

Proposing a new Archaeology Visualizing and Interacting (AVI) System for Education

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Abstract: This paper introduces a new Archaeology Visualizing and Interacting (AVI) system. The system aims to apply new information technology in the Geographical Information Systems context to study historical and cultural heritage and comply with both scientific and cultural interest. The AVI System purposes to provide reliable and accurate information about tourism and culture for the students of archaeology and public communities in a new and attractive scientific framework. This system was developed to focus on two critical sections in the field of archaeology education. The first section focuses on applying new attractive methods to visualize archaeological data using Google Earth Program and providing 3D configurations for the archaeological locations with critical details and designs. The second part concentrates on finding and applying the Human-Computer-Interaction techniques that is innovated by the authors, a fact, which contributed to finding programs that can help public communities, especially the students of Archeology, to conduct analysis professionally and effortlessly. This program navigates through the archeological data in as many as three and four dimensions, thereby, contributing to the creation of an attractive new learning environment.

Keywords: historical and cultural heritage, tourism, geographic information system (GIS), human-computer interaction, archaeological data visualization, educational technology, information and communications technology (ICT).

1. Introduction

Today's society contemplates and admires the scientific and technological advances that have occurred during the last 50 years that had completely transformed all aspects of our lives. Knowledge, information and their connections to science and technology have become the most important resources that human beings can generate (Castells, 1996). There were significant changes generated in communications, transportation, commerce, information technology in the last decades. All these changes have also occurred in the paradigms of culture and social sciences, affecting the approaches and specific teaching methods in various education sciences. However, this situation of change is not reflected clearly in the educational system or the teaching strategies used by the vast majority of teachers. Thus, it can be said that the school is moving at a slower pace than the society (Kolikant, 2012).

To meet the demands of today's society, it is necessary to implement changes in the education system. More importantly, the orientation of the school curriculum towards the development and acquisition of basic skills, which includes digital competence and the treatment of information, are fundamental in the information society in which we are immersed.

New technologies are gaining weight, little by little, in all aspects of our lives, especially from the generalization of using computers, projectors or interactive whiteboards (PDIs) as work and communication tools. Thus, it is necessary to educate the new generation on the use of these new technologies present in all experiential fields.

The efforts made to date seem insufficient, as they have been endowed to resource centers (computers, projectors, PDAs, etc.), but the training of teachers regarding the introduction and use of Information and Communication Technologies (ICT) is undoubtedly unfinished business. Of course, the new training includes specific innovation subjects that affect the use of ICT as a motivating and supportive tool for teaching-learning processes. For example, the AVI system developed in this paper, aims to correct this initial lack of knowledge regarding innovative teaching strategies.

Despite the initiatives undertaken, there is still a clear difference between the importance of information technology in daily life and in educational context, something that must change if we want students to acquire skills for their personal and cognitive development. It would be important to know the influence of ICT in our lives, the training possibilities offered and the resources available for the improvement of the teaching profession (Davis and Tearle, 1999; Lemke and Coughlin, 1998).

In the specific case of teaching Geography and Archeology, we can say that there is a clear lack of integration in the current themes and approaches, keeping the practice inconsistent and rote in content of this science associated with routine learning strategies and little motivation.

The significant advancement of technologies seems to show a new approach to the teaching of Geography and Archeology based on new strategies and techniques that are part of this educational transformation through Information Technology, thereby promoting the development of new skills and abilities of the student and teacher and at a lower cost.

1.1 What is a Geographical Information Systems (GIS)?

One of the first definitions was developed by Dacey (1970): "Anything that works like a map, when communicating geographically, is the information requested by the users of the system". According to Cebrián and Mark (1986), the GIS is a computerized database containing spatial information", as well as, "a computer technology to manage and analyze spatial information". The definition of the NCGIA (National Center for Geographic Information and Analysis of USA), emphasizes the elements and functionality when considering GIS as: "A system of hardware, software and procedures developed to facilitate obtaining, managing, manipulating, analyzing, modeling, representing and delivering the spatially referenced data, to solve complex planning and management problems."

Finally, when focusing on the functionality of Archaeology application for a new Visualizing and Interacting (AVI), the system must allow the following operations:

- Reading, editing, storing and, in general terms, managing the spatial data.
- Analysis of archeological data. This can include simple consultations for the elaboration of complex models and can be carried out on the spatial component of the data (location of each value or element), as well as, on the thematic component (the value or the element per se).
- Generation of results such as maps, reports, graphs, etc."
- Models: generation of simulated situations.
- Using new human-computer interaction techniques to deal with the information on maps.

1.2 Proposed AVI system in Education

This line of research begins with the project of technological linkage that the Santiago de Compostela University developed for The Government of Galicia and EU FEDER funds. Under the program of consolidating and structuring competitive research units (GPC 2014/037) the archaeology application was developed to introduce a new Visualizing and Interacting (AVI) to be used in Jordan and is supported by the Royal Jordanian Geographic Centre (RJGC). In preparation for the expansion of this project and its use in the Middle Eastern Countries to learn about the community and to protect and preserve the heritage and archeological data in all countries suffering from the destruction of structured archeology and information due to terrorism and wars. Thus, hoping that this will help raise a new generation that is conscious of the archaeological and historical data value, which is positively reflected on the communities' education.

One of the key points of the AVI system is its ability to model reality in layers of information to enable the treatment and analysis of different dimensions found at the archaeological sites. The conversion of traditional archeological maps into digital forms, which usually contain many data that can be extracted, converted and interpreted, would facilitate the progressive integration of GIS into the educational context. The AVI system helps you to go beyond mere visual exploration to understand its structure and how we can take full advantage of it. In this way, the AVI system is based on the resolution of real problems and enables students to face everyday situations and act as a critical agent before the reality presented to them, with a look for possible solutions. In

other words, AVI system in the educational context provides a simulated environment of reality that allows the analysis of spatial and archeological relationships and interactions to attain their conclusions.

2. The Archaeological Application for a New Visualizing and Interacting (AVI)

The Archaeology application (AVI) integrates a new visualizing and interacting technology that can help students to analyze and understand geographical and archeological information correctly and efficiently. This would preserve and protect the heritage of archeological data. It also enables users to engage in virtual tourism without any charge.

2.1 Why use AVI in the classroom

The application of new technologies in the classroom such as AVI system is a real educational challenge for current teachers. It would provide greater dynamism and interactivity in classes, from both the transfer and production of archeological knowledge. It is essential to use, understand and interpret the immense amount of information generated daily in various areas. The use of AVI system in the classroom, especially in the GIS domain, is positive because it:

- Provides a powerful and motivating didactic resource.
- Breaks with traditional cartography and imaging (static).
- Allows working at different scales of spatial analysis.
- Powers meaningful learning through creation and treatment of georeferenced information.
- Generates skills to select information from varied sources.
- Facilitates the representation of and dealing with data and results using new techniques.
- Makes it possible to relate information (database) to geographical locations (map).

Typically, AVI system is used for a variety of real-world applications, but they can also be introduced in the classroom as an important pedagogical tool that allows "an intentional reading, integrated and meaningful reality at different scales" to be carried out. In this paper, we will discuss some of the visual paradigms and human-computer interaction techniques available in the AVI system.

3. System Architecture

Our system can be applied to various GIS applications, but Google Earth has been used in this paper as a visual framework to develop a novel dynamic system for visualizing Geo-referenced data. Therefore, developing a visual system that deals with dynamic and huge datasets besides being applied to educational environments is the main contribution of this paper, which also aims to enhance the interactivity of the system. In the AVI system, the required data will be extracted, analyzed and then delivered to the archaeologists and students. The system database (as a case study) within the current work is provided by the Galician Supercomputing Center (CESGA). Moreover, the data excavated from Rocha Forte Castle can be reached through the services of the Web, which is supplied by the SDI of CESGA. The VGE field will be enhanced by this system, which represents a novel tool to analyze and study the problems regarding the geographical environment as well as improve the impacts the system interactivity. Besides the simplicity of the system developed by the authors, it can be applied by archaeologists in various visual ways; see (Figure 1_A) which illustrates the system architecture with three Layers (Client, Application, and Data).

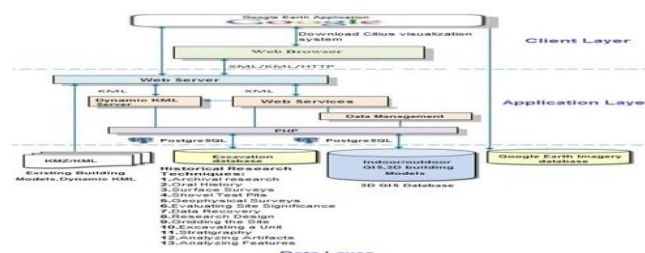


Figure 1_A. The architecture of the system

A data flow scheme in the system developed by the authors is illustrated ¹ in Figure 1_B. As shown, the user first sent a request to download the Rocha primary layer (The Main Layer) from the website. Then, the server of the website sends the answer, which involves the major placemark. The response is posted through KML file and will be imported into the Google Earth application of clients automatically. After that, the user reacts with the primary interface (The Main dynamic Interface) within the placemark description to simulate the results of visualization.

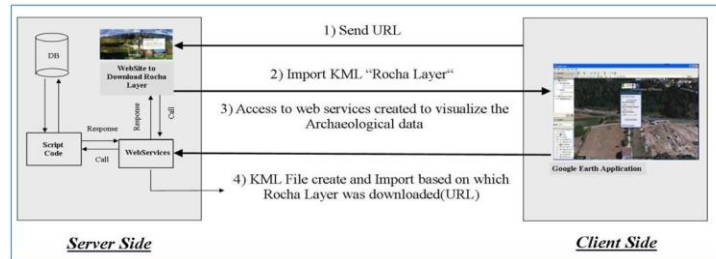


Figure 1_B. The data flow of the system

In summary, the most important requirement for applying this system is installing the Google Earth application only. This is a bright idea where the user does not need any extra condition apart from installing the Main Layer from the website (see Figure 2_A), and then instantly connecting and visualizing any information from the web services created by the authors.

4. Visualization Paradigms in AVI System

The AVI system was developed with information visualization principles to allow data to be represented efficiently. The integrated and interactive visualization system would aid students and archaeologists to explore, present, collaborate and communicate visually large information spaces through applied novel and dynamic paradigms. These can be used in Jordan and Spain in preparation for its implementation in Middle Eastern countries such as Syria, Iraq, Lebanon, with support and coordination with the Jordanian Royal Geographical Center. This will be an innovative way to increase knowledge in this area.

4.1 Paradigm of Sub-Placemark Dialogue Visualization

In the Sub-place dialog paradigm, a web service is called by a script code to show a novel method of visualization. Next, the main interface (included in the placemark description) is created by this paradigm to effectively display data, where this interface has the ability to dynamically fetch the demanded data from the database. Hence, the contents of the interface can be changed by modifying the database directly. After that, the user (teacher or student) can select the data required for visualization using a set of filters. The data are directly delivered to the system, which reads these data from the database and then categorizes them into independent groups. Finally, the system forms sub-placemarks to describe and store the dialogues of categorized data as well as their coordinates. The user can use the new dialogue according to the results of the primary dialogue to choose any data needed for paradigm visualization instead of performing a search on the overall database. The advantages of this paradigm in the context of geography and archeology education are:

- Ability to adjust the data accuracy to fit with a certain Level of Detail (LOD) through the reduction of 3D-object representation complexity.
- Ability to improve the retrieved data within one step to attain continuous visualization or appropriate interpolation and recovery of data, where this paradigm is based on the results of the primary dialogue through the research process.
- Ability to represent multiple objects at the identical coordinates to provide the user with clear sight.
- Ability to deal with constructed layers without any overlapping between them, where the mechanism of this paradigm separates the layers by displaying them above others.

¹ To see all images in this paper with more clarity; please download from the following link: <https://nextcloud.citius.usc.es/index.php/s/srWtXdaDAYxLkcc>

A dynamic interface has been developed as shown in Figure 2 (B) and Figure 3 (A); the interface provides the user with a description of the placemark. The description allows the users to effectively react with the interface and helps to generate the results of the visualization in a simpler way. Figure 3 (A) illustrates that the client can press the ‘Submit and Display’ button within the interface to categorize any data for visualization. This action sends a request to the web service to transform the data into the format of KML file in order to import it as a layer within Google Earth. This operation is visually explained in Figure 3 (B).

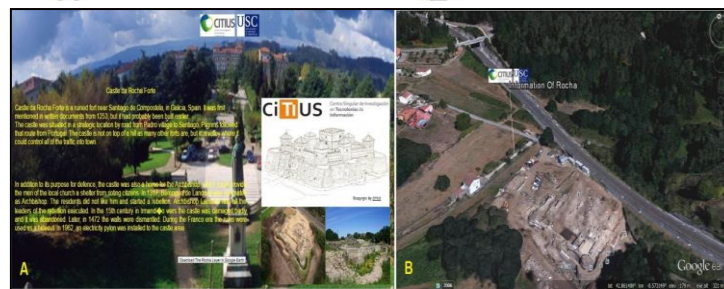


Figure 3 (A). The primary interface (B). Sub-placemark

As shown in Figure 3 (B), a KML file is created after choosing the data from the main layer that only contains the sub-placemarks where the distinct coordinates satisfy 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 have been checked, creating only the first sub-placemark, where any other new sub-placemark for the same coordinates will be included therein, without the need to create new sub-placemarks. The counter will adjust this step by automatically adding new sub-placemarks. Figure 4 (A) illustrates the sub-placemark icon size, which is flexible and directly proportionate to the elements number in the same coordinates. To enhance the system performance and to reduce the time of fetching, only the nested-placemarks elements that verify the sub-placemark conditions are authorized to appear in the same coordinate. Rather than searching for 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 4 (B). By selecting the targeted element, the client can retrieve the information (metadata) that these elements hold in one and two-dimension(s). Figure 4 (C) illustrates an example of the previous case, where a 2D image and associated metadata of an archeological piece is shown at the same position where it was found on the ground.



Figure 4(A). Icon to modify sub-placemark (B). Nested placemark (C). Element information

4.2 Direct Visualization Paradigm

Large numbers of archeological pieces are located at identical coordinates within the archeological excavations. For this reason, a direct visualization paradigm has been used to solve this problem by modifying the altitude based on objects and elements presented within the identical coordinates.

Indeed, the representation of elements that are common at identical coordinates is one of the major drawbacks of Google Earth, where this issue can negatively impact the user's decision to select the appropriate elements for visualization. The complexity of this issue would increase with the increasing number of elements that demand representation. An instance of this problem is shown in Figure 5 (A), where three elements are common in the identical coordinates; element "550+551+552" and element "541+542". The solution of altitude-based shape has been applied to overcome this problem. A vertical line has also been used to join the elements that are common in identical coordinates together as illustrated in Figure 5 (B).



Figure 5.(A.) Example of two objects that existed in the identical coordinate B) Applying direct visualization paradigm

4.3 Equation of Levels Contents

The equation of levels contents paradigm working is dependent on the selection of the main placemark interface (the column name of the dataset and the number of layers) for visualizing data (Artifacts) and how is dealt with (see Figure 6).

In this paradigm, there are two cases based on the column names of the data type. The first case is when the user chooses a column with data type for any type of text, so the system will deactivate the number of layers (list box) automatically, because the system will distribute the created layers based on the items' names (without redundancy) according to the column which has been chosen. The second case is when the data type is numeric. In this case, the system will distribute the data at intervals (the First interval starts with a minimum number of the column chosen, and the last interval is the maximum number of it). The numbers of the created intervals commensurate with the number of layers selected by the user.

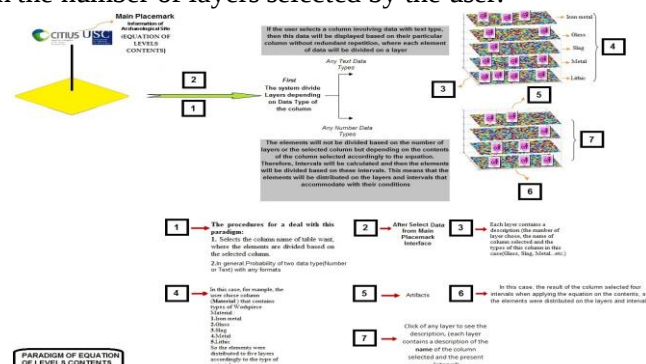


Figure 6. General diagram of EQUATION OF LEVELS CONTENTS paradigm

5. Human Computer Interaction Techniques in AVI System

In this section, we focus on how to apply the innovative techniques by the authors to utilize the previous new visualization paradigms in conjunction with the GIS by finding attractive and useful ways for students and teachers alike. Recently, GISs are playing an increasingly significant role in society. For they have not only expanded the abilities of GIS packages, but their spectrum has been

broadened by the generalization of software such as Google Earth. These softwares add another dimension to navigation, while still using the same interaction method. We argue that conventional GIS interfaces would limit productivity by not being intuitive enough to new users and by causing extra delay due to the dispensable modality. As an effort to solve these problems, the authors propose new Human Interaction Techniques, which have been applied in Galicia Supercomputing Center at the University of Santiago de Compostela (Spain) and the Royal Jordanian geographic centre (Jordan), which back up our assumptions about the importance of these techniques for teachers and higher education students.

5.1 Control Voice Using Kinect and Location (CVUKL_GE)

This method aims to help disabled people in browsing by setting a copy of the keywords for control browsing and another copy for the Google Earth program with absolute ease, where it combines several mechanisms involving navigations, cities and mouse. These mechanisms are based on the voice, except the mouse mechanism, which is based on hand movement. The mechanism 'cities' has been added to this method to allow the user to select the name of the desired city by vocalization and then it will be translated into text. Moreover, the user should firstly open the 'mouse' and 'navigation' programs to be able to cruise any wanted mechanism by vocalization of these words. The mouse word is used in this method to activate the control of mouse functions, while the navigation word is used to activate the navigation and control processes using different keywords.

On the other hand, the opening of mouse mechanism allows the user to open and activate other mechanisms easily by raising the left hand over the head. Table 1 illustrates the keywords of this method.

Table 1.

Keywords of (CVUKL_GE) Method

Keywords	Actions (Functions)
Mouse	Control the mouse using gesture (Kinect)
Cities	allow the user to select the name of the wanted city by vocalization and then it will be translated into text and go directly to this location name
Zoom in	Make the image of map appear much larger and nearer; execute once and stop after this
Zoom out	Make the image of map appear much smaller and further away; execute once and stop after this
Stop	Finish doing any functions of the keywords
Up	Towards a higher position (top of the monitor)
Down	Towards a low or lower position (bottom of the monitor)
Go to Right	Go in right direction (right of monitor)
Go to Left	Go in left direction(left of monitor)
Navigation	Activate the navigation program and control processes by using the different previous keywords (Stop, Up, Go to right,...etc)

5.2 CiTIUS_Smart Board for GE (CITIUS_GE)

The initial form of this method has faced many challenges, where patience and scrutiny were demanded to dynamically come up with an elastic program, which has the capacity to cope with different changes. The key challenges associated with this method are:

- 1) The variation in the size of data viewer (projector) from one user to another.
- 2) Resolution of the Computer screen from one device to another.
- 3) Kinect angle on the tripod.
- 4) The distance between wall and the Kinect.
- 5) The height of Kinect above the ground.

A basic form of this method has been set to overcome these challenges, where three angles have been formalized to improve the method performance. When the user puts his right hand on set button and then press on it, the dimensions will be then calculated and stored. This process will be repeated for the remaining two angles, where the X, Y and Z dimensions are found out. After that, the average dimension Z will be manipulated to identify the distance between the wall and the

Kinect, the fulcrum of the Kinect is located at the middle of the image and it is represented by (0, 0). However, the fulcrum of the computer screen is located at the left angle of the image. Hence, the angle and the displacement have been evaluated based on the fulcrums of the Kinect and computer. Therefore, the fulcrum of the Kinect will be calculated for the place where the user pressures the wall and then it will be transferred into the computer screen to attain more accuracy. The structure of the device used to calculate the fulcrum value is shown in Figure 7. Moreover, the structure of devices can be changed, but the terminal equipment should be a projector and a Kinect.

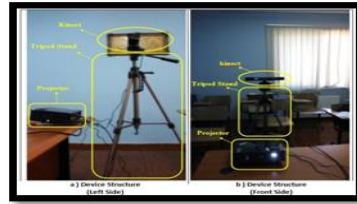


Figure 7. Structure of devices

The calibration Form (Set_Form) will appear to calculate the fulcrum and correct the dimensions; this Form is shown in Figure 8(A). After that, the Google Earth will be automatically opened and display the ‘hide top menu,’ which only appears when a hand is raised at the top of the screen. The menu involves many buttons as shown in Figure 8(B). These buttons are: drag, reset calibration, double click, left click, right click and exit. Therefore, if any of these buttons is pressed, a corresponding “operational” sound will be activated. On the other hand, a status menu is presented on the lower part of the screen, where it indicates the status of activation. Besides, the order of the user's hand clicking a button in the ‘hide top menu’ can be processed when reaching the value of “Z” that was calculated by the calibration form, and then activates this button. The functions of these buttons are shown in Figure 10 (B, C) and Table 2.

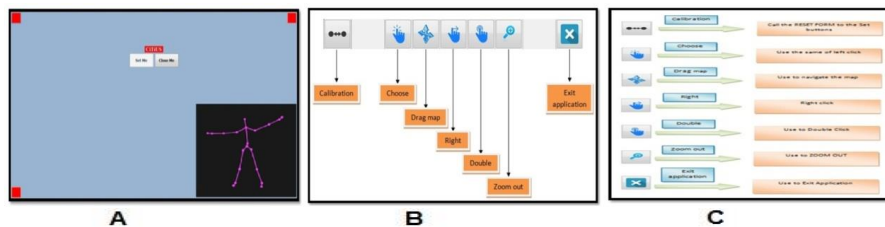


Figure 8(A). The Main form of calibration (Set_Form) (B). Hide top menu description (C). Hid top menu buttons functions

As shown in Figure 8(A), while running the program the main Form of calibration, the ‘Set_Form’, will come out directly, and the user can set the points of corners by putting his hand on it and making sure that the skeleton does not move through the ‘Right_Down Stream’ Form. After finishing this step the system will show the desktop of the computer and activate the control menu, the ‘Hide Top Menu’ at the top of screen to explain more, this is shown in Figure 8(B). Every button has a particular action, and Figure 8(C) shows that the display contains the Hide_Top Menu buttons functions, where the user can activate any button simply by touching it.

Table 2

Activation of Calibration using Different Buttons in CITIUS_GE Method

CiTIUS smart board for Google Earth "CITIUS_GE"		
Description of button selection using figures	Button name	Description of calibration process activation
	Set (up-left corner) button	Put your hand on the button (up-left corner on the screen) after that click on this button to start the calibration process
	Set (up-right) corner button	Put your hand on the button (up-right corner on the screen) after that click on this button and calibration process will start

	Set (down-left) corner button	Put your hand on the button (down-left corner on the screen) after that click on this button and calibration process will start
	show (hide top) menu	Raise your hand to the top of the screen and directly show the hide-top menu
	Click any button on the hide top menu	Put your hand on any wanted button on hiding top menu to select it and then it will be automatically clicked

6. Evaluation Usability of the (AVI) System

In this section, we will discuss tests usability of the AVI system; this process occurred in a laboratory in collaboration with two types of users (Teachers and Students) at the Royal Jordanian geographic center and the University of Santiago de Compostela to evaluate, incorporate and focus on the design and implementation.

Usability surveys:

- 1) The assessment of the functionalities and design of the app was carried out through the development of a usability survey (Table 3)
- 2) The design of its questions was based on software usability questionnaires (Cortes, 2018), especially on the system usability scale (SUS) questionnaire (Brooke, 1998), which was developed by John Brooke in 1986 as part of usability engineering introduction to the systems of Digital Equipment Co. Ltd.

The survey consisted of 13 items. These items include the assessment of diverse aspects: tasks, structure design, terminology, speed and iteration. Each of these items has four possible answers, which are ranging from 1 to 4 according to the degree of agreement (1. Strongly disagree, 2. Disagree, 3. Agree, 4. Strongly agree). The maximum overall score for the survey is 52. The app was evaluated as a proof-of-concept study with ten students and five teachers as users. All users received detailed explanations about the goal and the functionality of the app. The scores obtained from users (teachers and students) were greater than 75% of the total score, which is therefore considered to have been successfully assessed.

Table 3
Usability Survey

Items	Achieved Average Rating		
	Teacher	Student	Total AVG(Teacher+Student)
1. I think it is an easy System to use	3.5	3.6	3.6
2. The Structure and organization of the System	4.0	3.2	3.6
3. The tasks I performed were very meaningful to me.	4.0	3.0	3.5
4. The tasks were usually interesting enough to keep me from getting bored.	3.0	3.0	3.0
5. I felt the current Techniques and Paradigms structure design is good enough for me to perform the tasks.	3.5	3.8	3.7
6. The presentation of the product is pleasant and not shabby	4.0	3.8	3.9
7. I am in general satisfied with the kind of work I performed in the different (HCI) Techniques and visualization Paradigms tasks.	4.0	3.8	3.9
8. I felt very satisfied with the amount of challenge in these tasks.	4.0	3.8	3.9
9. I know at what stage I am in the system	4.0	3.8	3.9
10. I felt very satisfied with the accomplishment I got from performing the tasks.	3.5	3.6	3.6
11. I felt very satisfied with the amount of independent thought and action I could exercise in the tasks.	4.0	3.8	3.9
12. I did not need any help to manage the program	2.5	2.8	2.7
13. The processing speed of the System is fast	3.5	3.0	3.3
TOTAL	47.5	45.0	46.3

We conclude from the results of the questionnaire about the AVI system that it has achieved all requirements, and has advantages such as (good-quality results, flexibility, simplicity, interactivity). The visualization paradigms and Human-Computer interaction techniques in the (AVI) system will add significantly to the evidence base necessary for the educational community to guide the production of high-quality visualization techniques in this field, facilitate adoption by users, promote successful commercialization and guide future research tasks. In summary, based on the AVI system assessment, knowledge creation and sharing becomes more convenient. Through the AVI system, learners can be a concept map provider or a mentor for their peers.

7. Conclusion

All the literature reviewed show an increasing presence of ICT in various fields, and to a lesser extent the use of GISs in educational systems. Neither higher educational students nor teachers are aware of the training potential these tools that they use in their day-to-day lives can bring. Even more so, with the introduction of necessary competencies in the curriculum, it presents an excellent opportunity to incorporate the information technology and GIS, in the sense that these contributes to the acquisition of several competencies, such as digital, mathematical, knowledge of the physical world. However, not all resources are applicable for the classroom, it is necessary for teachers to perform an analysis to know if these technologies support their objectives and purposes, and to what extent they will improve their professional work and teaching-learning processes. Teacher training related to information and communication technologies can be key to making the introduction and assimilation of these in schools a reality. There are pioneering experiences in the introduction of ICT and GIS in education, and although they occur mostly in advanced countries, they are being produced in Middle Eastern countries as the current work shows. This represents a new advancement in the field of Geography and Archaeology. However, this is an exploratory development and there is still much more work to be done, the use of the AVI system would provide an inexhaustible source of historical information, especially in Middle Eastern Countries, where various contents that were impossible to see can be made possible for the learning and teaching of Geography and Archaeology. The use of the tool will help students to play a more participative role and enrich the entire teaching-learning process. Among the numerous resources available free on the network, we want to recommend the AVI application in education. It is a very applicable GIS for its use in subjects associated with Geography and Archeology since it allows new ways to search, treat and obtain of geographic information. In addition, it has some simple tools that can encourage students to pick up this technology. This will allow the development of practices that can complement and deepen the theoretical contents explained in the classrooms without having to deal with data from the Human-Computer Interaction framework.

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