The EPOCH Multimodal Interface for Interacting with Digital Heritage Artefacts

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Abstract. In recent years, 3D and virtual reality have emerged as areas of extreme interest as methods for visualizing digital museum artefacts in context, and particularly over the Internet. The technology associated with these new visualization techniques has until now been very expensive. The advent of cheap computing and graphics cards coupled with increasing Internet 'broadband' access has made possible the implementation of effective virtual museums both online and within the museum. Virtual museums are valuable for the end-user for efficient and remote learning about their local heritage in a diverse multimodal manner. Multimodal access to museum artefacts can help the user to better understand and appreciate the objects and stories that the museum brings forward, but also creates a closer psychological bond between the user and his past. If we now couple cheap computing technologies, 3D and virtual reality with appropriate 3D interaction techniques based on formal usability evaluations, museums are able to implement high fidelity exhibitions that are intuitive for the museum visitor. This paper reports on the latest technological additions to the EPOCH Multimodal Interface, which is used as an interaction interface that can be implemented as part of a virtual museum interactive system.

1. Introduction

Museums small or large play a unique role in preserving our heritage and exhibiting that heritage in the traditional way, i.e. through exhibitions within the museum. Depending on the type of museum, e.g. the Natural Science Museum in the UK, and the like, interactive exhibitions loosely engineered into so called 'kiosk' based systems are quite popular.

However, innovative multimodal visualisation technology is now starting to make an appearance, that of virtual and augmented reality [16, 18, 22, 30]. Integrating 3D content, for example, into a museum's website has been shown to enhance the experience of learning acquired by a visitor's interaction with an online exhibition, either within the museum or on the Internet. Further, virtual reality interfaces offer curators new technological tools for preservation and access. The curator could utilize these tools to extend their already existing digital preservation techniques by adding digital 3D models of artefacts to their digital archives, and then repurpose these digital surrogates for presentation in visualisation systems (perhaps built into kiosks) that also allow access online by the citizen.

Museum artefacts can now be digitised accurately, using laser, photogrammetry and cheap software, and thus create photorealistic 3D models for display online. Innovative interaction systems can be designed that expand on the traditional museum approach of displaying an artefact in a glass case with the curators' viewpoint on a simple card. In short, we can liberate the physical artefact in the form of a digital surrogate and interact with it through physical touch and tactile handling [22]. Of particular interest for a museum is the ability to create interaction systems composed of replicas of a museum's physical artefact linked to a 3D model (digital surrogate) of that artefact organised to deliver a contextual heritage view on the artefact.

One can imagine such a system in a museum whereby the actual artefact as before is displayed in its glass case, perhaps by a wall, and a large display is situated next to the glass case. Further, a robust physical replica of the artefact is linked to the display, which presents a virtual environment containing a 3D model of the artefact. The museum visitor can then explore the artefact simply by picking up the replica and observing that, as they turn the replica, the 3D model turns in unison. Thus, the visitor will obtain tactile information that is traditionally impossible, and by selecting attached sensors on the replica they can also explore a 3D world that digitally narrates the story of the artefact on the display. This paper reports on the latest technological developments of such a system and investigates key issues in virtual heritage environments that serve to drive such implementation systems.

2. Background

There are several key issues which should be considered when designing museum interactive systems:

1. Museum interactive systems should be as cost effective as possible given the limited funds available to the average museum.
2. 3D content should be created as cheaply as possible in addition to digitisation of supporting data.
3. Consideration should be given to the costs of maintaining the museum interactive systems because this implies new skills that need to be acquired by the museums, etc. The museum may in effect be converting itself from a learning institute to a so called hybrid institution [5, 24] where the institution exhibits not only analogue (i.e. the physical artefact), but also the digital surrogate or resources. In this context, it is important that authoring tools contain all tools necessary for proper digital curation.
4. Appropriate interaction techniques should be devised to augment the digital resource so as to effectively engage the user. In order to identify suitable interaction techniques for the end-user but also the curator, formal usability evaluation studies are necessary. Relevant skills are, therefore, needed.
5. Museum hardware and software should be repurposed in order to create innovative museum interactive systems cost effectively. This is achieved by accommodating generic hardware such as PC systems with appropriate museum based management and visualisation software such as that demonstrated by the ARCO system [11, 12, 18, 30] and EPOCH multimodal interface [16, 19, 21, 22].
6. Any museum interactive system should present the information as a story that reinforces the heritage behind the artefact that is on display targeted at different users and age groups. Using the new opportunities that digital storytelling [33] offers requires to extend the skill set of museum curators and their staff.
7. Perceived 'presence' [27] is shown to be enhanced when modalities such as sound and 3D content are added in a museum interactive system in order for the visitor to feel part of the virtual exhibition.

The museum community has now recognized the benefits of virtual museums towards efficient learning about their local heritage. Off-the-shelf technologies allow cheaper digitisation of collections, however cost does vary with complexity; digitising software for capturing internet quality 3D can cost as little as a few hundred dollars.

One of the limitations in the development of virtual museums by traditional establishments is the need for 3D content, which has been up to now expensive because 3D modelling is a time consuming and complex process. However, cheap software for 3D modelling allows even the smallest museum to create virtual artefacts using simple photography skills [24]. EPOCH partners are developing highly qualitative but efficient and cheap workflows for 3D digitalisation of museum objects in the 3DKIOSK activity [34]. These models can easily be exported as VRML/X3D models and incorporated into a virtual environment designed to offer interactive virtual content that provides a valuable experience for remote users [15] in addition to seeing an artefact in a museum glass case with a simple description on a card. Implemented virtual museums including a thorough collection of 3D content has transformed the so called learning institutions (e.g. museums, libraries, online catalogues, etc.) into "hybrid institutions" that accommodate both analogue and digital resources [18, 25, 30].

Interaction techniques and devices employing novel virtual reality interfaces are currently developing at a rapid pace [2]. Interaction technologies such as the space mouse, game pad controller, motion and orientation trackers, etc. are now available that can be integrated into multi-modal virtual and augmented reality interactive interfaces. Innovative 3D interaction techniques can now be developed and coupled to the virtual museums cost effectively. Such a virtual museum could be created in the form of a museum kiosk. An example museum interactive kiosk could consist of a simple but powerful PC desktop system rather than a bespoke and expensive kiosk that only has one use. A major advantage of this approach is that standard PCs with cheap interfaces can be re-purposed for new virtual exhibitions simply by replacing repository content, and display method [11, 12, 17, 18, 30].

3D content and virtual interfaces in virtual exhibitions do not just present virtual objects and descriptions; such content should be set in a story that reinforces the visitors learning and understanding of the cultural context in place. Therefore, one of the goals of museum interactive systems is to communicate and enhance the feeling of 'presence' related to a past era. Presence in virtual reality world (or virtual environment) can be explained as the participant's sense of 'being there'; the degree to which the users feel that they are somewhere other than they physically are, while experiencing a computer generated simulation [31]. It has been shown that both visual and tactical senses enhance perceived 'presence' while exposed to a virtual environment [29]. Thus, it is worthwhile investigating whether any multimodal interface enhances perceived presence in comparison to traditional interfaces. Formal usability evaluation studies have been recently conducted to investigate this issue [22]. Studies on the impact aspects of multimodal interfaces need to be carried out, to investigate if improved presence and access to the object changes the visitor engagement and appraisal of that piece of heritage and creates personal involvement in the sense of "this is my heritage".

The incorporation of new technologies in museums signifies challenging research opportunities having as main goal to provide novel ways to present regional or national heritage, as well as offering new consultation methods for archaeological or cultural sites and museums [4]. Our previous work has focused on systems for building virtual museums while our current work and the focus of this paper is on developing interaction systems and appropriate input devices.

3. Interaction Devices

In this paper, we are focusing on multimodal interaction with a digital surrogate of a museum artefact. We are particularly concerned in how effective 3D manipulation using the artefact as an input device is in comparison with lower fidelity interaction devices such as a simple mouse or keyboard [1, 3, 6, 8, 9, 16]. User interfaces for computer applications are becoming more diverse, e.g. 2D interaction devices such as mice, keyboards, windows, menus and icons are still prevalent but non traditional devices and interfaces can now be created rapidly and cost effectively. These include spatial input devices using motion and orientation trackers, 3D pointing devices, whole hand devices and three dimensional multi-sensor output technologies such as stereoscopic projection displays, head mounted displays, spatial audio systems, and haptic devices [3].

The method of interacting with typical 2D devices is common place; however interacting with 3D devices needs more consideration of the tasks involved. Interaction tasks according to Wuthrich [32] can be broken down into three elementary actions: selection/grabbing, positioning with N degrees of freedom and deforming [1]. Research carried out by Subramanian [28] has shown that an increase in the number of available DOF (degrees of freedom) in an interaction device can improve performance. By exploiting the interface requirements of specific tasks, the complexity of the 3D interface could be ultimately reduced, however, diverse application needs can also be identified [7]. For example, adding modalities such as sound, text or tactile feedback could enhance relevant visualization metaphors.

Our multimodal interface allows tactile feedback, sound, text and any manner of multimedia feedback to occur. Multimodal input systems process two or more combined user input modes in a coordinated manner with the multimedia system [20]. Our method matches the shape and appearance of the virtual object with the shape and appearance of the physical object so that the user can both ‘see’ and ‘feel’ the virtual object. By physically touching a virtual object (mixing the real objects and virtual reality) the quality of the virtual experience can be improved [8, 9].

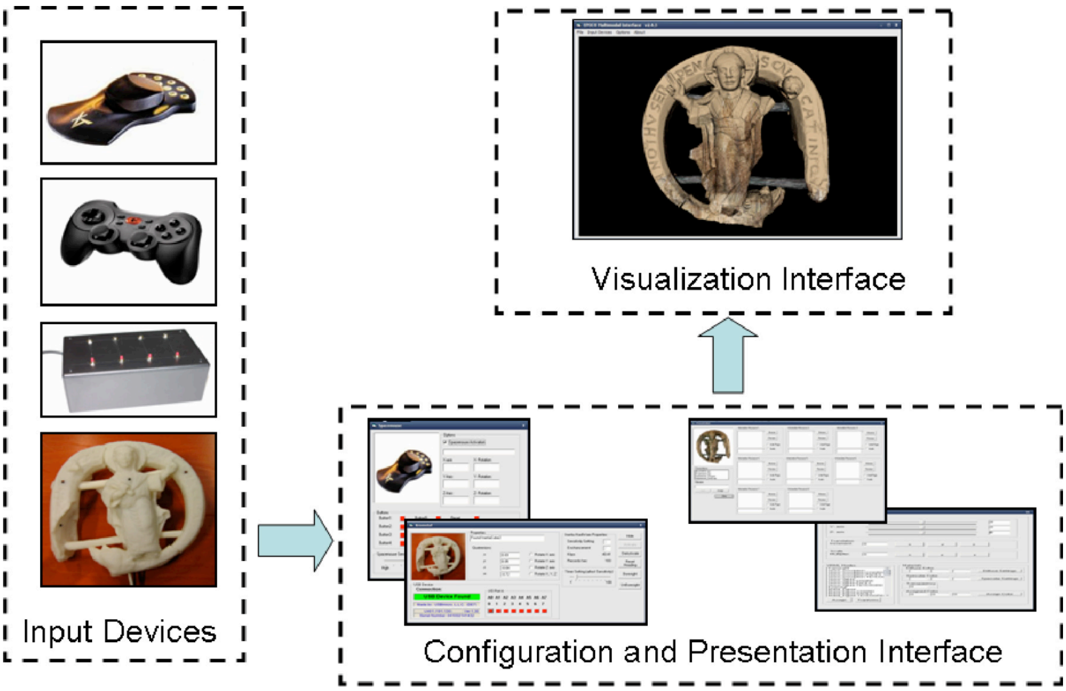

Figure 1: Overall System Architecture of the EPOCH Multimodal Interface

4. The EPOCH Multimodal Interface

We have developed several example applications in which our multimodal interface is demonstrated. In one application the multimodal interface has been integrated with a standard web browser including information content delivered as a part of an internet based virtual museum [21]. A standalone version which is a separate application has been developed and it was analysed in detail at VSMM2005 [22]. This version had only the ability to integrate one input device, the museum object ("Kromstaf") replica. This paper presents new technological developments which are implemented in a standalone application. The overall system architecture is shown on Figure 1.

The EPOCH Multimodal interface now incorporates many new features including:

1. The ability to use different input devices, Figure 1 illustrates:
    - The original Kromstaf input device reported in [19, 22]
    - A simple 'box' interface that has all the functionality of the Kromstaf but without the 'tactile' feel—includes orientation tracking and touch sensors.
    - A space mouse, which is a common input device for controlling 3D models in CAD software.
    - A Game pad, which provides a good interface for children used to playing games using this type of input.
    - The ability to add other input devices by simply creating a new input driver.
2. A new configuration and presentation interface incorporating:
    - A setup interface for the touch sensors.
    - A variety of input device interfaces, e.g. space mouse shown in Figure 1.
    - A simple content management system that allows the museum to assign content for display to each of the touch sensors.
    - A calibration interface for the orientation tracker.

The main purpose of the EPOCH Multimodal interface is to expand the presentation of a methodology that provides an alternative exhibition of an artefact through the use of a safe hybrid 2D/3D multimodal interface based on the integration of an orientation tracking device and touch sensor electronics with a physical artefact replica to provide tactile feedback [16, 19, 21, 22]. However, because we now include support for several orientation trackers from Intersense [10] (Intertrax, IS-300, IS-600, IS-900 and IS-1200), a SpaceMouse and support for any type of joystick/game pad the multimodal interface is very flexible. It can be adapted to the build of other bespoke input devices as demonstrated by the simple 'box' interface or if a museum did not want to go the expense of developing such an interface other cheaper input devices such as the space mouse or game pad can be used. Furthermore, in addition to the support of the above input devices, speech was integrated to the system and a simple content management tool has been added.

5. Alternative Input Devices

In the latest version of the EPOCH multimodal interface we foresaw the need to provide cheaper alternatives to the development of a bespoke input device such as the Kromstaf. As reported in [22] the development of an artefact replica involves laser scanning of the artefact in order to build both the 3D model and the rapid prototyping of the replica. The cost of developing the replica can be saved by using perhaps a less effective input device. Further, a cheaper alternative to developing a replica, which gives the same functionality, is to use the same orientation tracker and electronics in a simple box—or shape of choice. Even cheaper still is to use off-the-shelf 3D input devices. The box interface uses exactly the software setup interface as the Kromstaf. The two new setup interfaces are the for the space mouse and game pad.

The Magellan SpaceMouse plus XT [26] is a USB device providing a six degree-of-freedom (6DOF) mouse and a nine button menu interface, see Figure 2. All nine buttons are programmable. The user can program the buttons to perform several graphics operations and the user can now programme into the buttons so called 'information actions', i.e. calls to supporting information on web pages or other presentation media, e.g. movies, etc., or other events in the virtual world.

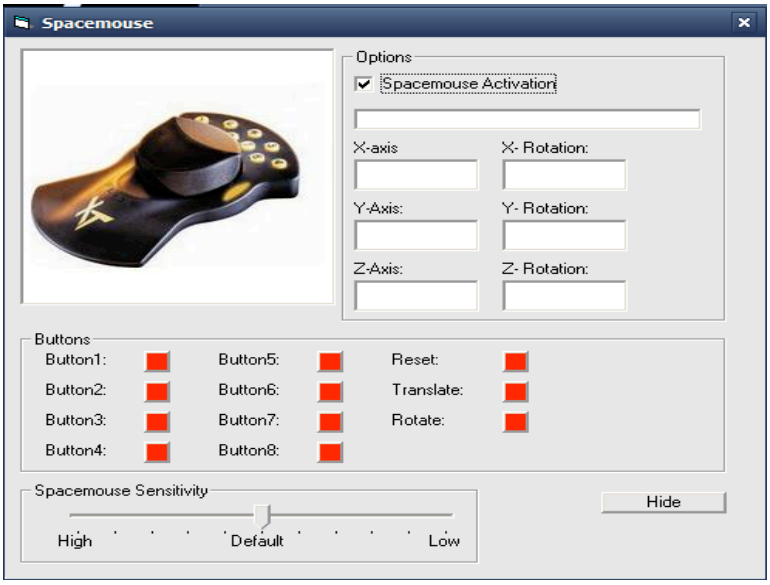

Figure 2: SpaceMouse Interface

The cheapest input device, which can be had for less that 40 dollars is a typical 'game pad', which can easily be integrated using the standard Microsoft 'Joystick' drivers. This provides an easy to use input device in comparison with the other input devices. Each button of the game pad is fully programmable. In our case three buttons are used to enable basic transformations, one button resets the scene and eight buttons are used to provide information about the cultural object such as historical information and a multimedia presentation of the artefact. The number of the buttons may vary according to the type of the joystick or game pad used. An interesting development is the new game pad input device that comes with the Sony PlayStation 3. This game pad is both wireless (nothing new there, we have tested wireless game pads currently available) and is reported to include a motion tracker. Such a game pad would provide a very effective and cost effective equivalent to the box interface.

We mentioned above that support for several trackers have been added to the system in order to provide the user with more flexibility. An example fragment of the Visual Basic code detecting the tracker is presented in Figure 4.

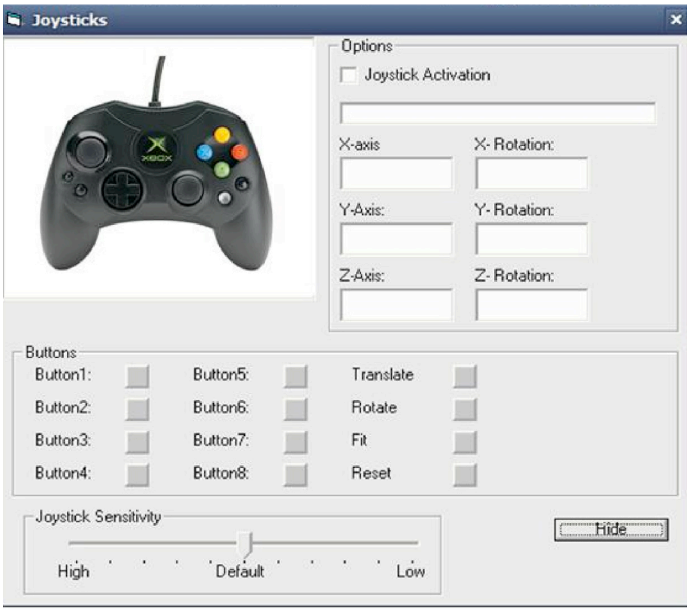

Figure 3: Game Pad Interface

```
If status Then
        Select Case MyTracker.TrackerModel
          Case 1
            Kromstaf.Text1 = "Found IS-300"
                            ..............................
                            ..............................
          Case 10
            Kromstaf.Text1 = "Found IS-1200"
          Case Else
            Kromstaf.Text1 = "Unknown tracker model"
        End Select
End If
```

Figure 4: Input Device Selection

Finally, in order to add multimodal input to the presentation methodologies speech has been integrated into the system. The software architecture is build around Microsoft Speech SDK SAPI 5.1 [14]. One of the functions responsible for converting the 'Text into Speech' is shown in Figure 5. A typical use scenario here is that the museum enters some text associated with a particular touch sensor (button) on the input device. A check box is then selected on the input interface to select whether the user wants to see the text display in the virtual environment or the text converted to audio and played when the button is oppressed, or both.

```
Function SpeakIt (Text As String)

  If Not Text = "" Then
     Voice.Speak Text, SVSFlagsAsync
     ' sp_flag = 1
  End If
Speak_Error:
  MsgBox "Speak Error!", vbOKOnly

End Function
```

Figure 5: Speak Function

6. Evaluation of the EPOCH Tangible User Interface

A formal usability evaluation has been performed in order to assess the usability of the EPOCH Tangible User interface by comparing a physical mock-up of the artefact (Kromstaf) with a Spacemouse and a blackbox for manipulating 3D Content. Fifty-four participants were recruited from the University of Sussex undergraduate and postgraduate population and were asked to interact with the system. The participants were divided into three groups corresponding to the three types of the interface (i.e. Kromstaf, blackbox and Spacemouse). Each group was balanced in terms of age, gender and their background. The experiment was divided into two stages. During the first stage we tested the written memory recall of the cultural artefact by manipulating either the artefact replica, the SpaceMouse or the plain black box for a brief exposure to the system. During the second stage we assessed the users' perceived level of presence and user satisfaction across all conditions. By analysis the data we collected from the two stages we discovered that the participants using the Kromstaf interface performed better in terms of memory recall performance compared to the other devices. Furthermore although there was a clear difference between the replica as well as the blackbox and the SpaceMouse provoking better user satisfaction, an overall statistically significant difference was not observed between the replica and the blackbox. For a more detailed analysis of the results of this evaluation study please refer to [23].

7. Conclusions

A user-friendly and interactive visualisation interface specifically designed for interacting with virtual museum and associated virtual artefacts has been described. Our system combines several types of interactions utilizing sophisticated devices such as the spacemouse, game pad, orientation trackers and touch sensors. This transforms the EPOCH Multimodal Interface from an interface designed for a specific task (manipulating only the Kromstaf replica) to a generic multimodal interface that the user can manipulate different items by using several input devices.

Further improvements to the system will be the addition of input devices such as virtual reality gloves, the integration to the system with the ARCOLite architecture reported in [11, 12, 17, 21] and extending the system so that it can be used with mobile devices.

8. Acknowledgements

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