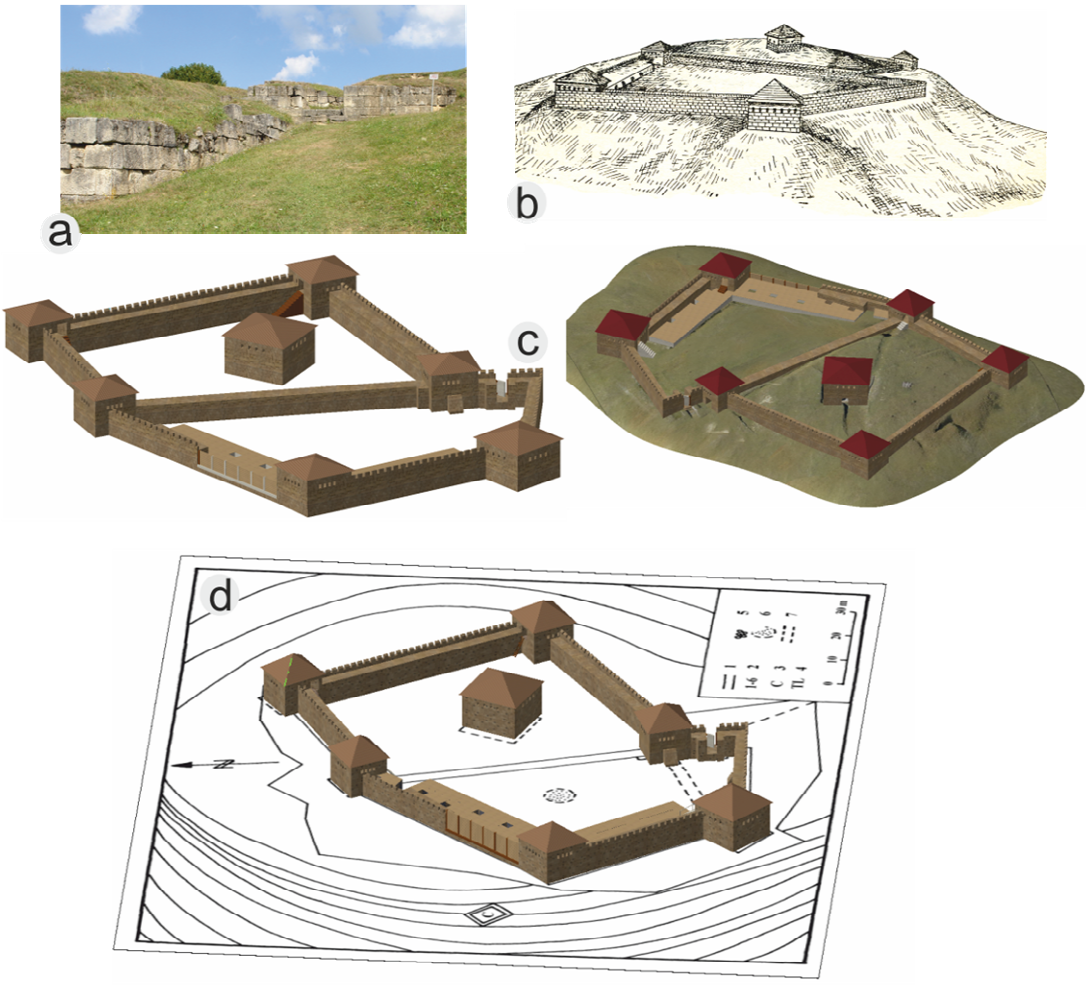

Fig. 3 - Reconstruction of Blidaru fortress :a-picture with the Dacian walls; b-classical reconstruction proposal; c-3d reconstruction proposal;d-topographic map and reconstruction proposal at 1:1 scale

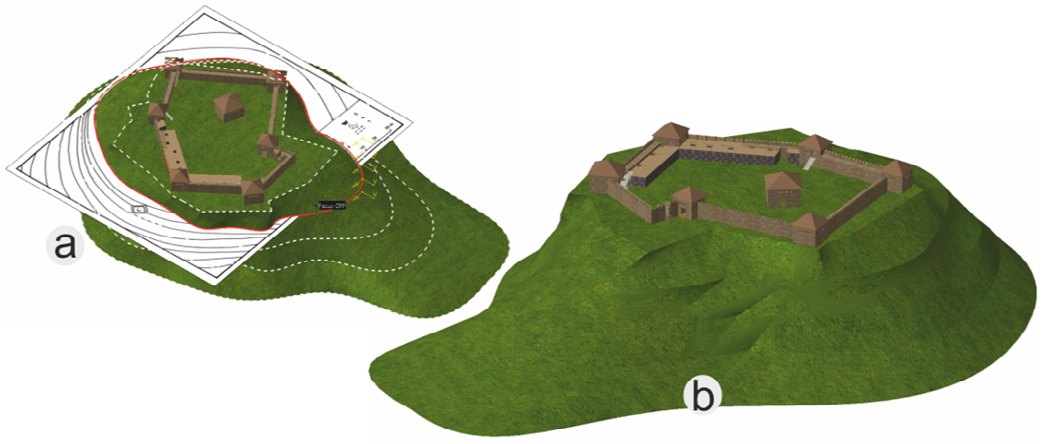

Fig. 4 - Modeling relief - Blidaru fortress: a – relief and topographic map; b- fortress on the actual relief

Starting from level curves take by a topographer on the actual relief, this can be modeled for a better recreation of the defense reinforcement, access ways and other aspects regarding the position of fortress or building.

The 3D modeling of the relief allows for the creation of a model that underlines the natural advantages of the placement of the site. After modeling of the current situation, it can be reshaped in order to bring the relief as close as possible to the initial configuration by recreating plateaus, terraces or other landscaping elements that have faded away with the passing of time.

Scanning and reconstruction of an artifact

Using a special plugin like Handyscan Scanning Module (HSM) for Catia V5 (from Creaform) is possible to scan a 3D object directly in the Catia environment. After the cloud point is acquired, it can be processed using *Digitized Shape Editor* and *Shape Sculptor* for obtain the mesh. The mesh can be used directly for manufacturing the missing part from an object using CNC (Computer Numerical Control) equipment, or for generating the surface using *Quick Surface Reconstruction.* Generated surfaces can be edited with a many of instruments from the *Generative Shape Editor* module.

In Catia V5 is possible to reconstruct a broken artifact using a graphical algorithm [V. Kilikoglou, 2002]. Using the module *Imagine and Shape* is possible to work using the principle of photogrammetry. Catia V5 can work with a lot of components grouped in assemblies and subassemblies, modeled directly in Catia or imported using the most common 3D file formats.

Rendering scenes and objects

Catia V5 offers many tools for rendering in modules like *Photo Studio* and *Real Time Rendering*; maybe they cannot be compared with similar facilities from software used in the movies and game industry, but Catia has the most important functions that also exist in these software packages.

With the *Material Library* module, the users can define their own materials with physical and visual properties that are 100% custom.

Catia V5 has a standard mode for rendering and offers the possibility to set-up a fully custom mode for the rendering engine (Figure 7).

The result can be very realistic, similar to the real environment, because users can take properties such as color, reflectivity and transparency from real objects.

Drafting and 2D details for 3D models

2D documentation is probably as important to archaeology as it is to engineering. Once transposed in 3D format, we can generate automatically the 2D documentation for any element, showing different views, sections and details

Catia V5 offers a large number of engineering instruments for generating 2D drawings, which can be successfully used for generating the production drawings for a 3D model or for digitizing an existing drawing.

Human activity simulation

There are many differences between animation and simulations of human activity. Using modules grouped under the name *Ergonomics Design & Analysis*, is possible to simulate the human activity with antique hand tools.

Human Activity Analysis in Catia highlights: Clash detection; Analyze Lifting/Lowering; Pushing/Pulling and Carrying; Snook & Ciriello as well as NIOSH Analysis; Repetitive motion analysis such as RULA (Rapid Upper Limb Assessment); Balance computation and Biomechanics analysis [8].

3Dvia and virtual reality

Through 3DVia Dassault Systèmes offers a powerful instrument that allows the import of 3D models from Catia V5 (and from the other proprietary applications) and their transformation into virtual reality applications that are compatible with most 3D projection systems, anaglyph, Nvidia 3DVison, etc. By using this instrument, virtual exhibitions and museums can be created containing all the 3D models realized with Catia V5, thus making them accessible to the public via the Internet. In this way, visualizing the on-line 3D models can be performed with minimal costs to the user (costs are incurred by the chosen 3D visualization

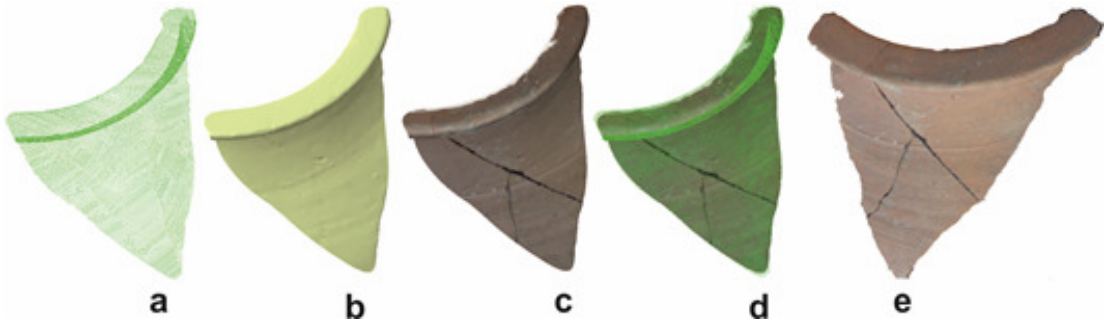

Fig.5: Digitized vessel fragment: a-point cloud; b-surface; c-textured surface; d-point cloud and textured surface overlapped; e-fragment discovered at Grădistea de Munte.

Fig. 6 - Vessel reconstruction: left-original chiup, right-digitized vessel in Catia V5

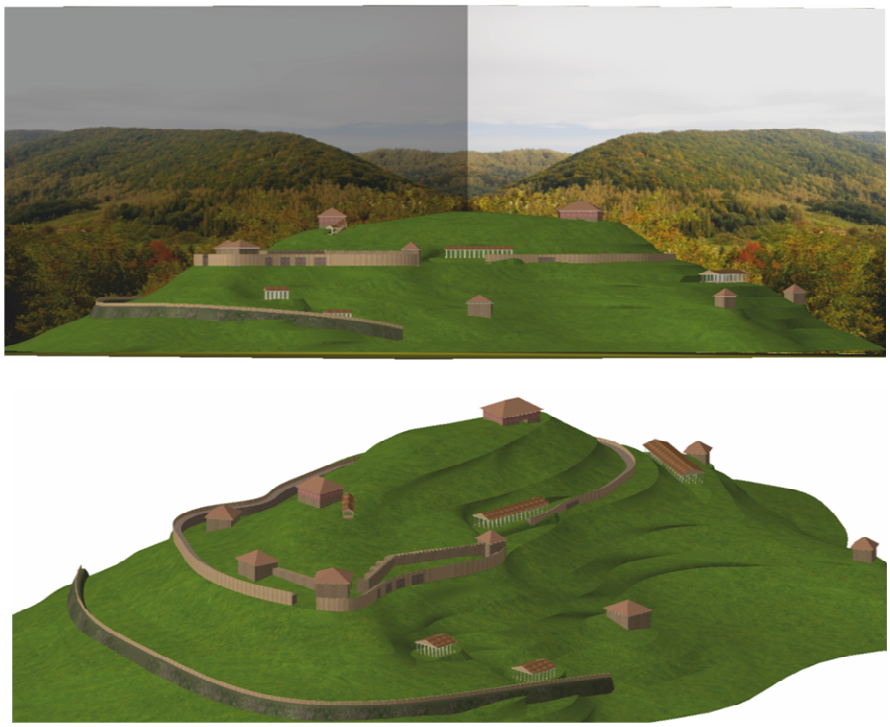

Fig. 7 - Rendering objects-the fortress from Costesti: up-real time rendering with panorama, down-simple rendering image

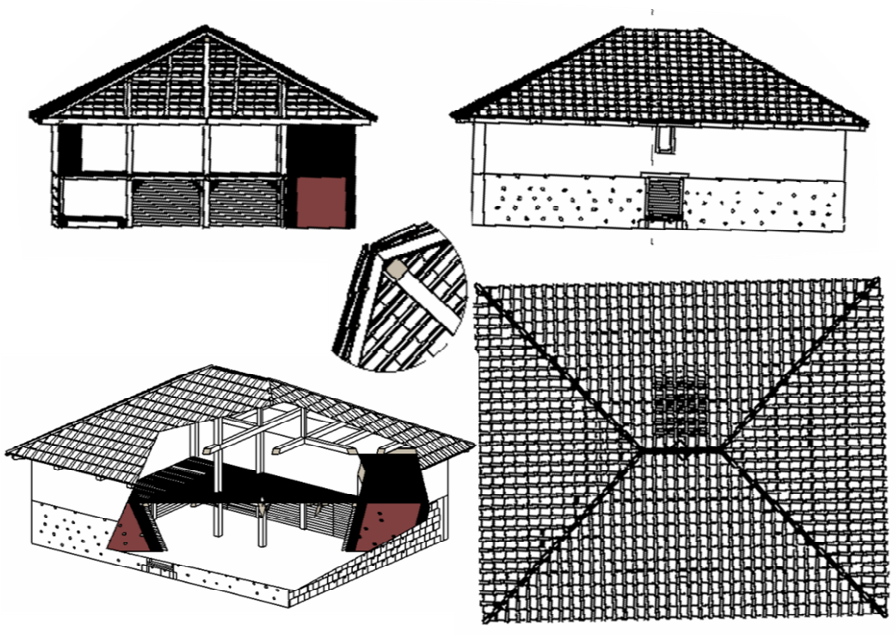

Fig. 8 - Drafting for a defense tower in Catia V5

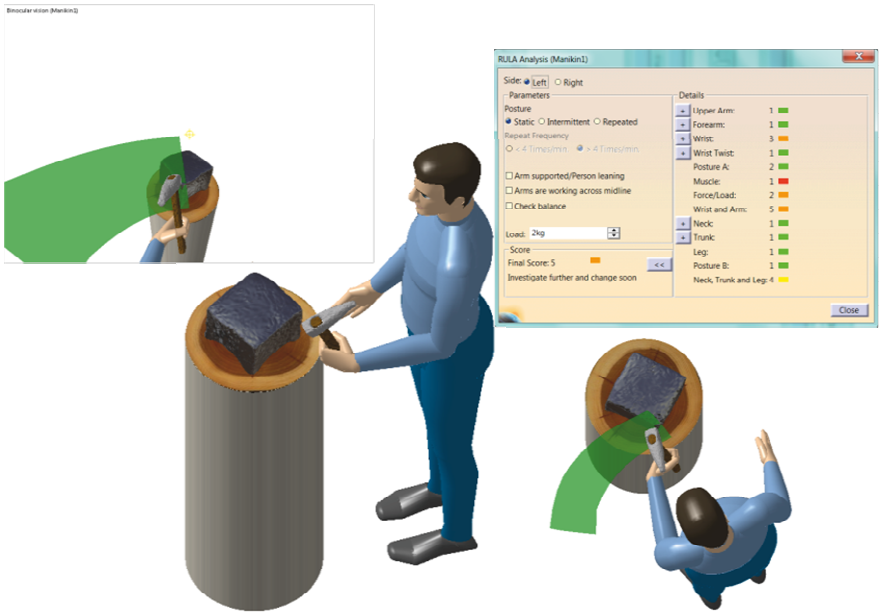

Fig. 9 - Ergonomics Design & Analysis: a-human with hammer, b-vision space, c-results of RULA analysis, d-top view with reach position analysis

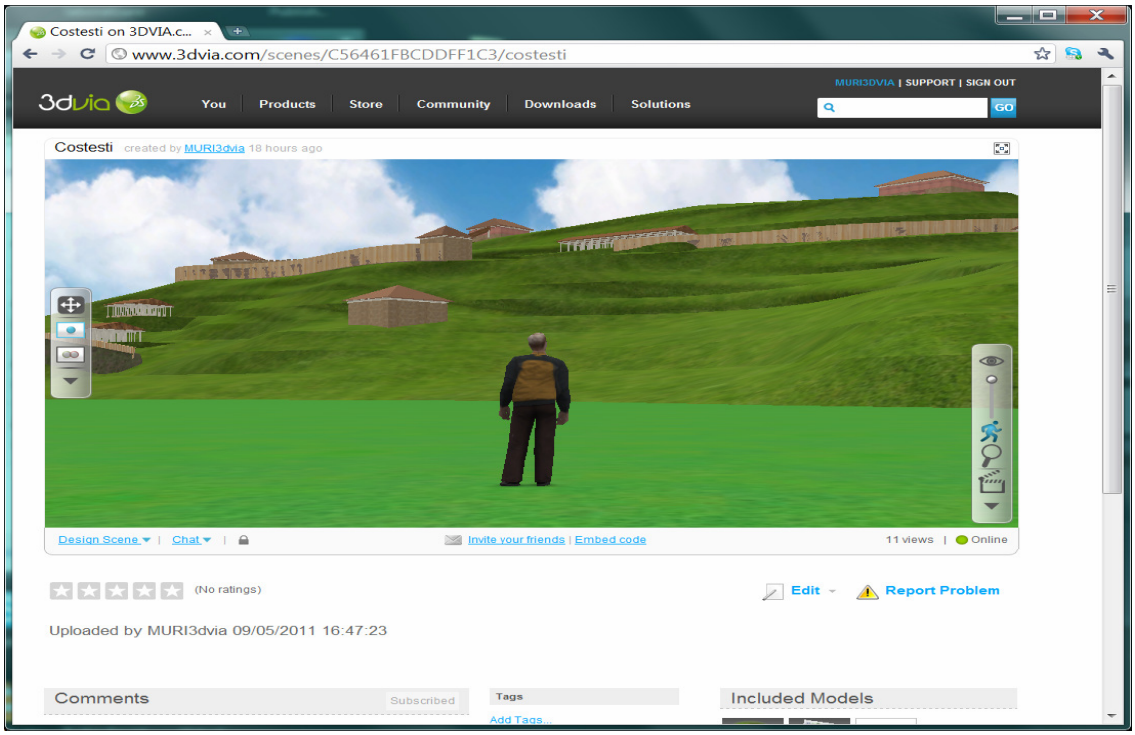

Fig. 10 - Virtual museum: Costesti fortress

system - e.g. anaglyph has costs related to the special glasses needed) by using a web browser and free plugin.

Conclusions

The 3D digitization of some categories of archaeological information can be performed using the CAD instrument Catia V5. The areas in which it can be used start with transforming archaeological excavation documentation (generally 2D drawings) into 3D models, and continue with digitizing artifacts and reconstructing large historical sites. The degree of detail is specific to the engineering sciences and is limited only by the patience of the CAD engineer and the availability of historical information needed for realizing the 3D model.

By using specific ad-ons for Catia, entire or partial artifacts can be scanned and transformed into 3D models with a high degree of fidelity. Pottery or even entire fortresses can be reconstructed with in-depth detail, at 1:1 scale, and in this way help in the confirmation or debunking of research hypotheses, or they can even lead to the appearance of new avenues for research.

Using Catia V5, one can realize detailed 2D documentations for any 3D model and also create simulations of some activities with the help of a virtual manikin that duplicates entirely the characteristics of the human body.

With the help of 3Dvia, virtual reality applications can be created, that use the 3D models realized in Catia, and which can be disseminated through the web towards the public at large for promoting the national patrimony.

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