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***Research paper***

# Usability Testing of "CHIsel": Cultural Heritage Information System Extended Layers of Interactive 3D Computer Generated Images and Relational Database

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**Abstract**

CHISel is a cultural heritage information system that supports the extensive organization, tracking, and implementation of data on 3D computer generated models of archaeological artefacts and site. We conducted a detailed user test of CHISel, to assess the usability of the complex and numerous system features, in order to assess the efficiency, user satisfaction, memorability, learnability, and accuracy. These qualities are particularly crucial to software like CHISel, which has a high learning curve for new and inexperienced users, involves professional, field-specific users, requires high-precision, high accuracy and contains a large amount of complex system features that must function well in order for the program to work as an apt integrative system.

***Keywords***: *Cultural Heritage, 3D Archaeological Model; Usability; Cognitive Walkthrough; Virtual Reality.*

## 1. Introduction

Recent destruction of archaeological sites and cultural heritage artefacts, reported in the news have reinforced the importance of preservation of these fragile cultural heritage artefacts. In addition, the quantity of archaeological data produced grows on a massive scale, which necessitates a bridge between primary and secondary information [4]. Primary information features objects, configurations, or the archaeological data themselves. Secondary information features restauration attempts, documents, publications, images, and collections. The combination of new technologies such Virtual Reality (VR), 3D volumetric imaging and 360-degree imaging, are a new medium that is ideal for representing and reproducing these artefacts in a 3D computer generated environment. Researchers of archaeological artefacts must be able to determine relationships between data, particularly in terms of the spatial relationships, in order to develop an understanding of cultural heritage information [8]. Archaeologists and museum specialists need a major tool capable of helping them complete the complex tasks associated with restoring, tracking, organizing, and researching historical artefacts. Integration, connectivity, and cohesion of the many and complex cultural heritage artefact features and information types, in a 3D computer generated environment is a challenge. A standardization of programming languages used, techniques used for uploading the models, accessibility of tasks, geometric integration, user interactivity, and the system hierarchy of features (chronology of implementation, abilities and constraints for the user, etc) must be developed further to improve the platform of cultural heritage information systems [1]. The Internet and the World Wide Web allow us to link these virtual 3D artefacts with already available analyses and other historical and architectural information. This will allow us to preserve cultural heritage information, and collectively explore how they once looked and were used, and the documentation of all related spatial and non-spatial data [3, 4, 6, 9-15].

### 1.1. Description of CHISel

The aim of our application called the Cultural Heritage Information System, extended layers, (CHISel), is to enable cultural heritage researchers to determine relationships between data, particularly spatial relationships for cultural heritage information [8]. Archaeologists and museum specialists need a major tool capable of helping them complete the complex tasks associated with restoring, tracking, organizing, and researching historical sites. CHISel manages data linked to any surface of an uploaded 3D model, see figure 1 for an example. It is composed of many system features that allow the user to organize and communicate a wide array of data types on the model, which are often databased. The information tracked on specific areas of the model is created by the system and user by the adding and editing of visible layers, colours and text. The use of layers is the cornerstone to the software, since this provides color-coded and area-specific visualization of data on the model to multiple users who work as a team on the site, or who wish to research the site [8].

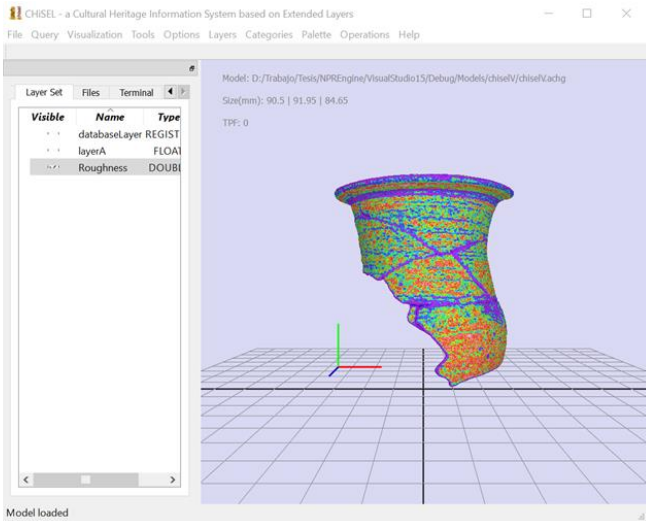


**Fig.1.** Geometry and Roughness. The user can activate the roughness feature under "*Geometry*" on the top menu to view roughness as a gradient [1, 8].

## 1.2. Literature Review

VisArq 1.0 is a digital elevation model accessible through different HTML pages which supports the distribution of archaeological sites [2]. VisArq 1.0 displays the archaeological evidence of Zaragoza, Spain, mapping a 3D visualization of the entire area. For this to be possible, a large information base is stored, implemented, and displayed on different levels. Four main tasks must be fulfilled for the correct implementation of this 3D software: 1. Design of database is established; 2. creating a Digital Elevation Model, 3. creating HTML interactive forms; 4. Implement the connection, management, and display of information. Connection of information databases, proved to be challenging, and the authors explain that it will continue to be a hurdle for cultural heritage information system applications [2].

Virtual Scenarios Manager (VisMan) was developed as a tool for virtual archaeology, VisMan is modelled after game design concepts to make it intuitive to use [2]. It implements the use of video game-like flyby and walkthrough functions, so that the user has a wide, meaningful field of view which creates a first-person immersive experience. Automatic navigation and image-based rendering are possible, and sounds can be added to specific events. The primary goal is to use VisMan as a museum application, allowing the user to "*Walk-up-and-Use*" and perform many related tasks. Data on the artwork, such as information on the artist, can be used as a starting point for the object selected. DHER VisMan is an open-source framework for virtual reconstructions of Roman houses, which stores various levels of data at a photo-realistic level [2]. It permits only one-on-one data visualization without querying of the data, partly due to the higher demands of integration of system features and connectivity of databases.

In terms of the 3D models themselves, factors that influence digitization of these models are:

1) Complexity in size and shape
2) Level of detail, and
3) Diversity of data [5].

Standards must be consistent for data preparation (*i.e. what technique is used and where does digitization take place*?). Digital recording and data processing require the unification of the model through scanning, geometric data processing, texture data processing, and texture mapping. Highly accurate geometric detection is key, as errors can cause terrible inaccuracy and the displacement of data, not to mention inefficiency of the program functions [5].

### 1.3 Usability Assessment of CHISel Prototype

The software application CHISel was developed at the Virtual Reality Lab of the University of Granada, is a 3D computer image manipulation system for analysis and annotation of cultural heritage artefacts [1, 8]. CHISel allows users to create extended layers of information and annotations on a 3D model of an archaeological artefact, and it manages data linked to any part of the surface of this 3D model. It supports the extensive organization, tracking, and implementation of restoration data and research notes from multiple users, on a 3D model of an archaeological object or site. The 3D model can be rotated and enlarged for inspection and analysis, and sections can be color-coded and labelled for sharing and collaboration with colleagues and for future reference. The storage of these diverse and vast amounts of data is crucial to succeeding in the preservation, associated documentation and restoration processes of cultural heritage artefacts. Advanced software is necessary for maintaining this data in an organized manner, that also allows multiple users to contribute and interact with the artefact and the data, by means of relating it to a specific spatial area of the 3D model. With such complexity in level of detail and the meticulous accuracy required for archaeologists to achieve success on cultural restoration, there lies a great responsibility in being able to track, implement, manipulate, and communicate different types of data on the object or site. This requires a software that is not only efficient, but flexible in implementing a large amount of data using complex system features for the user, while simultaneously promoting the proper constraints to such a flexible software. This means that, while providing the user the freedom to accomplish many tasks related to 3D artefact analysis, data storage and annotations on the 3D model, there must also be a level of standardization of system features established, for the sake of multi-user collaboration, and consistency and accuracy of the overall system functions. We report here on the user-centered evaluation of the first iteration of CHISel, V1.0. The application was assessed in terms of the usability of the complex and numerous system features, including all main tasks and associated subtasks. Usability is important to the enhancement of efficiency, user satisfaction, memorability, learnability, and accuracy (low error rate) of software programs in general, and strong usability is particularly crucial to software like CHISel, which:

1. Has a high learning curve for new and inexperienced users.
2. Involves professional, field-specific users,
3. Contains a large amount of complex system features that must function well in order for the program to work as an apt integrative system, and
4. Must allow multiple users to collaborate over time and leave meaningful notes for each other regarding the work in progress.

CHISel is composed of many system features that allow the user to organize and communicate a wide array of data types on the model. The information added by users to specific areas of the model are done so through the adding and editing of visible layers. The use of layers is the cornerstone to the software, since this provides color-coded and area-specific visualization of data on the model from multiple users who work as a team on the site, or who wish to research the site [8]. Thorough user testing of applications like CHISel will help guide these standardizations in a more accurate direction, hopefully closing the gap of complexity that continues to pose a challenge to such an advanced software.

## 2. Evaluation of CHIsel with the Cognitive Walkthrough Method

The methodology for the evaluation of this first prototype of CHISel consisted of an extensive Cognitive Walkthrough (CW), which we used to assess the main tasks involved in using a system, in terms of usability. The CW method was chosen as the most appropriate usability method because it can assess the system's learnability for new and inexperienced users. Since the software was still in a relatively early developmental stage, understanding learnability and system functionality was an important step for helping to improve future iterations [7]. The user-tasks assessed during the evaluation of CHISel V1.0 were: preparing and uploading a 3D model, editing layers related to data storage and databases, defining categories of data for database-type layers, editing the layers, obtaining model information from the query feature, activating features that displayed different ways of visualizing the model via textures, performing geometric operations, and editing color palettes of layers. These features were chosen as the primary focal points for user testing, as they encapsulate the majority of frequently used, vital features to the software's overall function.

**Methodology of the Study:** CHISel is a complex software with numerous features that are typically technical in nature. Extensive review of the software prior to designing the user-centered evaluation was essential in order to

1) Build a clear understanding of the general user experience with the software, and assessing what issues the users may go through, and
2) Writing an extensive and accurate CW to user test the important and frequently used system features.

The tasks for the CW were sequentially ordered based on training and a realistic "*simulation*" of what a user would do step-by-step when working with a model for the first time. Four representative users tested these system features and their subsequent multi-step tasks and subtasks, for over an hour each, to obtain detailed user feedback. Both observational (what the user did) and verbal (what the user said) data were recorded to obtain as many perspectives of the user experience of the application as possible.

***Training of the Experimenter:*** The software engineer trained the experimenter on system features and explained the process using an example 3D model. Training covered how system features were to be applied to the 3D model, showing the resulting effect each feature had on the model and the purpose of each system feature. After careful observation of the programmer's chosen features, the experimenter then reviewed these features and studied them alongside the CHISel manual. Self-training and extensive review of the software took approximately one week. The back-end programming (in C++) of CHISel was reviewed as well, so that the experimenter had a better understanding of the software's overall structure and functionality.

***Evaluation Method Cognitive Walkthrough:*** A CW was chosen as the most appropriate usability method because it assesses the system's learnability for new and inexperienced users. Since the software was still in a relatively early developmental stage, understanding learnability and system functionality was an important step for helping to improve future iterations [7]. The CW for CHISel 1.0 is described in full in [1]. A questionnaire probed user experiences with the model preparation, which included subtasks on importing and saving the model to the program, and how efficient the process was. Users were then asked to create two layers and create categories for each layer. Then, users were asked to edit the layers using the pen tip tool, query model information and statistics, rate the usefulness of the visualization features of model color, background color, bounding box, grid axis, and voxelized mesh. For geometry, users then performed curvature and roughness operations, and assessed the feedback of the program when making changes to the model with the palette. The steps of each topic task and subtask can be found in [1].

***Participants***: Four participants, 2 males and 2 females were recruited between the age of 24 - 45, all had an academic background and either human-computer interaction or computer interface studies, thus being representative of the anticipated end-user group. No participants had any prior knowledge or experience with the CHISel software or were familiar with cultural heritage information systems.

## 3. Results

Participants were asked to carefully go through each task in order on the CW, following every step. They were asked to verbalize their process aloud, explaining what they were doing and providing feedback on what features they were struggling with. For the CHISel CW, each participant took about one hour to one hour and twenty minutes. The experimenter took notes. These notes were analysed alongside the results from the CW and conclusions were drawn, as summarized below. Using the CW, usability issue types were identified, and scores were given for each usability problem that was found, to convey the impact of problematic usability issues on the user experience (see table 2). In this table only two of the 7 assessed tasks are presented due to length restrictions of this text, the full details of the other tasks can be found in [1]. From these two examples shown in Table 1 the relevant information can be drawn to illustrate the what kind of results a CW can produce and what the information can look like.

## 4. Discussion

Many usability issues were found at different severity levels for each task topic. For the scope of this discussion, the severe issues are highlighted for task 1 Model Preparation and for task 2 Creation of Layers only (see Table 2), to show how usability design ideas can be suggested based on the user data analysis. The full details on the other tasks can be found in [1].

Another way of analysis the user data is to look for common themes in the data. The majority of usability issues that were found, can be grouped into the following themes: Efficiency, Feedback, and Pop ups, see Table 3.

Additionally, some generally applicable user-centered design conclusions that are relevant for these types of touch screen, Walk-up-and-Use museum-based 3D VR applications, can be drawn from combining the evaluation data. The general recommendations that can be made about the screen layout of these types of systems relating to the Workspace, the Toolbox, and Pop up messages. Finally, from these a list of tentative guidelines to help make the user interface efficient and effective, can be established, see Table 4.

**Table 1:** Compilation of usability issues and issue types found, organized by topic

| CW Task | Issues Found | Usability Issue Type |
|---|---|---|
| 1 Model Preparation | - User must use keyboard arrows to adjust resolution<br>- Unnecessary bold text<br>- No difference between “chg” and “achg” file types for saving<br>- Saving to a folder creates extra step<br>- Frequent saving errors<br>- Unnecessary “ok” button<br>- “Loading triangles” message holds no meaning | - Font/visual crowding<br>- Consistency<br>- Navigation<br>- Navigation<br>- Efficiency<br>- Feedback |
| 2 Creation of Layers | - Many clicks required on “name box”<br>- Uncertainty of saved values<br>- “Size box” name ambiguous<br>- “Ok” should be changed to “save”<br>- Pop-up window disruptive to view of model<br>- Presence of pen tip is assumed for coloring mode and not rotation of model | - Minimal click rule<br>- Feedback<br>- Labeling/meaning<br>- Feedback/error prevention<br>- Pop-up<br>- Feedback/correct use of affordance<br>- Efficiency/training |

**Table 2.** Task 1 Model Preparation and Task 2 Creation of Layers

| | |
|---|---|
| **1: Model Preparation** | During the model preparation task, all four users had to spend extra time saving the model to a folder, which is unnecessary to the upload process of the model altogether. Eliminating this entirely should be prioritized. There were also many saving errors that forced the users to redo the process. This is an efficiency issue that alters the entire functionality of the program, especially at the very start. Frequent saving errors can be eliminated if the need to save the model to a folder is eliminated first. |
| **2: Creation of Layers** | All four users had to click several times before name box was activated. This should already be an automatic process, and pre-populated if possible to save time and steps. It would be better if the “ok” button is labeled as “save.” While this may seem like a simple labeling issue, it caused many errors. Confirming feedback that progress has been saved would be most helpful here. A pop-up window was also disruptive to the model view. A “clear values” button in close proximity of the “ok” button caused many user errors as well and should be moved further away. Clear Values also needs a more apparent explanation of meaning. |

**Table 3.** Three common themes in the usability data from the CW.

| |
|---|
| Efficiency: A lot of time was wasted on efficiency issues. Many of these can be avoided when feature icons are visible, and properties are visible. Promoting accessibility to frequently used features and properties will resolve a large portion of efficiency related issues. High priority features should always be the fastest to find. |
| Feedback: There was often a lack of feedback provided by the system. By focusing usability resolutions on useful text provided by retractable property windows juxtaposed alongside the workspace, with accurate units and concise information relevant to the task, many feedback issues found can be resolved. |
| Pop ups: The most common theme in terms of severe usability issues found. Pop ups should be rare and only used when necessary, but they were in fact a frequent occurrence in CHISel. By shifting some information provided in pop ups to property tabs, while making remaining pop-up windows easily disappear (perhaps a hide function to minimize and maximize the window as needed) in order for the workspace to be visible is an integral fix to the program as a whole. |

**Table 4:** Design for Touch screen Walk-up-and-Use interactive 3D visualisation museum display**.**

| |
|---|
| <u>The workspace:</u> This is the central area of focus on the interface, in which the environment or 3D model is featured. This space provides the user with an interactive environment in which to manipulate according to the specific tasks.<br><u>Workspace guidelines:</u> The workspace should maximize as much screen real estate as possible. This means that the toolbox and properties should not interfere with the quality or size of workspace visibility, and the workspace should be clearly displayed and easy to navigate, rotate, and drag. Rotation and drag features should be easy to use and promote smooth navigation throughout the environment.<br><u>The toolbox:</u> These are the icons that represent the system features that the user can access to manipulate the workspace.<br><u>Toolbox guidelines:</u> The toolbox should feature items of frequent use in areas the user can most quickly access. The icons should also be spaced appropriately - not too far apart and not too close together - so the user can access them with accuracy. Ideally, icons should best represent the action of the feature, such as an eraser icon representing a feature that erases. Rare or infrequent tools should not be displayed near frequently used tools. Frequently paired tools, which are features that are often used together for a particular task, or related tools (like a pen and eraser), should be displayed in close proximity of one another. |
| <u>The Pop-up:</u> These are the data featured in the form of tabs and windows that provide the user with feedback on manipulations made in the workspace, as well as the status of the environment or 3D model in that workspace.<br><u>Pop up guidelines:</u> Pop ups must achieve a balance between providing informative - never unnecessary - feedback, and the ability for the user to avoid distraction from information overload. Feedback should be clear and related to the task. The use of pop-up windows should be minimal, and when used should not obstruct the workspace. The units and measurements for numerical information should be clearly labeled and meaningful. Tab displays should be accessible and clearly labeled, and retractable when not in use. |

**Table 5.** Lessons from applying the CW to access a Cultural Heritage exhibit.

| |
|---|
| **<u>Preparing for the CHISel CW</u>**: This took approximately three weeks - two of these weeks composed of training on software use by the programmer, while one of these weeks composed of self-training, dry runs, and practice with the program. Program practice included many use case scenarios based on the two week training, and the features used most frequently and emphasized as the most important were considered in the design of the CW. Major software bugs were noted so that the CW would be affected as little as possible by crashes that would force the user to restart. The major tasks to assess where selected, and sequential steps of the subtasks were designed after several test cases were performed.<br><br>**<u>Tasks and Subtasks</u>**: The CW was designed to closely emulate the general tasks and subtasks a true user would complete on a given day using CHISel, from start to finish. Since four users were available to participate, the CW was designed to be extensive - the completion of the test took approximately one hour per participant. Training prior to the CW would have produced different results. The idea of a step-by-step instructional guide for tasks was to gauge an authentic, first-time experience with the program, much like driving down an unfamiliar highway. There was no prior awareness of the bumps in this software road, creating a testing environment for assessing the intuitiveness of the program's usability.<br><br>**<u>From Notes to Priority Re-designs</u>**: The first batch of results were handwritten notes taken during each walkthrough. These notes were carefully organized and cleaned - any notes not consistent with more than one user were disregarded. A bullet list was then compiled. It took several hours to carefully go through each note and rewrite the result in a cohesive, understandable way. Severity ratings were divided based on frequency of the issue, the importance of the task, how aesthetic the issue was, and whether the issue was a software bug. It is important to note that there is no qualitative basis of the results - they are qualitative, but follow usability guidelines as closely as possible.<br><br>**<u>From Mono-skilled to Multi-skilled Team Members</u>**: The programmer responsible for the engineering of CHISel received the feedback for CHISel results. Problems related to software bugs and perceptions of icon representativeness were included in these results. Due to the close collaboration between the programmer and the experimenter and the compilation of the CW results in themes, the programmer was able to learn about their strengths and weaknesses in terms of interface design and they learned in which areas they could improve. The experimenter learned more about the technical language and the design decision trade-off process that needs to take place when connecting functionality with the user interface. |

## 5. Conclusions

CHISel is a strong pilot of first iteration cultural heritage information software. Applying the CW method has provided us with rich, detailed evaluation data from which to assess the quality of the user experience and user interface. There are some final valuable lessons that can be drawn from our experiences applying the CW method, in terms of how to prepare for an evaluation using the CW method, preparing the materials and running the evaluation with real participants, and how to handle the rich source of information that a CW provides, see Table 5.

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