Space, place and digital media: link to the world portal for cultural heritage through 3D virtual reconstruction "Towards better multiple techniques approach"

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Now, archaeology is positioned to take advantage due to the capabilities offered by the Web3D Consortium's successor to Virtual Reality Modelling Language (VRML). Because of Information and Communication Technologies (ICT), digital media enable researchers and designers to drive better information processes in solving problems of historical architectural reconstruction and virtual archaeology, such as 3D modelling, digital reconstruction and animation. So we create digital ancient worlds in the discipline called Virtual Heritage. This paper attempts to explore a digital reconstruction procedure for historical architecture and cities showing 3D scanning, Virtual Reality cave technology, motion capture technology and discuss some projects that elicited new insight about the ancient world. In the majority of cases, the data recovered from prehistoric architectural features are inadequate for the complete virtual reconstruction of a structure and its contents. The underlying issue is therefore focused on how "real" we should make our models, especially since the realism is inherent in 3D modelling. If done well, then the new approach can open up new possibilities to explore not only the past but also still unknown future. These studies include discussing many issues surrounding the process of creating virtual prehistoric architecture

فى الوقت الحاضر أخذ علم التراث مكانة بسبب الإمكانيات والقدرات المتاحة عن طريق نجاح توافق الشبكة ثلاثية الأبعاد مع لغة النمذجة بالواقع الإفتراضى "VRML". ونظرا لاتساع المعلومات والإتصالات التكنولوجية "ICT" ساعدت الوسائط الرقمية الباحثين والمصممين لصياغة أفضل العمليات لحل المشاكل المعقدة وذلك لإعادة إنشاء وتصميم العمارة التاريخية وعلم التراث الحقيقى، مثل النمذجة الرقمية ثلاثية الأبعاد وإعادة الهيكلة الحقيقية والحركة حتى نخلق بتهذيب الرقمية في العالم القديم بما يسمى التراث الافتراضيى. وبالتالي يمكن خلق عالم تاريخى رقمى - الذى يطلق عليه التراث الافتراضيى. تهدف هذه الورقة البحثية إلى إستكتشاف طريقة للنمذجة الرقمية للعمارة التاريخية ومسح المدن ثلاثى الأبعاد وتكنولوجيا الواقع الإفتراضى، ويتناول البحث مناقشة بعض المشاريع التى تبرز بعض الرؤى الجديدة والخاصة بالعالم التاريخى القديم. وفى معظم الحالات تعتبر البيانات والمعلومات المستنبطة من ملامح عمارة ما قبل التاريخ مبهمة وغير كافية لنمذجة واقعية كاملة خاصة بمنشأ ما ومحتوياته، ويلقى هذا البحث الضوء على كيفية "واقعية" صنع نماذجنا وخصوصا منذ اكتشاف الواقعية فى النمذجة الثلاثية الأبعاد. إذا تم ذلك جيدا، فإن النهج الجديد يمكن أن يفتح إمكانيات جديدة ليس فقط لاستكشاف الماضي وإنما أيضا في مستقبل لا يزال مجهولا. وهذه الدراسة تشمل مناقشة العديد من القضايا التي تكتنف عملية خلق إفتراضية لعمارة ما قبل التاريخ.

Keywords: Cultural heritage, Digital media, Virtual reality, 3D virtual reconstruction

1. Introduction

In Archaeology, reconstruction of ancient artefacts and scenes is essential for scientific discovery and humanity inspiration, where science is not only logical reasoning but also creative perception, skilful crafting, and effective communication. In many cases, archaeologists are more or less like detectives who try to put pieces of information together and use scientific reasoning and visual rendering to fill the gaps among the evidences, [1]. Constructionism states that people do not simply get ideas but construct them. Simulation or reconstruction has been a key for understanding complex scene, spatiotemporal relationship and sequential context. Digital reconstruction is an emerging method for rapid and efficient prototyping of assumptions and visual reasoning.

The reconstruction of prehistoric architecture using three-dimensional (3D)

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modeling software involves a series of compromises concerning what should or should not be portrayed in a 3D model. In the majority of cases, the data recovered from prehistoric architectural features are inadequate for the complete virtual reconstruction of a structure and its contents. The underlying issue is therefore focused on how "real" we should make our models, especially since the realism inherent in 3D modeling is easy to construe as the past reality when in fact a large proportion of what the viewer sees is heavily dependent on numerous inferences made by the modeler in the absence of relevant data [2].

This paper discusses the many issues surrounding the process of creating virtual prehistoric architecture. In addition to the central concern of how to balance realism vs. reality, the discussion considers how decisions in the creation of virtual architecture are further constrained by the goals of the project and the intended audience, the desired product, the quality of archaeological information, and technological capabilities.

2. Documentation and preservation of our heritage

In an age of mass communication, rampant technology and growing cultural homogeneity, there is a need to search for our identity and relation to our ancestors who have left behind traces of their presence. For this purpose, a compelling experience of legacy structures can be created through the use of historical data and facts, three-dimensional graphics, virtual reality techniques, surround sound and immersive environments. Our ancient monuments are rich with memories of past events that can be revitalized and presented to the world through the use of immersive media environments. We now have a marriage between ancient history and contemporary technology, a channel through which we can view and experience the glory the ancient monuments in three-dimensional immersive media and surround sound, [3, 4]. See fig. 1.

3. Virtual reality as a new opportunity for scientific community

How technologies, and in particular virtual reality, can develop the organization, visualization, interpretation of cultural contents? How can they support us in the creation of integrated informative systems? Which are the most efficacious ways to interact with models and metadata? How can we share and exchange data? How can we make a model or a reconstruction "transparent"? [5].

In the last ten years the integration between visual technologies and cultural heritage has been developed through theoretical discussions, publications, applications, but, especially in the virtual reality domain, results are still quite partial in comparison with the great potentiality of virtual reality in this field of applications. It is not only a problem of accessibility and sustainability of digital technologies: the real problem is the creation and dissemination, in the field of cultural heritage, of a new language, a new alphabet, new metaphors of interaction, that can be recognized and accepted, first of all from the community of experts, as a new, useful approach both in interpretation processes and in communication of cultural contents, [6].

Virtual Reality (VR) offers new dimensions for presentation of spatial (3D) objects. One of the main advantages is the possibility to investigate these objects from any viewpoint and at any level of detail in a real time. This sort of investigation is very user friendly because the user behaves in virtual reality in similar way as in a real environment. Moreover virtual reality offers new possibilities that are mostly non-existent in real world (or possibilities that can be exploited with extreme difficulties), [7].

Many cultural heritage applications require 3D reconstruction of real world objects and scenes. The motives are numerous:

1. To document historic buildings, sites, and objects for reconstruction or restoration if they are ever destroyed, for example by fire, earthquake, flood, war, or erosion.
2. To create education resources for history and culture students and researchers.

3. To reconstruct historic monuments that no longer exist, or partially exist.
4. To Visualize scenes from viewpoints that are impossible in the real world due to size or surrounding objects.
5. To Interact with objects without risk of damage.
6. Virtual tourism and virtual museum.

In general, most applications specify a number of requirements:
1. High geometric accuracy
2. Capturing all details
3. Photo-realism
4. Full automation
5. Low cost
6. Portability
7. Flexibility in applications
8. Efficiency in model size

4. An approach to virtual heritage

"Our cultural and natural heritages are both irreplaceable sources of life and inspiration. They are our touchstones, our points of reference, our identity". UNESCO, 2000.

Heritage is considered to encompass more than the material archaeological retrieval of past evidence. Heritage also includes tradition, artistic expression and "cultural evidences" [8]. UNESCO (United Nations Educational Scientific and Cultural Organization) defines heritage as "our legacy from the past, what we live with today, and what we pass on to future generations" (UNESCO, 2000). In both definitions, the concept is not restricted to manmade concrete artifacts, but includes natural landscape sites and abstract cultural manifestations, [9]. See fig. 2.

4.1. Virtual reconstruction

The process of creating images for the visualization of historical buildings is not exclusive to the digital age. Recent computer generated imagery represents a modern version of previous hand drawn reconstructions [19], and likewise old image production techniques aim at producing visual outputs from the acquired or generated three-dimensional information [11].

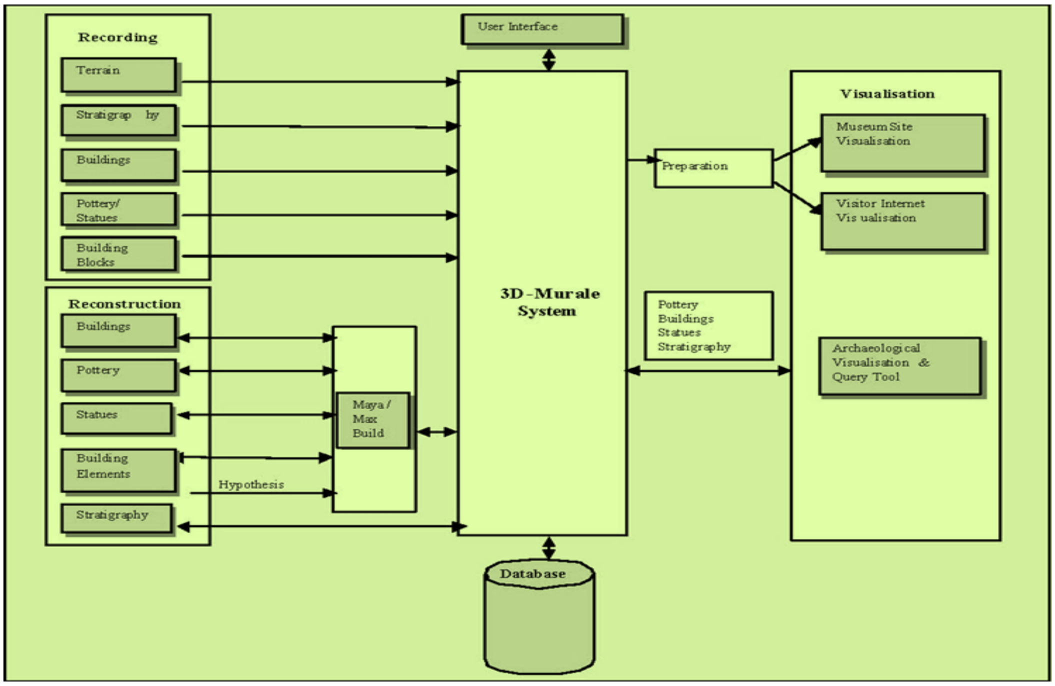


Fig. 1. Archaeological process, source: [4].

4.1.1. Benefits of 3d computer technology

Using 3D computer technology for Virtual Reconstruction allows us: [12, 13]

- The preservation of remnants.
- To study the different chronological stages of a project.
- To understand the different phases in the construction of a site.
- A representation and to evolve following new discoveries.
- To study different hypothetical theories.
- A better conservation of an archaeological site keeping maintenance to a minimum.
- To reduce degradation and destruction resulting from the frequency of visitors and atmospheric conditions.
- To preserve, in the event of re construction, the dilemma between old and new constructions.
- To avoid lengthy administrative authorizations, and the various standards to be met.
- A large variety of elements for use in publication (fixed images, videos, CD-rom, etc…)
- To provide a more accessible and comprehensible vision to the public.

4.1.2. Digital reconstruction and interactive presentation of heritage

Reconstructing a historical site as it once was or as it evolved over time is one of the most important goals of virtual heritage. The remains of the site, or the site in its present state, either at its original location or where it is currently residing, can be digitized in 3D using digital cameras or laser scanners. Non-existing parts or changed elements have to be reconstructed from any available records such as paintings, old photos, sketches/drawings, written accounts, expert information, and data from similar more complete remains of objects from the same, [14]. Constructionism states that people do not simply get ideas but construct them. Simulation or reconstruction has been a key for understanding complex scene, spatiotemporal relationship and sequential context. Digital reconstruction is an emerging method for rapid and efficient prototyping of assumptions and visual reasoning, [15]. One can anticipate two scenarios:

1. The site/object has changed, damaged, or destroyed.
2. Parts or the entire site have been removed and scattered at various locations such as museums.

Both have modeling and visualisation challenges and require novel presentation to create a virtual site as it has originally been or during other time periods and as it is now, considering that both experts and non-experts are to use the system.

Fig. 2. High-end VR displays considered for sagalassos virtual guide, source: [10].

4.1.3. Virtual reconstruction as inverse physics

The reconstruction work is beyond simple logical reasoning and crafting. The discovery process is similar to a crime scene investigation. The importance of realism VS reality in 3D modeling depends to a large degree on the goals of the reconstruction and on the constraints that affect the modeling process. The problem solving process involves significant '*inverse physics*.' Thus, given remaining pieces, reconstruct the artifact, process or relationship. The goals of a virtual reconstruction and the intended audience are not the only factors that structure how the modeler moves between the reality of the archaeological record and the realism represented by the 3D model. Also important are the quality of the available archaeological information from which to draw interpretations as well as the technological capabilities available to the modeler. The virtual reconstruction of architectural features has yet to play a substantial role in archaeological research.

There are many cognitive processes involved in the reconstruction, such as assumptions and analogies, which play a significant role in the reconstruction. Unfortunately, those inverse physics processes are hidden as 'experience', or ambient intelligence rather than explicit science. We know that 'forward physics' can be solved by mathematical equations, however, inverse physics normally has multiple solutions and mainly is pattern recognition-based. A rapid reconstruction method is desirable to verify, or often present the assumptions to archaeologists. In addition, the reconstructed models often serve as a media for the communication between people in different fields or in public media, [1]. The discovery process is illustrated, See fig. 3.

Archaeologists have been involved in 3D reconstructions of prehistoric architectural features for as long as the discipline has existed. The modeling of prehistoric architecture to address research questions is obviously concerned with the faithful replication of the archaeological record. In archaeology, there are significant spatiotemporal analogies for reconstruction:

• Timeline analogy – In archeology, history is divided by 'ages', e.g. stone age. By estimating which age the artifacts belong to, archaeologists can reason about the possible process, culture, figures that are not in the excavation scenes.

• Proxy analogy – The figure, culture and habitation in a location today might similar to the inhabits in the past, given limited time span.

While analogy can generate endless solutions, there are some 'principles' to reduce the number of solutions:

• Physical principle – the best possible solution is the one with less negative evidences and most consist supporting evidence.

• Minimal principle – the selectable solution is the one with minimal assumptions and minimal supporting materials, and minimal energy consumption.

Therefore the reconstruction is a process of selections along with a growing decision tree. The scientific discoveries lie in the reconstruction process. So, the production of 3D reconstructions of non extant prehistoric architecture requires a careful consideration of the amount of realism conveyed and the faithfulness of the model to archaeological reality. At the basic level, these two objectives will never be commensurate simply because the archaeological record is necessarily an incomplete reflection of prehistoric reality, [16].

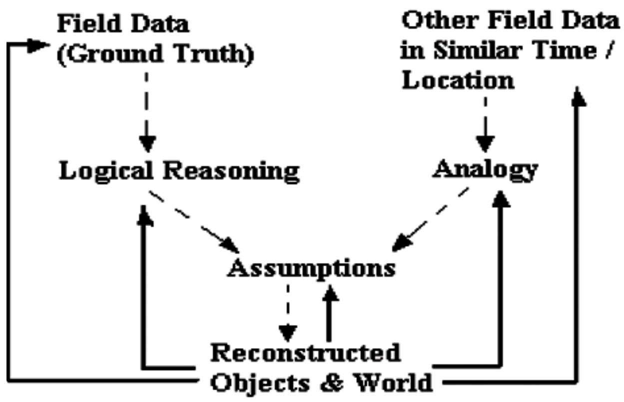


Fig. 3. Inverse physics process, source: [1].

4.1.4. Reconstruction as a bridge between minds

One possible use of Virtual Heritage (VH), is by an archeologist is working on a site, so that s/he can use VR to convey his or her mental images of some fragmentary site or object. On a superficial level, this is certainly possible; the Archeologist can simply create a virtual model of the space or object for others to look at. In this way, VR can be a bridge between the expert and the novice, so knowledge can be conveyed to the student. In addition, VR can also be used to assist two-way communication-allowing the students to interact with each other, constructing mutually understood knowledge under the instructor's guidance. However, the novice most needs to understand the meaning of what s/he sees and that is much more difficult to convey. It is possible to add some features to the VR experience which conveys some of the meaning of an archeological site or objects. Other senses can be used as well, [17].

One of the best uses of a virtual model is that it is mental tool to help the student organize the things s/he is learning about the site or artifact. However, VR is best used in combination with other media and methods for an integrated learning approach. Nevertheless VR brings unique advantages such as allowing the student to explore places and things that long longer exist or that might be too dangerous or too expensive to visit. It allows the students and instructor interact in a new way, opening many possibilities for collaboration. Most importantly, VR can also bring things to life, especially allowing the user to explore ancient cultures, [17].

Heritage virtual models disseminated through the Internet, and in numerous websites provide a vast number of examples with diverse objectives and presentation technologies. An initial contact with web-based heritage models shows recognizable presentation levels. Recent technological development grew from previous mistakes, now constituting a "new hope" for virtual heritage according to Addison [18]. Who groups the emerging technologies into the following domains:

1. 3D documentation – related to methods and processes applied to site investigation and information acquisition, "everything from site surveys to epigraphy".
2. 3D representation – involves "historic reconstruction to visualization".
3. 3D dissemination – responsible for providing access to the generated content, “from immersive networked worlds to "in situ" augmented reality".

A common agreement among several analyses of the virtual reconstruction process refers to the initial project phase, or data acquisition. Barceló (2000) defines four necessary stages to produce a heritage geometric model: data research, pre processing, parameter estimation and modeling, [19]. Addison (2000) uses a similar classification with different terms, and adds one more step to the information flow: presentation and dissemination, addressing the problem of maximizing the public exposure of the content produced by the three-dimensional visualization. (Addison, 2000) groups the process in the following stages: "documentation – getting the data in", "representation – authoring, modeling, and rendering" and "presentation – dissemination", [18].

4.2. Virtual heritage

"Virtual heritage can be an invaluable tool, but if not applied wisely has the potential to do as much harm as good". Addison, 2000, [18].

As well as the hypertext that retakes and transforms the old interfaces of the writing, the technology of Virtual Heritage changes the Computer Graphic. The Virtual Heritage, direct heiress of the Virtual Reality, allows to the current and future generations, the observation of the construction of cities of the antique, today just in ruins, or even of the contemporary cities.

VH is the use of electronic media to recreate, or interpret, culture and cultural artifacts as they are today or as they might have been in the past. By definition, VH applications employ some kind of three dimensional representations and the means used to display it range from still photos to immersive virtual reality. This is a very active area of research and development. The majority of VH applications are architectural reconstructions, centered on a reconstructed building or monument, and most of them use VRML technology [17].

Roussou (2000), describes virtual heritage as a six step process involving "synthesis, conservation, reproduction, representation, digital reprocessing, and display with the use of advanced imaging technology" The term is similar to 'virtual archaeology' [8], according to Forte (2000) a "digital reconstructive archaeology" which is "applied to the reconstruction of three-dimensional archaeological ecosystems" [11]. Ryan (2000) relates both concepts by mentioning that virtual archaeology expanded from its initial uses as a tool solely related to "excavation recording" and presentation [20], to a wider set of applications covering "visualization and presentation methods to the 'reconstruction' of past environments, including buildings, landscapes and artifacts" [21].

The Virtual Heritage, in its quality of new technology, is not precisely defined. Several researchers are working in that new border of the knowledge, creating their own researches and generating a new bibliography. "The concept of Virtual Heritage comes to be an evolution of the idea of Virtual Archaeology, that Paul Reilly defined in 1990 as the use of computers modeling workmanship and old buildings. Using the computer, with modeling in 3D to recreate workmanship and buildings of the antique. So the purpose of Virtual Heritage is the utilization of technology for the education, interpretation, conservation and preservation of Natural, Cultural and World Heritage sites". In conclusion, we can say that Virtual Heritage consists of [22].

• A tool originated in the Virtual Reality aiming at a better study of the past.
• An economical way of to preserve and to diffuse the cultural legacy of a country; and
• A form of promoting the democratization, with the diffusion of the information, of the country's cultural Heritage.

Boukhari (2000) developed an elaborate list of functions and possible benefits that "digitization and animation techniques" p. 40 may present when applied to heritage reconstruction [23].

1. "Recreate the appearance of famous historical figures and sites that have crumbled away".
2. "Restoration of fragile or badly damaged artworks".
3. "Provide useful tools for archaeologists and curators of museums and sites".

Also mentions the testing of possible alternatives in virtual reconstructions and improvement of available information databases, leading to the fourth and fifth functions:

4. "Simulation of archaeological hypotheses".
5. "Acquisition of new knowledge".

A sixth function relates to the preservation of heritage threatened by human activities such as "wars, pollution, urban expansion and theft":

6. "Back-up digital images of monuments and objects".

The following topics are associated with the contribution of virtual models to real reconstruction initiatives:

7. "Guide in the real-life reconstruction".
8. "Fund raising tool for a real reconstruction project".

A ninth function refers the use of a computer model for structural analysis of the original real
building or object:

9. "Structural simulation".

And finally the last usage possibility cites general public applications intended to:

10. "Educate and entertain visitors" in museums.

4.3. Limitations of virtual heritage

An archaeological reconstruction is necessarily pieced together from existing evidence which requires many judgments during construction. Depending on the level of conjecture tolerated by the reconstruction project, the creators may produce a reconstruction based on one of several competing theories of what the artifact really looked like. However, the final appearance of a static model is emphatic in the way it presents the model as the way the artifact looked. Uninformed viewers are likely to accept the model as authoritative, [24, 25]. A static visual solution, like coding features with colors or with opacity would seriously degrade the appearance and the effectiveness of the model. Temporal solutions, like toggling certain features on and off, are probably best, but they complicate interaction design and are more difficult to implement, [17]. Also, archaeological evidence of any site reflects its entire history, not some snapshot in time. For example, ancient monuments with a long history may have features from more than one time period. Deciding what to put into the virtual reconstruction requires considerable judgment and sensitivity from the authors. The Venice Charter [26], on physical restorations and reconstructions recommends that all time periods represented in an artifact should be respected.

5. Reality and realism in 3D architectural reconstructions

Archaeologists have been involved in 3D reconstructions of prehistoric architectural features for as long as the discipline has existed. Sketches showing intact structures embellished with complete artifacts and surrounded by human figures have often accompanied both popular summaries of prehistoric societies and technical site reports, [27]. The intent of these sketches has always clearly been to portray how the architecture might have looked in the past when it was in active use by prehistoric groups. Such depictions have never been so realistic that they were confused with a past reality; in other words, viewers of these sketches have always been able to tell that their creators employed a considerable amount of artistic license to "bring the past alive." The importance of realism vs. reality in 3D modeling depends to a large degree on the goals of the reconstruction and on the constraints that affect the modeling process, [28].

6. Fusion of 3D information for site and object modeling

When describing and explaining the history of a heritage site or an artifact, the use of spatial information becomes very important in order to facilitate an understanding of that particular site. One can resort to hand drawn or computer generated isometric views, CAD models based on more of less reality and 3D models built from reality. The source of information includes among other things drawing/paintings, papers/digital photographs, or laser scanner data. Some of these provide dimensions directly but others need indirect ways to get scale and/or dimensions. In many cases, one has to model complex environments. These are composed of several objects with various characteristics and it is essential to combine data from different sensors and information from different sources. There is no single approach that works for all types of environment and at the same time is fully automated and satisfies the requirements of every application.

A general approach combines models created from multiple images, single images, range sensors, known shapes, CAD drawings, existing maps, survey data, and GPS data. A survey of the literature on multi-sensor data fusion can generate a long list of papers and books describing the theory and the different applications where data fusion is critical. We will say that it is known that multi-sensor data fusion techniques combine data from multiple sensors and related information from associated databases, to achieve improved accuracies and more specific inferences than could be achieved by the use of a single sensor alone. An example of this approach is the integration of laser scanning and close-range photogrammetry from a multi-sensor and information fusion point of view. Beraldin presents the key features of different laser scanner technologies and photogrammetry-based systems that should be considered in order to realize the benefits expected in a multi-sensor platform, [29].

7. Technological capabilities

Appropriate technology and skills can play a major role in determining the scope and quality of a 3D model of prehistoric architecture. If the archaeologist is attempting to construct the model alone, he or she might not be expected to have either the modeling skills or the access to powerful hardware and software needed to produce a superior model. Accordingly, the most successful examples of high-quality reconstructions involve collaborations between archaeologists and either architects or computer artists specializing in architectural visualization, in which case the degree of communication between those with the archaeological knowledge and those with the modeling skills becomes critical. The increasing desire to create 3D models of prehistoric architecture is also beginning to sustain a small private industry of professionals with both the tools and experience to create superior 3D reconstructions. Many of these professionals have been trained both in archaeology and in computer graphics, making them perfect for bridging between the prehistoric reality and a model's realism, [28].

8. Overview of 3d modeling techniques (collecting data for 3d reconstruction of VR)

Techniques and related work of modeling complex architectures is reviewed in this section. The effectiveness of the techniques in modeling such architectures will be argued. Problems associated with each will also be discussed and, when possible, a solution will be proposed, [30].

8.1. Cad and architectural drawings

A standard approach to create a model is to build it from scratch using tools, such as CAD software, that offer building blocks in the form of primitive 3D shapes. Some surveying data, or measurements from drawings and maps will also be required, [31], Traditional 3-D CAD techniques using architectural drawings remain the most common. Many use synthetic textures, which yield a computer-generated look. Some projects used textures from images, which offer a more realistic appearance, [30].

In the case of drawings created directly in digital information to be arranged in separate layers, each containing different type of elements. Some adjustments to obtain consistent local geometry and layout topology are needed, [30, 32].

8.2. Laser scanning

Form from surveying data, file formats such as AutoCAD or DXF allow the laser scanning is increasingly being used for large site digitization. Laser scanners promise to provide highly detailed and accurate representation of any shape. Combined with color information, either from the scanner itself or from a digital camera, a realistic-looking model can be created. The accuracy at a given range varies significantly from one scanner to another. Also, due to object size, shape, and occlusions, it is usually necessary to use multiple scans from different locations to cover every surface. Aligning and integrating the different scans will affect the final accuracy of the 3-D model. The generated data can also be too large in size to be practical for a large complex site without significant simplification, [30, 32].

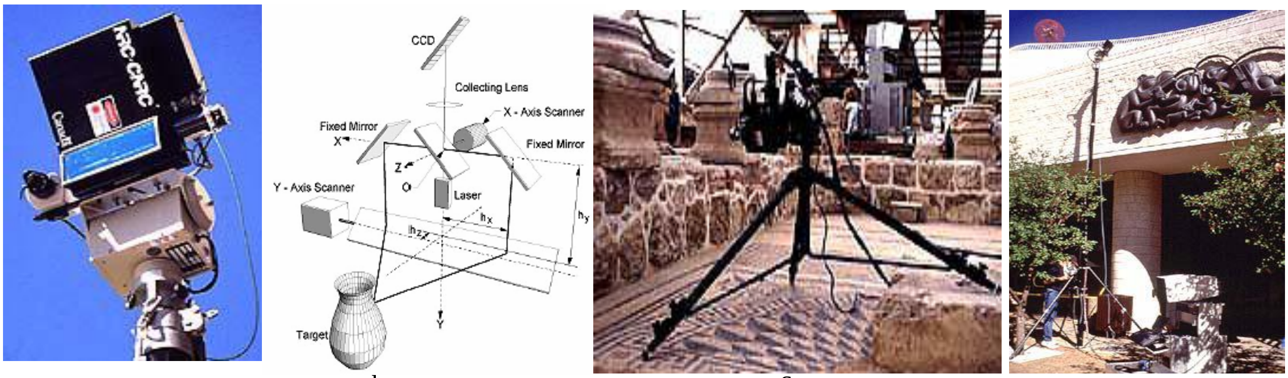
For example The Visual Information Technology Group of the National Research Council of Canada (NRC), has developed three high resolution 3D digital or "laser scanner" imaging systems and processing algorithms which have been applied to a variety of heritage recording projects. They have been used in the field to digitize archaeological site features, architectural elements on historic buildings and large sculptures, See fig 4. [33].

Christian Früh has developed a mobile ground-based data acquisition system consisting of two Sick LMS 2D laser scanners and a digital color camera with a wide-angle lens [6]. The data acquisition is performed in a fast drive-by rather than a stop-and-go fashion, enabling short acquisition times limited only by traffic conditions. As shown in Figure 3, our acquisition system is mounted on a rack on top of a truck, enabling us to obtain measurements that are not obstructed by objects such as pedestrians and cars, see fig. 5, 6, [34].

Most of laser scanner application, also in Cultural Heritage applications, presented in last years makes use of time of flight scanning systems. 3D coordinates of an object are derived measuring the time the laser signal spent from the laser head to the object and back. Generally time of flight systems allow unambiguous measurements of distances up to several hundred of metres and are generally characterized by middle speed of acquisition. Beside the time of flight principle, the phase measurement principle is the other technique for medium ranges. High acquisition rate and high density of 3D point's acquisition are the peculiar characteristics of phase-shift systems. Several instrument configuration of the measuring head and of the internal mirrors are available for both the measuring technologies; the geometry of the laser field of acquisition can varies from a fixed window – like a digital camera – to approximately 360° field of view, [35].

Both laser scanner instruments and 3D data software are in continuous development. *Laser scanner* development is mainly oriented: [35]

• To reduce laser dimension and weigh.
• To increase accuracy and resolution.
• To increase range of acquisition.
• To reduce time of acquisition.
• To increase accuracy in positioning laser head along the local verticality: the possibility to set instrument verticality with high accuracy should simplify geo-referencing phase.
• To acquire colours information using internal or external digital camera.
• To reduce laser control by external PC by simplifying acquisition set up and including memory unit inside laser machine.



a b c d

Fig. 4-a. The Large Volume Laser Scanner mounted on pan and tilt unit. The system includes a video camera to facilitate remote positioning of the scanner. b. Schematic optical configuration of the dual axis scanner. c. The scanner is mounded on a conventional tripod to scan archaeological site features at Caesarea in Israel. d. The camera is mounted on a telescoping tripod to scan the sculpture Mythic Messengers at the Canadian Museum of Civilization. The sculpture is mounted 4 m above ground [33].

Fig. 5. Acquisition vehicle, source: [34].

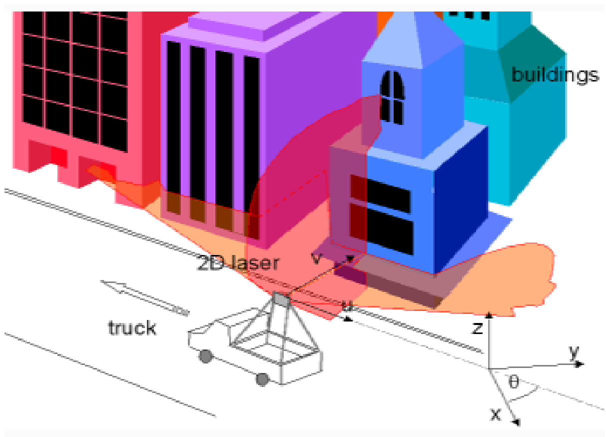


Fig. 6. Ground-based acquisition setup, source: [34].

8.3. Photogrammetry [*30*]

Many successful interactive photogrammetric and image-based techniques are available. Also several commercial software products are available and were successfully used in many projects over the past few years. Photogrammetry and surveying was used to model medieval castles in Western Sicily. The methods are still labor intensive and the projects may take several years to complete.

8.4. Automated image-based techniques

Image based modeling entails widely available hardware and potentially the same system can be used for a wide range of objects and scenes. They are also capable of producing realistic looking models and those based on photogrammetry have high geometric accuracy. Three-dimensional measurement from images naturally requires that interest points or edges be visible in the image. This is often not possible either because a region is hidden or occluded behind an object or a surface, or because there is no mark, edge, or visual feature to extract. In objects such as monuments in their normal settings we are also faced with the restrictions of limited locations from which the images can be taken as well as the existence of other objects, shadows and illumination, [31].

Most of the efforts of current techniques are focused on the automatic recovery of internal and external camera parameters and the stereo matching of extracted points. On the other hand, acquiring points suitable for modeling and creating the model itself, which involves segmenting the point clouds into topologically meaningful groups, remain interactive, [36]. To our knowledge, no large complex site model was completed based purely on fully automated image-based techniques. Only small sections of large structures have been modeled automatically. Closely spaced images, like low-resolution videos, are required for robust matching. This may be difficult to acquire for a large complex structure, [30].

8.5. Combination of multiple techniques

From the above summary of current techniques, it is obvious that none by itself can satisfy all the requirements of culture heritage applications**.** Tools to assemble models created by various techniques are required to create one model suitable for documentation and visualization, [37]. In addition to differences in coordinate systems and scale, the models will also not perfectly match at joint primitives such as surfaces, edges, and vertices. Some of those will overlap or intersect and some will be disjointed, which is unacceptable. Again, commercial CAD and rendering software do not address these problems therefore special tools must be developed for this purpose.

Sabry El-Hakim had proposed procedure which is hierarchical, depending on the data source, where the details, accuracy and reliability increase as we advance from one data type level to the next. Therefore, data in one level overrides the data in previous levels, [30]. See fig 7.

The following steps provide a general outline of the approach to fully model a complex site. Note that the first six steps can be performed in any order or simultaneously: [30].

1. Calibrate the digital camera for its internal parameters.
2. Survey some points, for example with a total station.
3. Acquire a floor plan in digital form and create rough 3-D model. This model will lack most of the details.
4. Acquire aerial images and create the overall model.
5. Acquire terrestrial images and create detailed models.
6. Acquire data from a high-accuracy laser scanner if available and create fine detailed models.
7. Register and integrate the models created from sensor data
8. Parts without data exposure are completed from floor plans. Missing sensor data can be intentional for uninteresting parts, or inevitable due to lack of access or improper coverage.

9. Additional sources of data may be needed to reconstruct lost parts of the castle.

Those are usually drawings, sketches, paintings, or frescos. They will usually be incorrect as a source of 3D reconstruction, but they can be calibrated if some elements in the drawings still exist now. For example, parts of the Stenico castle towers as depicted in the January panel of the "cycle of months" frescoes in Aquila Tower at Buonconsiglio castle in Trento, are now destroyed. We will use the frescos to reconstruct those parts, See fig 8, 9, 10, 11, 12 example of VR of old castle made by Sabry El-Hakim, [30].

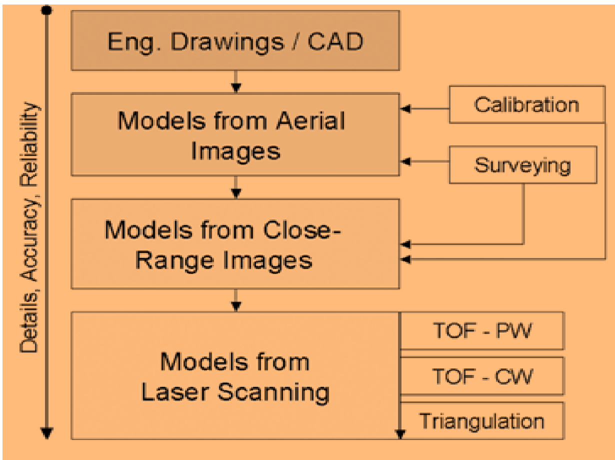
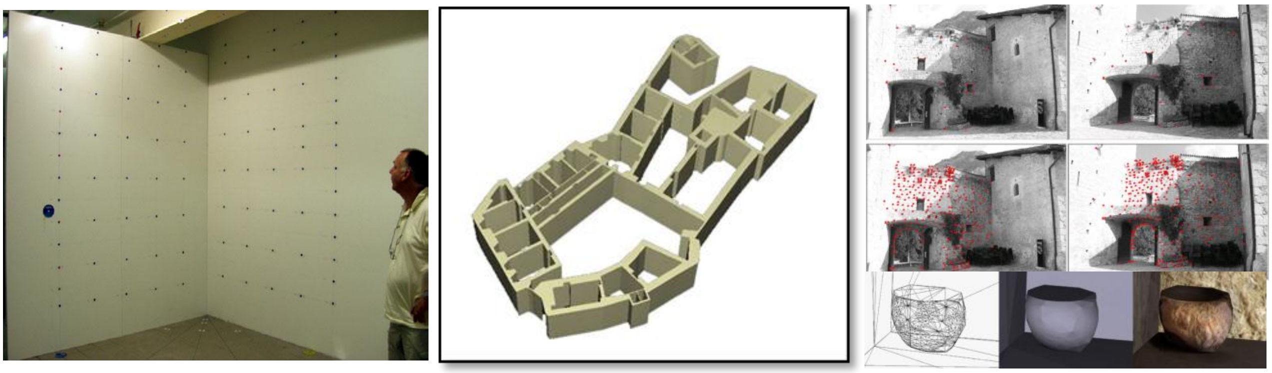


Fig. 7. Hierarchy of model assembly, source: [30].



(a) (b) (c)

Fig. 8 –a. Calibration targets, b. 3-D building model extruded from floor plans. c. Top pair with manually picked seed points, middle pair with automatically matched points on a castle entrance, bottom Detailed model where matching was applied.

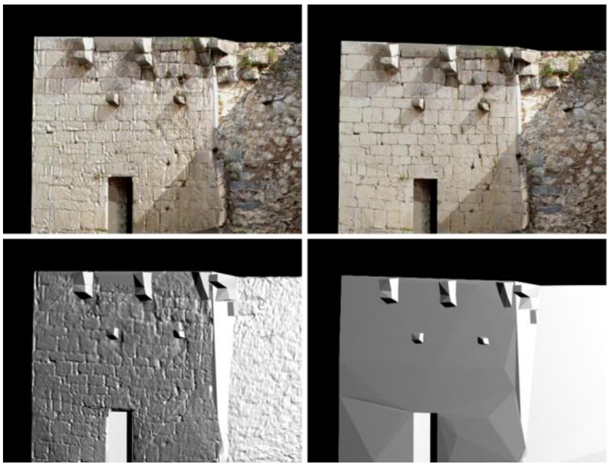


Fig. 9. Left pair with displace modifier approximating stone surface geometry. Right pair has flat surfaces.

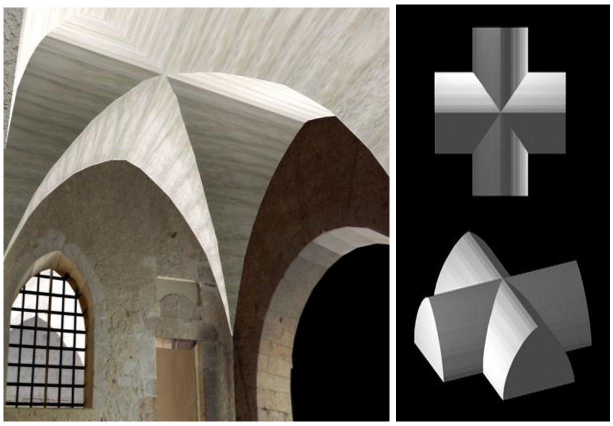


Fig. 10. Left: Groin vaulted ceiling modeled with 3ds max®. Right: Two arches extruded at right angles form a mould for the ceiling model.

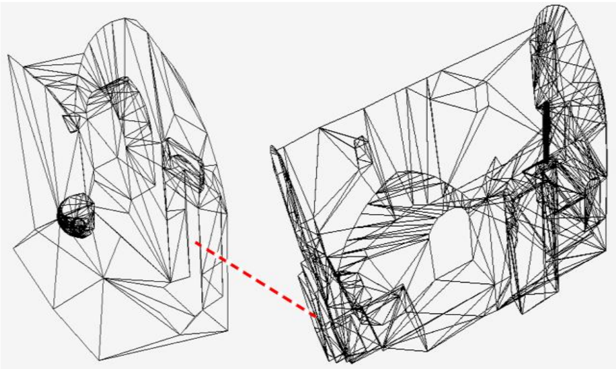


Fig. 11. Two adjacent models connected by a portal.

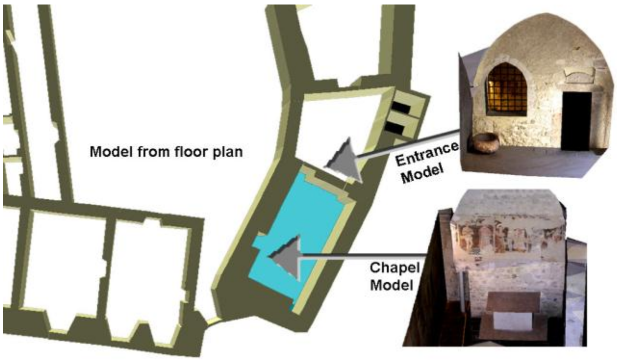


Fig. 12. Position detailed models using floor plans.

An example of VR of Hagia Sophia building source: [6]. See fig 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24.

(a) (b)

(b)

Fig. 13 –a. Exterior photograph, b. lithography from the album by the Fossati brothers.

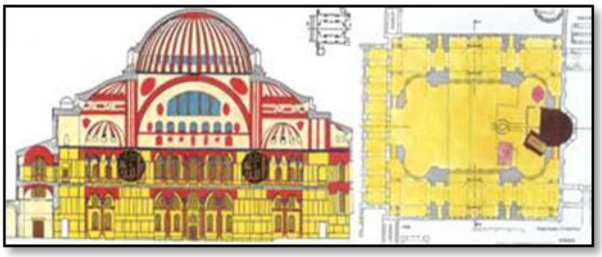


Fig. 14. Architectural plans of the Hagia Sophia building.

Fig. 15. On-site interior photos.

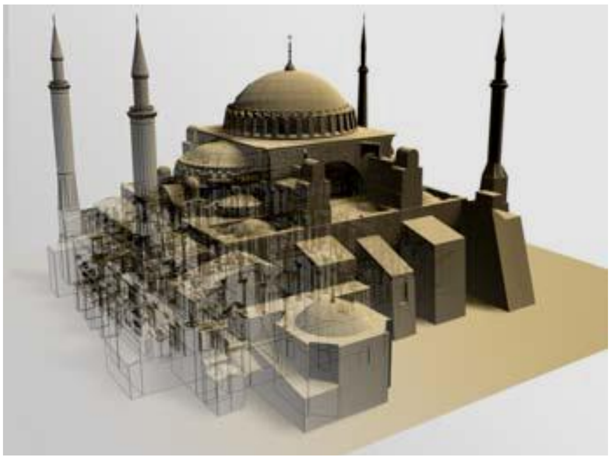


Fig. 16. View of the 3D model with wire-frame details

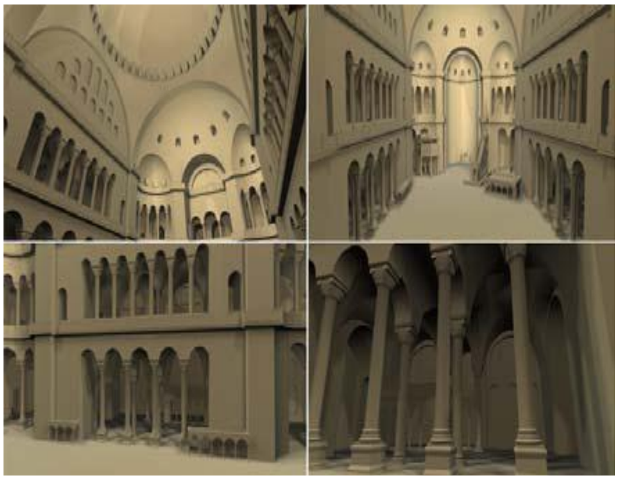


Fig. 17. Non-textured 3D model of the interior

Fig. 18. Details of the state of preservation of the surfaces inside the building.

Fig. 19. Virtually restored textures (upper part) vs. acquired textures (lower part).

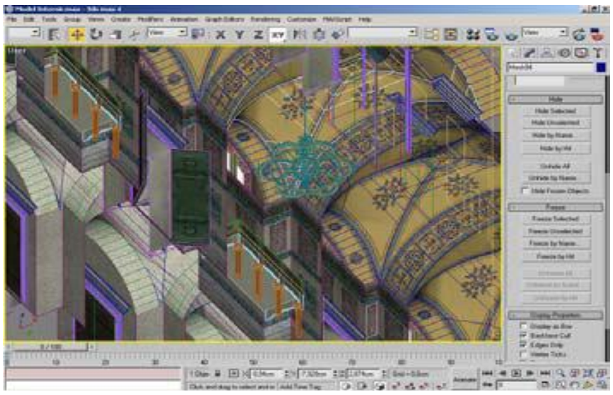


Fig. 20. Screenshot of the textured model during UV editing in 3D Studio MAX tm software package.

Fig. 21. Composed textures vs. source images.

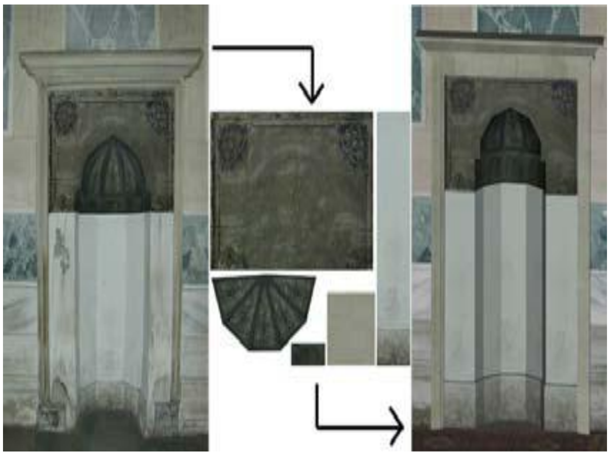


Fig. 22. image (left) and mapping to its corresponding 3D model Texture extraction from a photographic source (right).

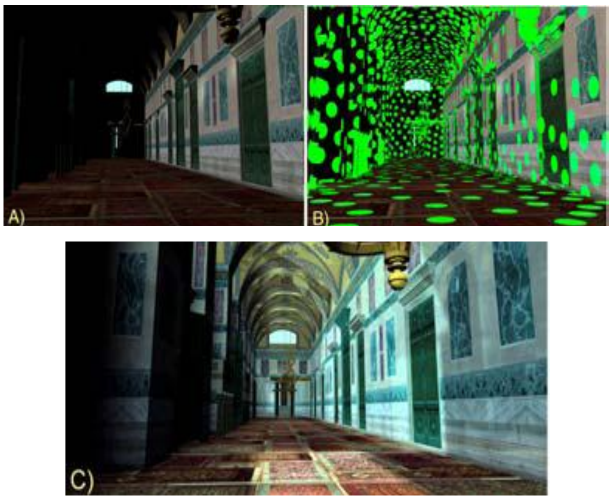


Fig. 23- A. 3D Studio MAX direct light, B. Final Render sampling points, C. Photon traced model.

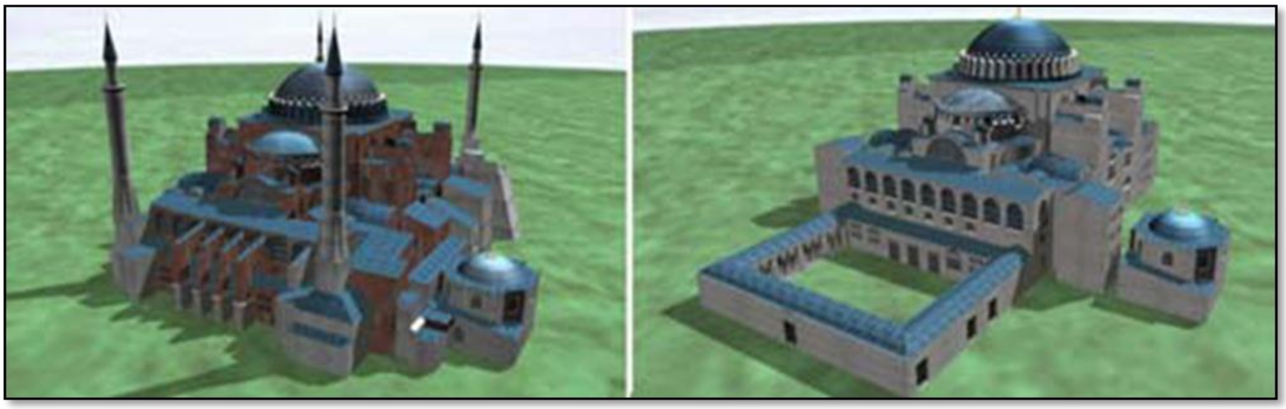


Fig. 24. 3D model of the exterior of the Islamic mosque (left) and of the Byzantine Cathedral (rig

9. Related work

9.1. Modeling and rendering procedure

To apply for modeling and visualisation of a heritage site through time are as follows:

• Collecting material and documents from different time periods and investigating the validity of each (is it a true representation or an artist's conception?)
• Creating 3D models from the documents using modeling from painting and old photos and CAD modeling from drawings and other information.
• Creating 3D models of existing parts with imaging and laser scanning techniques.
• Assembling all 3D models and other data; linking components to each other, correcting scale, filling gaps, and creating smooth transitions.
• Creating an interactive presentation and high quality pre-rendered animations with all models and data.
• Light modeling with different light types at various daytimes and seasons. [14, 38], See fig. 25.

9.2. Modeling 3D spatial vector data

With the developments of 3D GIS, a lot of research has been done to provide interactive visualization systems for 3D spatial data models of growing size and complexity. Interactive and high-fidelity 3D spatial data visualization plays an increasing important role in modern 3D GIS. 3D architecture modeling in an urban area in 3D GIS is an interesting case of the general modeling problem since geometries of architectures are typically very structured. People are familiar with what the results should look like, they have higher expectations of the quality for the results.

The difficulties in realizing 3D GIS or 3D geo-spatial systems result from these different side. Although spatial data can be modeled in different ways, the first difficulty is still the construction of a conceptual model of 3D data. The conceptual 3D model integrates information about semantics, 3D geometry and 3D spatial relationships (3D topology). The conceptual model provides the methods for describing real-world objects and spatial relationships between them. The design of a conceptual model is a subject of intensive investigations and several 3D models have already been reported, [39].

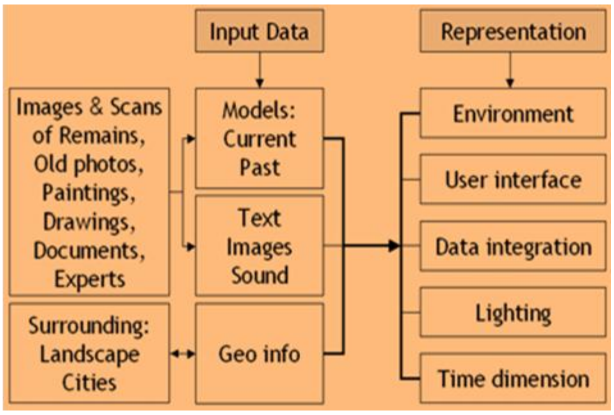


Fig. 25. Data input and representation, source: [14].

9.3. Virtual tour application

In order to make the virtual site accessible to users all over the world, the model needs to be distributed in an Internet-compliant way. Several choices exist ranging from a simple VRML-based scene that can be explored by today's standard web browsers to a customized plug-in offering functionality that is only relevant in the context of archaeology, [4].

A Web-based virtual tour system is built for the presentation of cultural heritage. In the proposed approach, the scene is captured from multiple viewpoints utilizing off-the shelf equipment. Y. Bastanlar and his group have developed and presented the techniques to extract the 3D structure from the acquired images based on stereoscopic techniques. For presentation and 3D modeling of outdoor cultural heritage, the proposed approach as a whole constitutes an economic and practical alternative to the 3D scanner technology. Generated 3D model of the scene, detailed site plans and interactive virtual tour tools such as 360° viewing were integrated with GIS technologies. The reconstructed VRML models are integrated with GIS technologies within a Web-based virtual tour system, after converting them to the XML-based Collada 3D file format and then referencing to them in Keyhole Markup Language (KML), a format supported by the Google Earth™ GIS platform. Reconstructed part of the archaeological site is placed at its exact location on the terrain. They added a hyperlink to the application described above, which directs users to a panoramic image based virtual-tour. The main item in this a tour is a viewing window that the user can control. Using Java Applet technology is one proper way of creating such Web-based applications. In addition to the images, audio or textual information related to the site can be presented to the users with extra WWW tools. Using a map of the archaeological site increases the comprehension of the tour and enhances the user's sense of orientation. A step further is making this site plan interactive and integrated with the viewing window. With such tools, more information is communicated to the virtual tour users in an ergonomic fashion, [40]. See fig 26, 27.

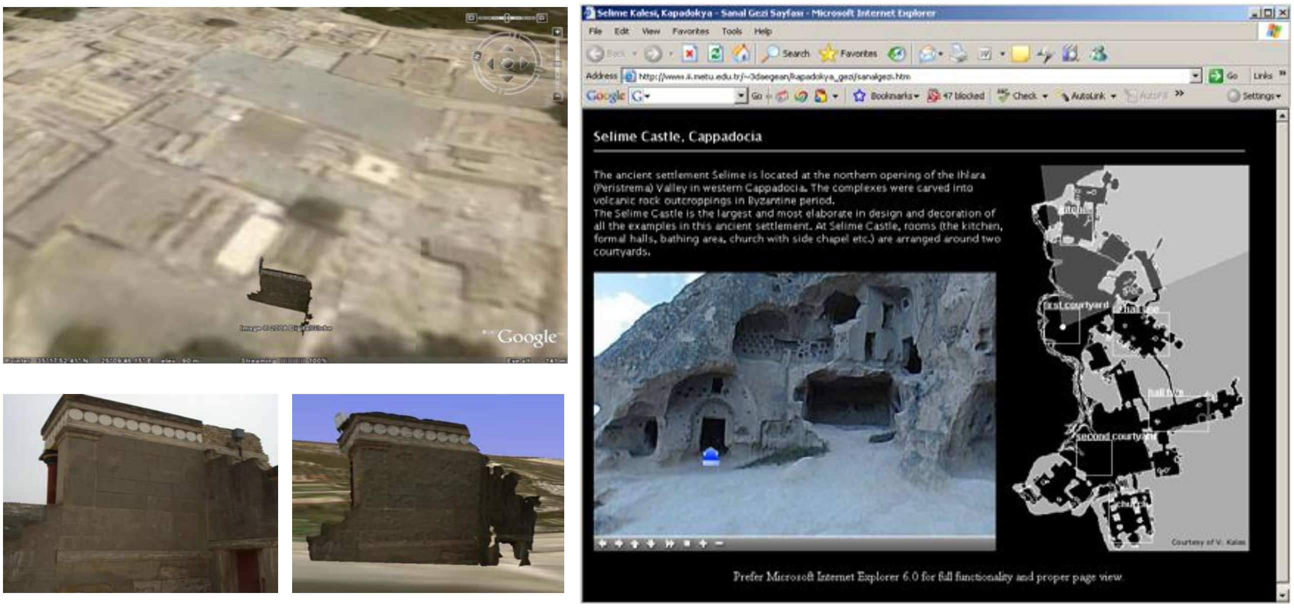


Fig. 26. (Left) Viewing models in Google Earth™. At the top, overall view of the site together with the reconstructed wall. Bottom-left is the close view of the 3D model of the reconstructed section. The image at bottom-right is a real photograph taken from archaeological site. (Right) A screenshot from the panoramic image based virtual tour, source: [40].

Fig. 27- a. Central Web Pages Navigation Scheme Designed by Jozef Martinka, b. A Screenshot from Virtual Bratislava Navigation Tool by Stanislav Stanek. Aerial Photo Courtesy Eurosense Slovakia. Terrestrial Photos by Matej Zeman. c. Strereoscopic View Created by Peter Borovsky, source: [7].

10. Conclusions

10.1. Link to the world portal for cultural heritag

The paper has addressed several critical issues in the virtual reconstruction and interactive visualisation of heritage sites that have undergone changes over time or no longer or partially exist. A multi-technique approach to creating detailed 3D models of cultural heritage sites, classical architectures, and monuments was presented. The production of 3D reconstructions of nonextant prehistoric architecture requires a careful consideration of the amount of realism conveyed and the faithfulness of the model to archaeological reality. At the basic level, these two objectives will never be commensurate simply because the archaeological record is necessarily an incomplete reflection of prehistoric reality. Further complicating the modeling process are the goals of the model, the intended audience, the quality of archaeological information, and the access to sufficient technology and skills. These factors can often work against each other, substantially complicating the production of the 3D model. Reconstructions will therefore benefit by a careful consideration of all potential constraints prior to the actual potential constraints prior to the actual modeling process. Perhaps most importantly, the presentation of the final model should be accompanied by a description of the original archaeological material and the inferences that were made to build a complete model. As 3D modeling software and hardware become more sophisticated, the amount of realism that can be created can mislead end users into believing that the model represents true prehistoric reality. While the power of these models to advance our pedagogical and research goals is undisputed, we need to be aware of the dangers of misrepresenting the past.

Virtual restitution of highly complex heritage sites requires accurate choices for each phase of the modeling, and special attention must be used when the models have to be prepared for real-time platforms. Furthermore precise and reliable source data is critical for a scientifically correct and accurate restitution. Interpretative and comparative issues are also necessary when the restitution is targeting lost architectural elements of the heritage site. Finally the use of new information technologies, in conjunction and with the essential sources and materials, has been presented here in order to describe a complete methodology for the restoration and renovation process of ancient monuments as a Link to world portal for cultural heritage. Hence with the utilization of the mentioned methodology for the situations where architectural restoration and protection are not available, virtual restoration and conservation is exhibited. Such virtual heritage simulations are a fundamental aspect for the full understanding of the historical and social development of vast communities and form a 'virtual material witness' of the process of civilization

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