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Abstract

It has been observed that Virtual Geographic Environments (VGEs) has been taking a lot of attention over the last decade, particularly within the domain of geographical information systems (GIS) and geographic analysis area. In this paper, we shed the light on the benefits of implementing archaeological visualization systems through the use of Google Earth application. Our application helps the end users and archaeologists working in data exploration and excavation analysis to deal with new web services that allows them to visualize huge amount of data in a new and usable way. For the purposed of our study, have tested our system with data from The Rocha Castle (an historic castle in the Galicia region (Spain) that was built in the 12th century). The system provides access to the excavation database and automatically updates the visualization, whenever the database is changed. The system can handle various types of Data, which could be, one, two or three-dimensional data. The paper aims to answer four fundamental questions regarding archaeological GIS systems: I. How to integrate a one and three dimensions representation into the same scenes? II. How to adapt data resolution to fit them into a particular Level of Visualization Detail (LOD) III. How to optimize data retrieval for efficient recovery data interpolation or continuous visualization? And finally IV. How to represent many objects in the same coordinates without overlapping?

Keywords: Virtual Geographic Environments (VGEs), Archeological Data Visualization, Information Visualization, Keyhole Markup Language (KML), Geographic Information Science (GIScience).

1. INTRODUCTION

1.1 Virtual Geographic Environments (VGEs)

The term "geographic environment" has been previously defined as the surface on which human and other living creatures live on and reproduce (Lin, et al, 2013). Generally speaking, the term (geographic environment) is used to describe any type of information system that requires storing, analyzing, editing, sharing and exposing different types of geographical and spatial data. In this way, the Geographic Information System (GIS) was first developed as a tool that allows users to analyze spatial information (store, edit, create queries and present the results of all these operations) (Harris and Elmes 1993; Lin, et al. 2013). In brief, Geographic Information Systems can be considered as a tool that requires the integration of computer-based programs, which can store, analyze and manage geographic information in a manner that allows easy interpretation of the data. GIS systems were originally employed within the computer mapping domain, and mainly used in the analysis of spatial database. The strategies that are used in the analysis of GIS data, along with the mapping and analytical capabilities that are associated with it, has opened a wide variety of options to the users (Lin, et al, 2013). Numerous examples illustrate the successes of GIS systems in both physical and social domains as it has been illustrated by e.g. (Richardson, et al. 2013),(Khan, et al. 2006),(Konecny, et al. 2010). Moreover, GIS has been shown to be a very effective tool in building an archaeological site due the wide variety of options that it provides in terms of analysis and interpretation (Mejuto, et al. 2012).

Recently VGEs were proposed as an evolutionary step beyond the maps and prior GIS systems for geographic analysis, and the virtual environments has emerged due to its ability to host scientific research within many potential areas (Bainbridge 2007). The integration of the new analysis tools has contributed to the development of VGEs. In addition, these tools can also help in enhancing the human understanding of the geographic concepts and help them in finding suitable solutions for the majority of complex geographic problems.

After nearly a decade of using the term VGEs, there still an emergent need to develop systematic frameworks for the future development. Lin, et al. (2013), summarizes all the related efforts that have been contributed to build VGE frameworks, as well as practical implementations of VGE systems. Moreover, the authors suggested the use of four sub_environments system according to the function that they perform, related matters, as well as categorizing solutions as either (i) data environment, (ii) modeling and simulation environment, (iii) interactive environment, and (v) collaborative environment. Each sub_environment was designed with functions that are suitable for performing different steps of Computer-Aided Geographic Experiments (CAGEs). These functions are conducted in the virtual geographic environment, with designing simulation and analysis to demonstrate the ability of a VGE to support CAGEs in order to provide a more efficient exploring of the world. Therefore, the user (expert and non-expert) can: (1) Experience the visualized (real world), as is represented by the graphic engine, and explore data associated with this real world (environmental, social, structural, etc.). (2) Experience with geographic data from Spatial Data Infrastructure (meteorological, urban planning, soil uses, etc. (3) interacts with the environment with new multimodal techniques and displays (Kinect for motion capture, and cave to have a 3D immersive feeling). Moreover, general understanding of CAGES can be achieved in an effective manner if the users can put hands on practice of the relevant issues to digital geographic world, rather than reviewing several figures and tables.

1.2 Scientific and archaeological data representation challenges

VGEs are a kind of typical tool and computer-based geographic environment that is built for geographic understanding and problems solving (Lin and Gong 2001) and (Lin and Gong 2002). Our work involves the use of an Spatial Data Infrastructure (SDI) for archaeological data retrieving, in order to an optimal visualization in a 3D georeferenced environment. In this study, the main goal that we seek to achieve is to shed the light on some open issues and challenges in today's VGEs. Some of the examples that the user may face in the VGEs field may include:

1. The representation of 1,2 or 3 dimensional data or metadata in the same scene.
2. Adapting the resolution of data to fit them in a particular Level of Detail (LOD).
3. How to represent too many objects at the same coordinates (in such way that it suppose a clear view to the end user).
4. Generating a 3D archaeological building in Graphic Engine.
5. Optimizing the data storage for an efficient recovery and interpolation of data or a continuous visualization.

On the other hand, dealing with many layers can cause a lot of problems, which could lead to overlapping of these layers when they are visualized together, making the display objects in each layer inconspicuously. However, by analyzing the recently proposed scientific issues concerning GIS science, there is, as one might expect, a need to develop new systems and approaches that are driven by data concept. The users may face such problems under some cases, which include the change of the data type from static to dynamic and from the pattern of display or presentation to process modeling/simulation (Goodchild 2009). Therefore, it is crucial to develop new geographic model that is dynamic since the world often face dynamic changes that occur on a daily base (Lin, et al, 2013).

Our contribution to the literature is three fold; first, we propose three new visualization paradigms in terms of dealing with data and represent many objects in the same position. Second, our system proposed an enhanced multi-layers position without overlapping. Third, our Sub-place dialog paradigm lowers the time that is required to fetch the data from the database, which will indeed reflect positively on the system performance. All of these contributions, along with implementing the dynamic visualization model will enable the system interactivity.

1.3 Archaeological data

Spatial data can be simply defined as information that describes the distribution of things upon the surface of the earth (Larson 1996). Therefore, any information concerning the location, the shape of, and relationships among, or geographic features are considered as spatial data (Walker 1993); (DeMers 2008). Dealing with a huge amount of spatial data within the archaeology domain is widely known, where spatial data involved in archaeology could be on various scales. For instance, spatial data in archaeology could be as huge as continental landmass or it could be any type of artifacts [W2].

The archaeological information presented in this work comes from the archaeological excavation in the site Rocha Forte Castle. This castle was a historic castle in the province Galicia-Spain that been built in the 12th century, that was destroyed in the 15th century. One of the excavations that have been done at this site is the following project: «Archeological project for the study, recovery and appreciation of the fortress of Rocha Forte», which was funded by a nominal subvention of the Ministry of Education, Culture and Sports of Spain, and instigated and coordinated by Santiago de Compostela City Council [W1].

The work aimed at excavation and studying all of the archaeological evidence and recovered structures in a global treatment of all information collected. To accomplish this task, an information system has been developed.

The data model and methodology presented below has been developed long time ago and has been previously applied in numerous archaeological studies. The small part of the data model needed for this work is shown in figure 1.

This model is conceived in a modular way, so as to incorporate various aspects within a common logic work. Its development includes specific themes, which we will gradually incorporate depending on the needs. The layout of the data model is structured around basic units, deposits, interventions, registrations and field evidence recovered. Given the logic of GIS, each of these elements becomes a layer of independent information that allows its inclusion within the real coordinates, within a shared environment. The precision and accuracy of this system varies according to the elements involved in GIS system.

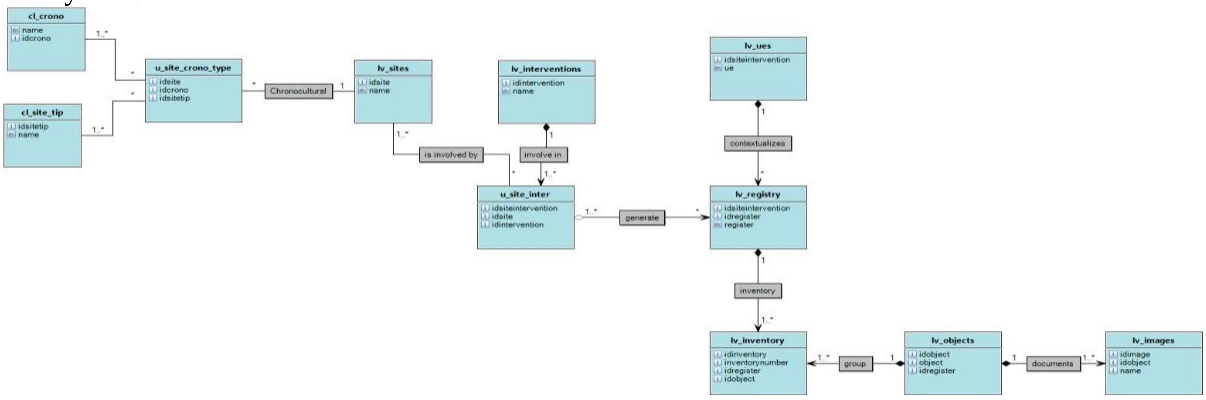

Figure 1. ER_Diagram

2. THE SYSTEM ARCHITECTURE

In this paper, we consider a motivation scenario coming from the need of developing a new dynamic visualization system of georeferenced data (geodata), using Google Earth as a framework for the visualization. Our contribution in this system can be summarized in using of dynamic visualization to enable the system interactivity and method to explore the large and dynamic datasets. Meanwhile, it extracts valuable information for visual analysis and provides them to archaeologists.

Our system is based on the database provided by the Galician Supercomputing Center (CESGA) regarding data acquisition. CESGA has an SDI that provides via web services access to the Rocha Forte excavation data. The system we propose here will improve the VGE domain as a new analysis tool to study the geographical environment problems and to enhance a cutting-edge issue related to the field, which referred as the interactivity of dynamic visualization. Despite the fact that one of our system strength points is manifested in its simplicity, archaeologists can use this system in different ways of visualization.

In figure 2 we clarify our system architecture, where the end-user is asked to download the primary layer of Rocha (see figure 3 (a)) from the website, (i.e. which runs in different script according to the selected model of visualization). Next, the website server answers with the main placemark by using a KML file that will be automatically imported into Google Earth application in the client-side. Finally, the user interacts with a dynamic interface in the description of the Placemark to simulate the visualization results.

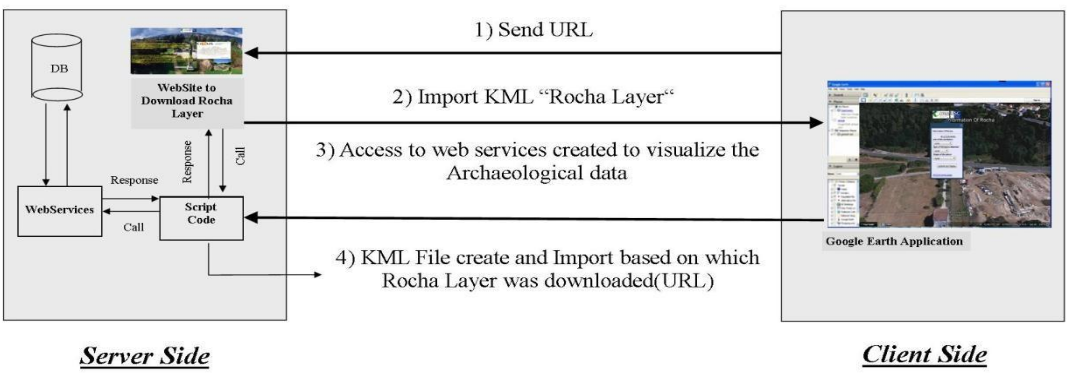

Figure 2. System Architecture

In terms of representing the data in an efficient way, the client is able to connect the website to download different paradigms of visualization. In our study, we suggest the use of three paradigms, which are Direct visualization, Sub-place dialog visualization and the Time-levels visualization. We will give a brief illustration of each of these paradigms below:

2.1 Sub-place dialog Visualization paradigm

In the Sub-place dialog paradigm, we create a web service that is called by a script code to make a new visualization method, to display the data by creating an interface that fetch the data from database in a dynamic approach. When the database is modified, the contents of the interface are directly changed. Later, the user chooses the data that he wants to visualize using a set of filters. Data are charged into the system directly: they are read from the database, classified them into separate groups and then the systems creates a sub_placemarks that contain the dialogs of this classified data accordingly with the coordinates. Through the new dialog, the user may choose any data to visualize the paradigm accordingly of the main dialog results, with no need to conduct a search in the whole database. This paradigm has four advantages; first, adapt the resolution of data to fit them into a particular Level of visualization Details (LOD) by decreasing the complexity of a 3D object representation. Second, optimize the data that has been retrieved in the first step to achieve optimal recovery and interpolation of data or continuous visualization because this paradigm depends on the main dialog results when searched. The third step requires representing many objects in the same coordinates to obtain a clear view to the end user. Fourth, when dealing with all these created layers is not overlapping at all because the mechanism involved in this paradigm display these layers above each other. For instance, in Figure 3(b) and Figure 4(a) we develop a dynamic interface in the description (Balloon), at the Placemark that enable the users to interact and simplify the whole work to show the visualization results. In the same way, classifying any information that needs to be visualized, clients will need to press submit and display buttons in the dynamic interface as shown in Figure 4(a). This indeed will request the web services to convert all data to a KML file format and import it to Google Earth as a layer. Figure 4(b) shows a visual illustration of the previous operation.

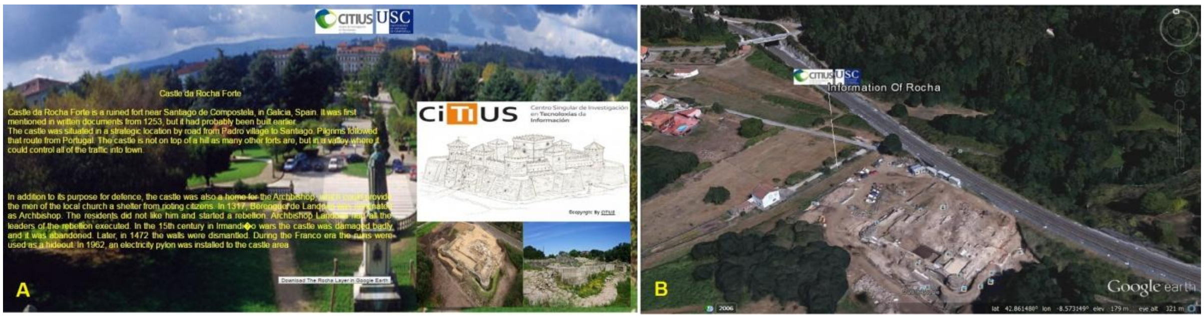

Figure 3. A) The website download the Rocha Layer B) The Main Placemark

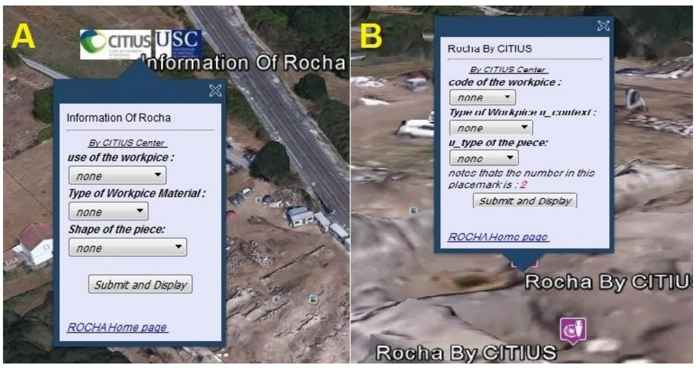

Figure 4. A) The Main Interface B) Sub placemark

In (Figure 4(b)), KML file is created after choosing the data from the main layer that contains the sub- placemarks only when the distinct coordinates satisfies the condition of the main layer. As an example, the figure describes only two Sub-placemarks that satisfy the condition, Hence, for the same coordinates that has been checked, it only creates the first Sub-placemark, where any other new sub-placemark for the same coordinates will be included to, without the need to create new sub-placemarks. The counter will adjust this step by automatically adding new Sub-palcemarks. Figure 5(a) illustrates the Sub-placemark icon size, where it is elastic (flexible) and directly proportional to the elements number in the same coordinates. To enhance the system performance and to reduce time of fetch, only the nested-placemarks elements that verify the Sub-placemark conditions are authorized to appear in the same coordinate. Rather than searching all the elements within different coordinates and to avoid the overlap of layers, the new elements (Layer) are introduced in an altitude shape as shown in Figure 5(b)). By selecting the targeted element, client can retrieve the information (metadata) that these elements hold in a 1and 2 dimensions. Figure 5(c) illustrates an example of the previous case, where a 2D image and associated metadata of an archeologic piece is showed at the same position where it was found at the ground.

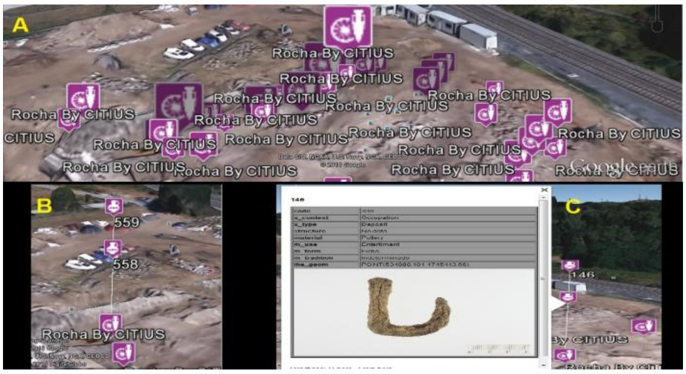

Figure 5. A) Icon Change sub placemark B) Nested placemark C) The Information of element

2.2 Direct visualization paradigm

This sub section will discuss a new paradigm, which focuses on solving the problem caused by representing many objects at the same coordinates. It's usual in archeologic excavations to have too many pieces associated with the same coordinates (latitude, longitude). This proposed solution enables displaying all elements by adjusting the altitude consistently of each object based on the number of elements within the same coordinate.

Additionally, one of Google Earth draws back regarding elements presentation appears when more than one elements share the same coordinate, which can cause trouble for the end user when choosing the elements to visualize. This is particularly challenging when there are a wide number of elements to present. Figure 6(a) illustrates an example of this case, where two elements share the same coordinate (elements"547+548" and "145+146"). To deal and handle this problem, our system proposes the use of an altitude-based shape solution. Moreover, in regards of joining the same coordinate elements together, an orthogonally line that links these elements is applied. This can be presented within (Figure 6 (b)).

Figure 6. a) Two Objects in the same coordinates b) Direct altitude visualize

2.3 Time-levels visualization paradigm

In this sub section, we linked the archaeological materials with their appearing date in the sites.

This solve the problem of representing pieces from the same archeological site that have been extracted in different excavations along the time.

The aim of doing this is to enhance the representation of our visualization system within different time phases (Levels). To do that, he user must select the target interval (by years) through a main dialog. The systems will automatically create a layer for each interval specified.

Based on the database provided by the CESGA’s SDI, the table had a specific column for the phases of materials that shows the appearing date at the castle excavation and the appearing dates had been divided into 72 intervals. These intervals had been used to present and divide the placemarks results of the elements in a new model of visualization to phase's column. On our first implementation, the whole time-level layers (even those with empty record intervals) appear upon client's conditions. Thus, this could result a complexity and confusion that need to be solved, see (Figure 7(a)). This way of visualization can be useful only if there is little number of intervals to present (as in Figure 7(b)). In addition, the client may review the description of the level by selecting the level that is needed, as it is presented in (Figure 7(c))" *this represent year UE2178=> 1467-1480 of excavation*". Eventually, this paradigm was able to amend the resolution of data to fit them into a particular Level of visualization Details (LOD) and represent many objects in the same coordinates with their appearance date.

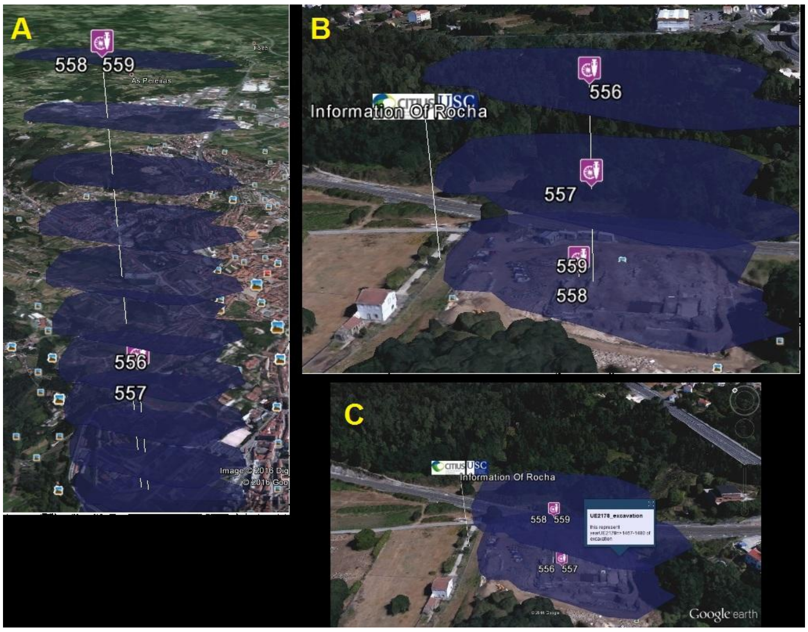

Figure 7. A) The time levels layer B) Few number of levels C) Enhanced Time levels Visualization

3. 3D MODELS ENVIRONMENT

Google Earth supports managing three dimensional geospatial data through Keyhole Markup Language that is known as KML (https://developers.google.com/kml/), and which consists of users’ submissions. This makes Google Earth simply based on 3D maps. While SketchUp is powerful modeling tool, it still requires a lot of manual labor to model each building, like the Golden Gate Bridge or Sydney Opera House, that were hand modeled.

The challenge for us here was mainly the lack of the castle documentation and available pictures. Hence, we depend on one images provided by an archaeologist [W3] and the description of other archaeologists from the CESGA. The castle design was divided into three main stages (phases) according to the image of actual castle design; in the first place, the main gate was designed with the outer wall, later, the internal walls and towers as illustrated in (Figure 8(b) and Figure 8(c)). The necessity for employing high accuracy of details in the design is crucial. For instance, maintaining the actual straight line and forward slash line in the walls, made the design stage a very difficult task to accomplish. Eventually, the model was successfully implemented and added as a layer in the system as illustrated in figure 8(a).

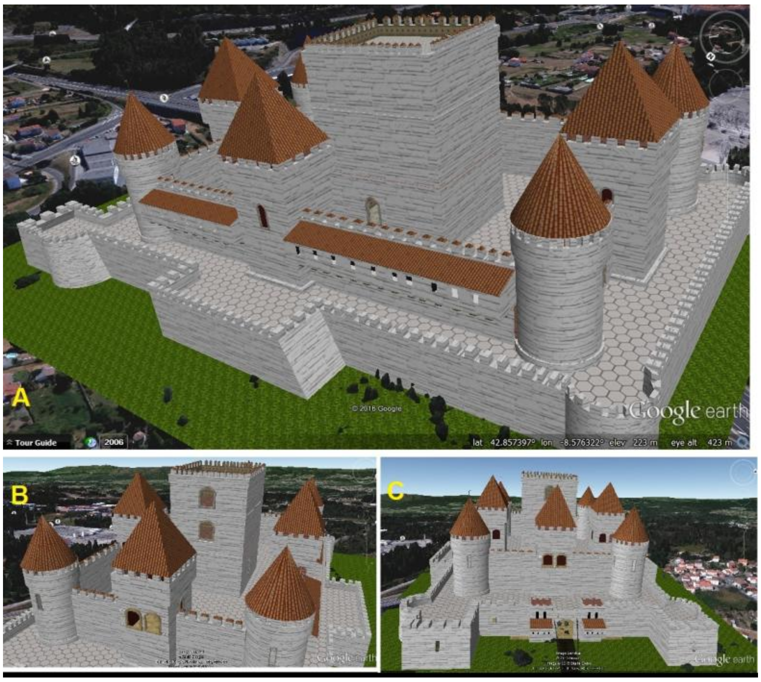

Figure 8. A) Rocha Castle Model B) 3 Dimention Towers C) 3 Dimention Entrance Of Castle

4. CONCLUSION AND FUTURE WORK

Overall, this paper presents some procedures that could be implemented along with the use of Google Earth to visualize different types of archeological places in an efficient and satisfying way. The integration of *Virtual Geographical Environments* system was found to be very efficient as it could handle different types of data in 1, 2 or 3-dimentional images. Moreover, this system was found to be efficient as it could provide access to the excavation database and updates the visualization of it in an efficient manner. Our proposed system involves the use of new visualization paradigms that could deal with data and represent objects in a similar position. In addition, this system can provide an enhanced multilayers position without causing an overlap and a sub-place dialog paradigm that could reduce the time to fetch the information from the database.

Our system is scalable and easy to implement and scale to lot of other archaeological locations. Though, it is planned to add some other functionalities to the system architecture, which will contribute to push the cutting-edge in the domain of archeology for using modern applications. For future reference, we will optimize the data storage for an efficient recovery of data, and for a continuous visualization. Furthermore, we will investigate the human computer interaction techniques, in order to enable the users to use their gestures instead of using the traditional way.

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