A CONTACT-LESS INTERACTIVE TOOL FOR EXPLORING ARCHAEOLOGICAL DATA

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ABSTRACT:

We describe a contact-less system that allows interactive information retrieval and exploration. In particular we focus our attention on the development of a contact-less interactive system that can be used for the exploration and visualization of artefacts with archeological interest, using a GIS-based system. The basis of our approach is a tracking algorithm that is able to track head movements of the user. Based on head motion it is possible to move a cursor and select different options, in order to enable data exploration and presentation. The work for this project is in progress. We are currently in the process of implementing an information retrieval system that allows users to retrieve and view information related to Cypriot archaeological artefacts. Although the primary scope of our work is to develop a system that can be used in museums, it is possible to use such systems in other environments such as airports, information kiosks and for general internet browsing. The only extra requirement for using our system is a standard web camera used for capturing images of the user. When compared with other systems currently is use in similar applications (i.e. systems using touch screens), the proposed system offers similar functionality at significantly reduced cost. The results of a preliminary experimental investigation, demonstrate the potential of using the proposed system in applications involving the dissemination of cultural heritage related information.

1. INTRODUCTION

Quite often in museums and other public places, computer-based systems are used for providing additional information related to exhibits. An important issue in such cases is the mode of interaction between perspective users of the system and the information dissemination tool. In most cases the interaction is carried out through the use of standard keyboards, mice or touch screens. The use of conventional human interaction methods that require physical contact may not be the best option for this type of applications because visitors usually carry other items during their visits (i.e. cameras, leaflets, bags etc) that prevent them from using Human Computer Interaction (HCI) devices that require the use of hands.

As an alternative we describe the use of a contact-less human computer interaction system that enables visitors to use computer-based information retrieval systems using head motion. Interfaces based on head motion provide the following advantages when compared to other type of interfaces:

- Ability to interact with a system in a hands free fashion.
- The overall cost involved in setting up a contact-less HCI system can be lower than the cost involved for other types of interfaces (i.e. touch screens).
- The possibility of damage to the interface hardware and the host computer is limited, as users do not have physical contact with the hardware.
- Due to the contemporary nature of this type of interfaces, visitors (especially young children) are attracted to using the information system. As a result they can receive information and knowledge in an interesting game-based environment. According to Prensky (Prensky, 2003) learning activities in game-based environments can be more effective than traditional ways of learning.
- Since the interaction is done in a contact-less way, potential users will not have hygiene related reservations in using the interface.

The proposed system is based on a head and eye-tracker capable of tracking eye movements of users within the optical view of a standard web-camera. The tracking process is activated automatically when users enter the field of view of the camera, so that users can use the system instantaneously. The face tracker activates cursor movements consistent with the detected head motion allowing the user to control cursor movements and activate mouse clicks. Figure 1 shows a user using a computer system based on the system developed.

The operation of the head tracking system is optimized for use in relation to an information retrieval application that can be used for obtaining information related to archaeological Cypriot artefacts from the Cyprus Archaeological Museum in Nicosia. The applicability of the contact-less system in relation to the application mentioned above was evaluated by a number of volunteers. Early results demonstrate the potential of this approach for applications involving information dissemination for cultural heritage (CH) applications.

Figure 1: Example of the head-motion-based interaction system

In the remainder of the paper we provide a brief literature review related to interfaces used in museums and we describe briefly the head–based contact-less HCI system. In section 4 we describe the application that we used in conjunction with the HCI system and in section 5 we present preliminary results of a human-based evaluation experiment that aims to assess the applicability of the proposed system for interfacing with computers in museums. Concluding comments and plans for future work are presented in section 6.

2. LITERATURE REVIEW

The topic of developing improved ways of disseminating information in museums (Stock, 2007; Hornecker, 2006; Hsi, 2002) or information kiosks (Maguire, 1999) received significant attention. The aim for these efforts is to attract and encourage visitors to seek information related to the exhibits, using elegant and non-invasive methods. Such efforts focus on four elements which are (1) an effort to design contemporary interaction methods so that users are attracted to use information systems, (2) to provide an easy way to use the system (3) to increase the educational impact of a system, by presenting information in an interesting and engaging way and (4) to enable interaction between visitors (Grinter, 2002). With our work we concentrate on dealing with the first two issues, since we aim to present a contemporary head motion-based interaction scheme that facilitates the process on information retrieval.

Human computer interaction using head movements has been investigated by a number of researchers. In a related survey paper, Duchowski (Duchowski, 2002) provides a thorough discussion on the use of eye tracking in different applications, including the control of interactive displays. Toyama (Toyama, 1998) describes a face-tracking algorithm consisting of a number of layers. The tracking process starts with a layer dedicated to skin detection and through an incremental approach they introduce more capabilities into the tracker. Information related to the face position and pose recovered during tracking, is used for moving the cursor on the screen. Gorodnichy and Roth (Gorodnichy, 2004) describe a template matching based method for tracking the nose tip in image sequences captured by a web camera. In the final implementation cursor movements are controlled by nose movements, thus the user is able to perform mouse operations using nose movements. Zhu and Ji (Zhu, 2004), perform eye tracking based on infra red illumination and the use a neural-network based approach for mapping the position of the eyes to screen coordinates, enabling in that way the control of cursor movements using eye-motion. Zhu and Ji tested their system on using graphic displays applications involving the retrieval of information from maps. Frangeskides (Frangeskides, 2006; Frangeskides, 2007) describe a multi-modal head-based HCI system that enables paraplegics to use a computer in a hands-free fashion.

Several commercial head movement-based HCI systems are available (www.abilityhub.com/mouse/). In most cases head tracking relies on special hardware such as infrared detectors and reflectors (www.naturalpoint.com/smartnav) or special helmets (www.orin.com/index). Hands free non-invasive systems are also available in the market (www.cameramouse.com). Such systems usually aim to provide an interaction tool for the handicapped rather than providing a generic human computer interaction facility suited for applications in public areas.

With our work we aim to target specifically the problem of designing an interface, which can be used for disseminating information in a museum environment. Both the case study and the evaluation process employed, target these types of applications.

3. CONTACT-LESS HCI SYSTEM

In this section we briefly describe the operation of the contact-less HCI system developed as part of our work.

3.1 Face tracking method

We have developed a face-tracking algorithm based on integral projections. An integral projection (Mateos, 2003) is a one-dimensional pattern, whose elements are defined as the average of a given set of pixels along a specific direction. The use of integral projections for representing rectangular image regions results in the representation of image windows using two one-dimensional vectors, enabling the implementation of efficient pattern matching methods. Apart from the ability to provide compact representation of image structures, representations based on internal projections can be noise free, since the process of estimating integral projections involves averaging operations that eliminate noisy responses.

During the tracking process we generate a template of the object to be tracked, by estimating the horizontal and vertical integral projections of the object. Given a new image frame we find the best match between the reference projections and the ones representing image regions located within a predefined search area. The centre of the region where the best match is obtained, defines the location of the object to be tracked in the current frame. This procedure is repeated on each new frame in an image sequence.

The method described above formed the basis of the face-tracking algorithm used for tracking faces in a public environment. The face tracker developed, tracks two facial regions – the eye region and the nose region (see figure 2). The nose region and eye region are primarily used for estimating the vertical and horizontal face movement respectively. Once the position of the two regions in an image frame is established, the exact location of the eyes is determined by performing local search in the eye region.

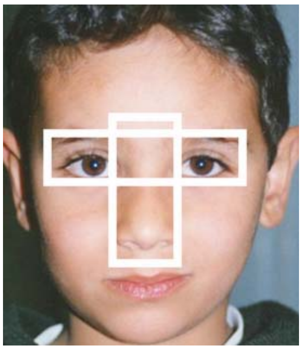


Figure 2: The Nose and Eye Regions

In order to improve the robustness of the face tracker to variation in lighting, we employ intensity normalization so that global intensity differences between integral projections derived from successive frames are removed. Robustness to face rotation is achieved by estimating the rotation angle of a face in a frame so that the eye and nose regions are rotated prior to the calculation of the integral projections. Constraints related to the relative position of the nose and eye regions are employed in an attempt to improve robustness to occlusion and excessive 3D rotation. In order to apply topological constraints related to the positions of the search areas, we collect statistics of the relative positioning of the two search areas so that during the tracking process excessive violations of the expected positions are not allowed. Both the enforcement of topological constraints and lighting normalization, improve the robustness of the system to lighting variation and extreme face rotation, making the system suitable for use in public interfaces.

The accuracy of the tracking algorithm was evaluated using pre-recorded image sequences showing different persons (Frangeskides, 2006). In the test sequences different aspects of the tracking algorithm such as the robustness to changes in lighting, occlusion and excessive face rotation were tested. According to the results of the experiments, the face-tracking algorithm is capable of locating the eyes of subjects in image sequences with less than a pixel mean accuracy. Even in the cases that the tracker fails to locate the eyes correctly, the system usually recovers and re-assumes accurate eye-tracking.

3.2 System Operation

In this section we describe the main operations supported by the system that include the initialization phase, cursor movement and mouse click operations. Although our system supports all types of possible interactions (i.e. double clicks, drag and drop etc) we only describe the operations which are utilized in conjunction with the in-museum information system.

System Initialization: When a user wishes to use the system he/she is required to go through an automatic initialization process, so that the system learns about the visual characteristics of the user. During the initialization process the user is requested to keep his/her face still and perform blink actions. Based on a frame-differencing algorithm the positions of the eyes and nose regions are determined and integral projections for those areas are computed. Once the projections are computed the face tracker is activated. The tracker initialisation process requires approximately 10 seconds to be completed. A screen shot of the initialisation tool is shown in figure 3.

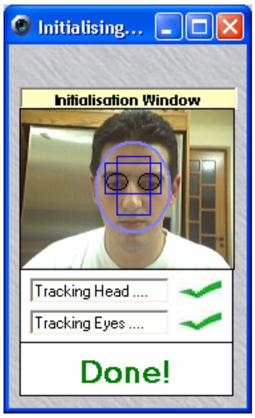


Figure 3: System Initialisation Window

Moving the cursor: The divergence of the face location from the initial location is translated in cursor movement speed, towards the direction of the movement. Based on this approach only minor face movements are required for initiating substantial cursor movement. The sensitivity of the cursor movement can be customized according to the abilities of different users.

Mouse Click: Mouse clicks are activated by the stabilization of the cursor to a certain location for a time period longer than a pre-selected threshold (usually around one second).

4. CASE STUDY

In order to evaluate the system in an application suited to information dissemination in a museum environment, we have implemented a prototype GIS-based application suitable for disseminating information related to Cypriot archaeological artefacts from the Archaeological Cyprus Museum (Nicosia). Such a system can be used in museums and other public places where it is useful to disseminate this type of information. In our preliminary investigation we have stored in the system the minimum amount of data required for staging evaluation experiments. Once the experimental evaluation is completed we plan to enrich the system with more data in order to create a complete e-handbook of all artefacts available at the Cyprus Archaeological Museum. Hereunder we describe the data stored in the system and the operation of the experimental information dissemination system.

4.1 Data Depository

Archaeological artefacts currently stored in the database belong to three different historical phases: the Late Cypriot period (c. 1600 – 1050 BC), the City-Kingdoms era (c. 1050 BC – 325 BC) and the Hellenistic historical period (c. 325 – 30 BC). In our preliminary work we have collected data for about 20 artefacts, from the Cyprus Archaeological Museum, belonging to the three historical phases under consideration. We are currently in the process of enriching the database with more artefacts belonging to a wider range of historical periods. For each data item in the database the following data was recorded:

- Artefact name
- Historical period
- Location where the artefact was found
- Image of the artefact
- Short description of the artefact

Samples of typical data items currently stored in the database are shown in figure 4.

(a)

(b)

(c)

Figure 4: Typical artefacts stored in the system. (a) Cylindrical box for cosmetics (Late Cypriot period), (b) Terracotta group of two men and bull (City-Kingdoms era) (c) Limestone head of a female figure (Hellenistic period)

4.2 System Interface

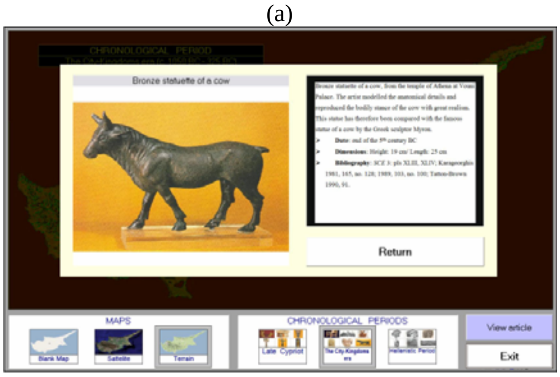
The system provides a GIS-based interface displaying the locations where each artefact belonging to a pre-selected historical phase, was first found. Figure 5 shows a typical screenshot that displays locations where artefacts belonging to the Late Cypriot period (c. 1600 – 1050 BC) were found.

Figure 5: Screenshot of the system showing the locations where artefacts belonging to the Late Cypriot period were found

The user can select the historical period of interest so that locations of artefacts belonging to the selected period are displayed on the map. Wherever the cursor is directed near an artefact location spot, a thumbnail of the artefact appears on the screen. A mouse click operation displays a full size image and appropriate information of the artefact. An illustration of the operation of the system is shown in figure 6.

Based on this interface a user of the system is able to retrieve information and photographs related to different artefacts using cursor movements and mouse clicks activated using head movements. Special emphasis was given to the design of the buttons and other controls of the interface since the results of a quantitative evaluation of the head-based HCI system indicated that users perform better when they have to click on large size buttons (Frangeskides, 2007).

(a)



(b)

Figure 6: Demonstration of the system operation. (a) Displaying a thumbnail related to an artefact wherever the cursor is near the artefact spot. (b) By clicking on the thumbnail information and full size image of the artefact are displayed

5. EVALUATION

In this section we describe our preliminary work in assessing the use of the contact less HCI system in relation with the proposed application. The evaluation process aims to evaluate two aspects of the proposed system. The first aspect is the performance of users in retrieving efficiently information using the head motion-based system. The second aspect of the evaluation aims to evaluate the appeal and educational significance of the system when compared to conventional HCI systems used in similar applications. The evaluation was done based both on quantitative and subjective measures.

In order to support the quantitative evaluation of the efficiency in retrieving data using the contact-less system, a dedicated version of the dissemination information system that contains a 'test-mode' option was developed. In the 'test mode', randomly selected spots on the map interface blink and the total time required by the user in accessing the information linked to the blinking spot is recorded. During the tests this procedure is repeated six times, so that the overall time for accessing information from six spots is recorded.

5.1 Experimental set up

Each volunteer who participated in the experiment had to complete the following evaluation procedure.

Benchmark performance: In order to define the benchmark performance, each volunteer was requested to use the system in 'test mode' using a standard computer mouse. The total time required for accessing information related to the six randomly selected spots is recorded for each volunteer.

Head Motion-based Test: Each volunteer was requested to complete the same test as the one used for specifying the benchmark performance. However in this case the control of the cursor movements and mouse-clicks are performed based on the head-motion system described in this paper.

Questionnaire: Each volunteer was requested to complete a simple questionnaire that contains few questions related to the system. In the questionnaire users were asked to compare the mouse-based against the head-based interaction system in terms of the appeal of each system, the practicality in using the system, the fun factor and educational impact. For each question volunteers were requested to assign an 1 to 5 score where 1 meant lowest mark and 5 meant top mark. The mean response among the 15 volunteers was quoted.

5.2 Results

In this section we present the preliminary evaluation results obtained when 15 volunteers participated in the experimental evaluation process. A summary of the results are shown in tables 7 and 8. Due to the small number of volunteers who participated so far in the experiments it is not safe to produce concrete conclusions. However the main trends among the test group can be identified. According to the results the total time required for accessing data using the head-motion based system is significantly longer when compared to the total access time required when a conventional mouse is utilized. This is expected since most users have experience in using a mouse for interactions tasks (see table 7). It is also expected that users rated the practicality of the mouse-based interaction system higher, since a mouse-based interface presents a highly practical interaction mode (see table 8, row 4).

However, in the remaining evaluation issues (see table 8) volunteers rated the appeal and fun factor of the head based system higher than the ratings for the mouse-based interaction system. These ratings prove that contemporary forms of interaction can attract subjects to use information retrieval systems so that information dissemination will take the form of an entertainment/computer game activity. We believe that the proposed system can play a significant role in attracting and encouraging visitors to spend more time seeking information through in-museum information systems.

Quantitative Performance (Mean Time required to access information from six spots)	
Mouse	**Head-Based**
18.1 seconds	79.3 seconds

Table 7: Summary of quantitative evaluation results

Questionnaire (answers in scale 1-5, lowest to highest score)		
Question	**Mouse**	**Head-based**
System Appeal	3.0	4.4
System Practicality	4.7	2.7
Fun Factor	2.2	4.7
Educational impact of system	3.5	3.9
Interested to use system again?	3.7	4.6
Are you going to recommend your friends to use the system?	3.6	4.5

Table 8: Preliminary questionnaire-based results

6. CONCLUSIONS

We have presented our preliminary work towards the design and evaluation of a head-based human computer interaction system that can be used for retrieving information about archaeological artefacts in a museum. As part of our work in this area we developed a customised head-based HCI method, that can be used for controlling interactive displays in public places such as museums and exhibitions. We also developed a prototype application that allows users to explore and visualize archaeological Cypriot artefacts belonging to three historical phases.

The results of a preliminary experimental evaluation proved that the use of the system does not result in faster interaction but it presents a more interesting and attractive way to use a computer information system in public places such as museums or information kiosks.

In the future we plan to carry out more work in this area in order to deal with the following issues:

- Improve the head-based interaction system, so that it will be possible to access data faster.

- A more rigorous evaluation process will be staged so that quantitative results and subjective results related to the performance and appeal of the system will be collected and analyzed. In particular we aim to run evaluation experiments using a large number of volunteers and analyze the findings for volunteers of different age groups, genders and educational backgrounds. Also we plan to run experiments in public places (i.e. museums) so that we get specific results of the appeal of the system among museum visitors.
- Enrich the database with Cypriot artefacts so that the system will operate on an almost complete selection of Cypriot artefacts.

Currently the system is an HCI system that can be used for retrieving information through the use of a computer application. In the future we also plan to upgrade the system so that the head motion of visitors of a museum standing in front of a display will be detected, and based on the eye location and direction, the artefacts currently viewed by a visitor will automatically be determined and information for that artefact will be displayed automatically in a display area. With this system visitors will be able to view simultaneously both the artefact and information about it.

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