Establishing a Museum Display Platform by Using Combination of Reflection Holograms and Tangible Augmented Reality

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Abstract. When we preview the current developments of Augmented Reality (AR) and holography, we realize that these tools have been applied separately. We combine these two technologies in order to create a powerful system for science, industry and education. This paper focuses on the feasible combination of reflection holograms and tangible AR starting with analysis of between both technologies. We investigated human/computer interaction with the tangible user interfaces (TUI) to ensure its usability. Experiments were conducted to verify the combination process. Later, experiments were conducted to manipulate the TUI where an artistic image made by reflection holograms and tangible AR was displayed. According to the experimental results, we named this combined application as the Augmented-Holograms Display Platform (AHDP).

Keywords: Augmented Reality, Holography, Reflection Holograms, Human/Computer Interaction, Augmented-Holograms Display Platform (AHDP).

1 Introduction

When one mentions Augmented Reality (AR) applications, one defines it as a combination of virtual objects and real world. One of the main issues in AR-based visualization is the combination of virtual items and the real world in a way that the user feels like he or she is viewing virtual objects as they have been really placed in the scene [1]. In Billinghurst [5], there are four types of AR interfaces: 1) Browsing Interfaces: Registering Information to real-world context [3]; 2) 3-D AR Interfaces: Displaying virtual objects in 3-D physical space and manipulating them [4]; 3) Tangible Interfaces: Applying physically based interactions [5]; 4) Tangible AR: Applying tangible user interfaces (TUI) to AR interface design [6].

Liarokapis et al [7] propose the use of specific system architecture, based on mobile devices, is for navigation in urban environments. Castro et al [8] present the

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development and design of a graphical user interface and a command line programming Toolbox for construction, edition and simulation of Interval Type-2 Fuzzy Inference Systems. Rohs [9] develops a number of spatial interaction techniques that optically capture the device's movement and orientation relative to a visual marker. Chen et al [10] present preliminary results from a real time markerless AR system for tracking natural features in an agricultural scene. Alicia et al [11] present an original method to determine not only the tip position but also the orientation of a laparoscopic tool with respect to the camera coordinate frame. A simple mathematical formula shows how segmented tool edges and how camera field of view defines the tool 3-D orientation. Pribeanu & Iordache [12] report on a user-centered formative usability evaluation of an AR-based learning scenario for Chemistry with a focus on the motivational value. After user testing, quantitative and qualitative data were collected to measure the educational and motivational values of the learning scenario. Wagner & Schmalstieg [13] report a platform for collaborative handheld AR application which uses specific and efficient techniques from embedded development to push the limits of AR application in terms of physical size, number of users and content intensity. The traditional personal computer with head-mounted displays (HMDs) is not only heavy but also limits the scope of space. The AR application especially necessitates the improvements of device design and usability. After all, users hope that in the future, they do not wear anything when watching. This trend has also been noticed by the authors of this paper.

In Lucente [14], computer graphics is confined chiefly to flat images. Only a real-time electronic holographic display can create a truly 3-D computer graphic image with all of the depth cues and resolution sufficient to provide extreme realism. A hologram is a photometric emulsion that records the interference patterns of coherent light. Nowadays, many kinds of application of optical holograms exist, including interferometry, copy protection, data storage, and holographic optical elements [15]. The recording itself stores the amplitude, wavelength, and phase information of light waves. In contrast to simple photographs, which can record only amplitude and wavelength information, holograms can reconstruct complete optical wave fronts. This results in the captured scenery with a three-dimensional appearance that can be observed form different viewing angles. Tsumoto & Hirano [16] discuss statistical independence in a contingency table from the viewpoint of matrix theory. Statistical independence is equivalent to linear dependence of all columns or rows. Also, the equations of statistical independence are equivalent to those on collinearity of projective geometry. In Bimber [17], it is shown that merging optical holograms with 3-D graphical elements can provide an acceptable trade-off between quality and interactivity. The holograms provides high-quality but static content allowing additional graphical information to be generated, inserted, modified and animated at interactive rates through interactive actions.

Both of the two basic optical holograms types, transmission and reflection, were reconstructed by lighting them with monochromatic light. This approach uses the light to hit the emulsion at the same angle as the reference beam used to record the hologram. Transmission holograms were lit from behind, bending the light as it passed through the holographic film to the eyes, producing a virtual image. Another characteristic of transmission holograms is that the object beam and the reference beam come in from the same side of the holographic film during the exposure.

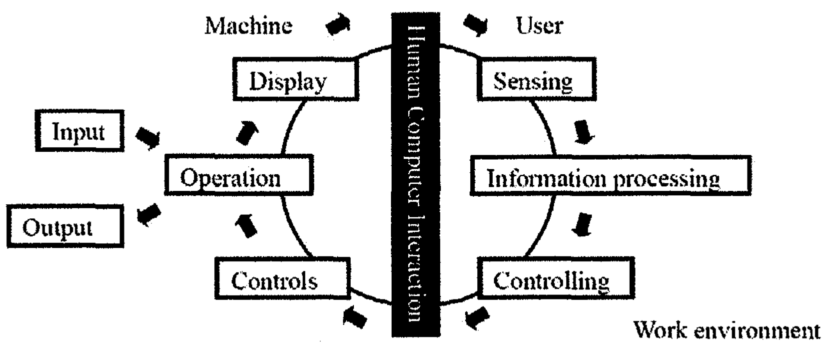

Fig. 1. The sequence in circulation of the proposed AHDP. This AHDP is divided into two sides (See Figure 1), i.e. the user side and machine side. On the user side, the steps are: (1) Sensing, (2) Information Processing, and (3) Controlling; while on the machine side, the steps are: (1) Controlling (2) Operating and (3) Displaying.

Typical types of user and machine interaction in AHDP are illustrated as follows based on Chapanis [18]. This AHDP is divided into two parts (See Figure 1), i.e. the user side and machine side. On the user side, the steps are: (1) Sensing, (2) Information Processing, and (3) Controlling; while on the machine side, the steps are: (1) Controlling, (2) Operating, and (3) Displaying.

On the user side, the steps are: 1) Sensing: The user receives the image feedback via TUI; 2) Information processing: The user judges the information content and decides to commence movements which are to be carried out; 3) Controlling: After the information processing judgment is conducted, operating TUI responds.

In the machine aspect the steps are: 1) Controlling: The platform provides two command ways. The first is watched by the user and viewed in different angles through the web camera in order to observe the necessary visual angle. The second is display interfaces in which the user can control the information content that the platform feedbacks through the menu on the interface; 2) Operating: This platform is divided into input and output parts. In the input part, the platform controls and interacts with the user; in the output part, the user obtains feedback after the information processing; 3) Displaying: This shows the information content that interacts with user on the platform.

Unceasing circulation between user and machine can make the interactive quality much higher and provide very rich incident.

Four experiments will be conducted to verify the prospect of augmented-holograms and its interactive quality as shown in Figure 2 and Figure 3 respectively. These four experiments are designed in such a way that the results can be used for cross reference, with gradual additions of the predetermined variables. They are also conducted in the sequence whereby it is easy to ensure the integrity of the experiment environment, with simple steps to start with.

Experiment 1: Optical holograms, the reflection holograms - watched and tested. This is to set the basics of the experiment environment.

Experiment 2: Combination of reflection holograms and augmented images - The effect of the union of both holograms and augmented virtual images - watched and tested. This is to compare the increased subtleties of the images with the result in Experiment 1.

Experiment 3: Observation of the augmented holograms interaction - By utilizing a web camera to sense the movement of the viewer, the corresponding augmented virtual image is projected on reflection holograms. The interaction can occur only through the viewer's movement but without handling it. This is to explore the ease of maneuverability of the devices and facilities and allows the user to get a hands-on feel of the application.

Experiment 4: Handling and control of the AHDP, as well as maneuver of the TUI.

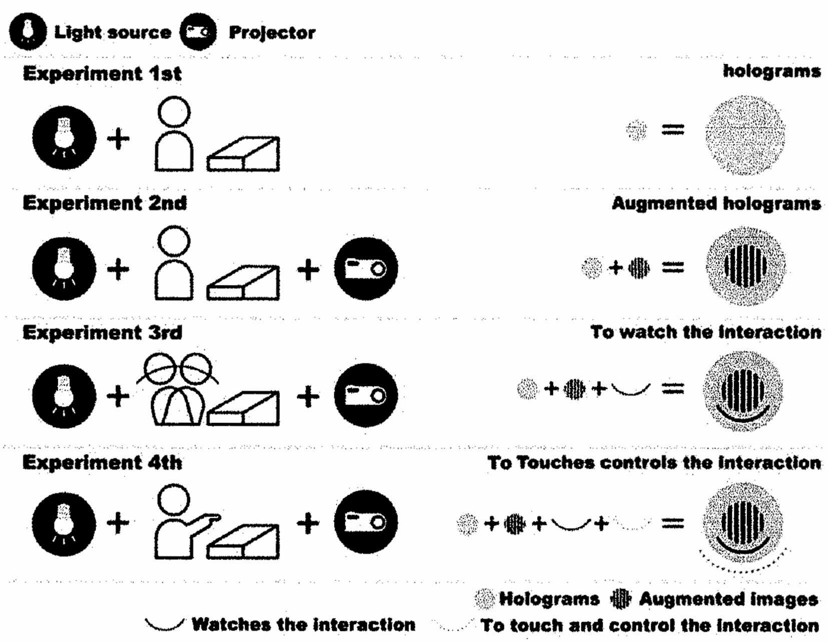

Fig. 2. Relationships of four experiments. These four experiments are designed in such a way that the results can be used for cross reference, with gradual additions of the predetermined variables. They are also conducted in the sequence whereby it is easy to ensure the integrity of the experiment environment, with simple steps to start with.

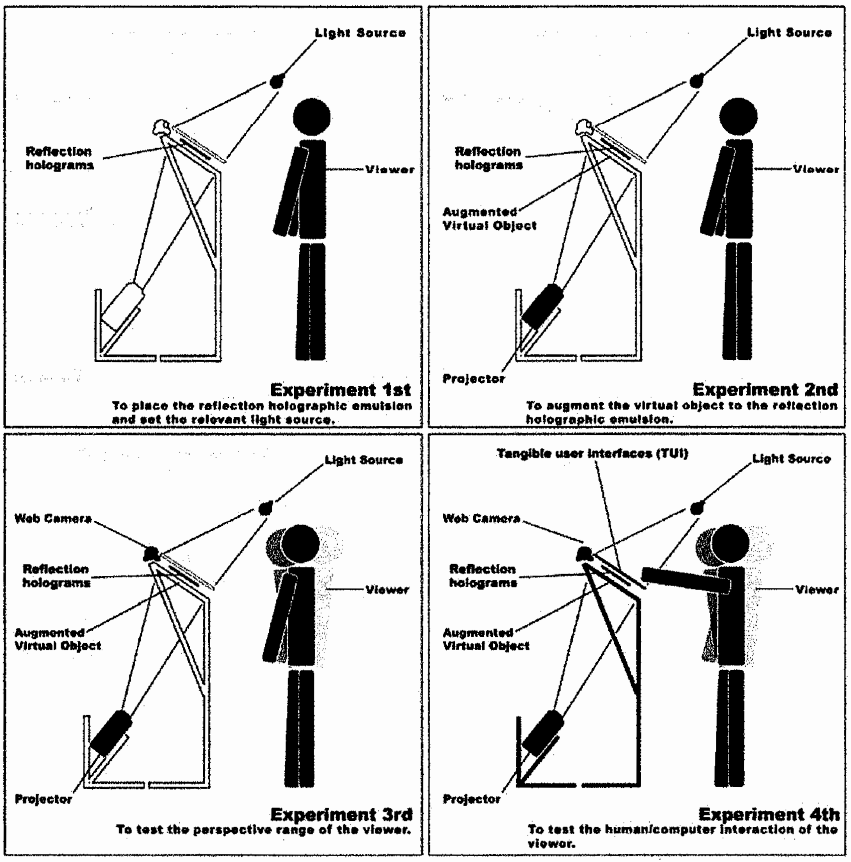

Fig. 3. Experiment design. Four experiments will be conducted to verify the prospect of augmented-holograms and its interactive quality in our study

AHDP is implemented as shown in Figure 4. The stratum step of experiment is as follows:

Experiment 1: Experiment 1:Placing of the reflection holograms and set-up of the relevant light source with a frontal and directional angle (at about 45 degrees), so as to watch the reflection holograms (See Figure 4 a. e.).

Experiment 2: Experiment 2: Augmentment of the virtual image to the reflection holograms, in order to display a better color quality, pattern and texture, so as to watch reflection holograms combining with augmented virtual image (See Figure 4 b. e.). This allows the comparison of enhanced effects of images.

Experiment 3: Experiment 3: Testing of the perspective range of the viewer, with the augmented virtual images to be synchronously changing according to the viewer's observational angles, in a higher quality of viewing (See Figure 4 c. f. g.). This sets the benchmark for the maneuverability of the user's device.

Experiment 4: Experiment 4: Testing of the TUI, with a touch screen of TUI provided. The viewer can touch and control the augmented virtual images on the interface to browse the displayed contents in a high quality real-time approach (See Figure 4 d. h. i.). This allows the viewer to manipulate the facilities and to get a good feel of the user friendliness.

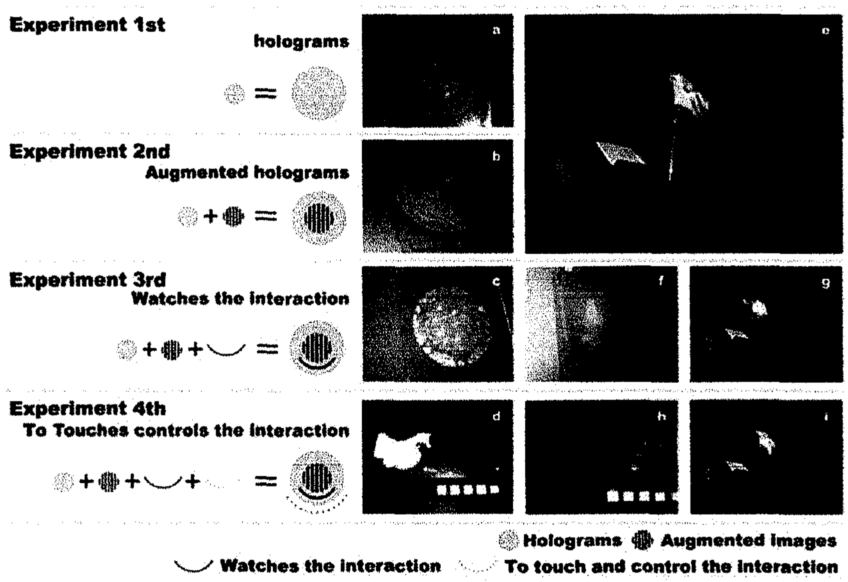

Fig. 4. Augmented-holograms display platform (AHDP) interaction design. Augmented virtual images and reflection holograms interaction in Experiments 1, 2 and 3 are shown in Figure 4 a. b. c. f. The operations of this tangible user interfaces (TUI) in Experiment 4 are shown in Figure 4 d. h. The different viewing angles are also shown in Figure 4 e. g. i.

Regarding the light source in AHDP, reflection holograms have been used, but not the transmission holograms. The light source of transmission holograms must be projected from the behind because it may interfere with the projected image of tangible AR. However, the light source of reflection holograms is projected from a frontal and directional angle (at about 45 degrees). Afterwards, the projected image of tangible AR will not be interfered by the light source of reflection holograms. Therefore, the reflection holograms is the best choice in AHDP, as the quality of the augmented reflection holograms is remarkably improved.

The user mainly utilizes a web camera for tracking while watching the reflection holograms combined with augmented virtual image. The user turned his or her head around in Experiment 3 and 4 (See Figure 5) so that augmented virtual images can be combined with the holograms, in tandem with the angle to which the user moves his or her head to. The range of the user's head, to the left and to the right of up to 45 degrees, is tracked in the image center (See Figure 5 a). To track the user's head

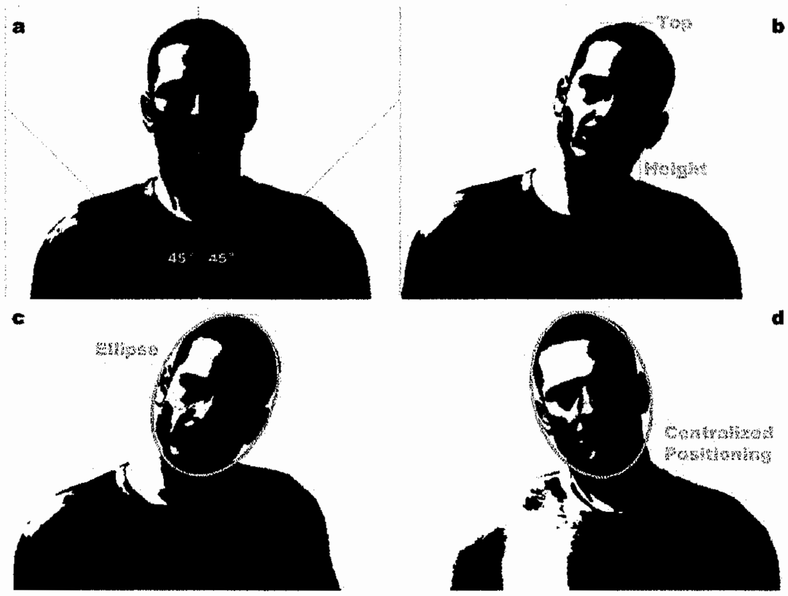

Fig. 5. Tracing the movements of the user's head to capture the image. The range of the user's head, to the left and to the right of up to 45 degrees, is tracked in the image center (See Figure 5 a). To trace the user's head movement, a method is used to fetch the images sequence through a web camera, and then find the peak of the motion to judge the user's head movements (See Figure 5 b). It exploits the difference in image pixels before and after the movements to identify the user's head movements. By benchmarking the face location, an approximate ellipse is composed with the centralized positioning (See Figure 5 c.d).

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We believe that interactive quality is the key success factor of modern computer graphics. AHDP boasts great potential as truly interactive holograms. However, several technological hurdles have to be dealt with before this becomes a solid application. The combination of holograms and interactive computer graphics represents an intermediate solution that can be achieved today with slight modifications of off-the-shelf device.

While the user watches the combination of reflection holograms and tangible AR, AHDP tracks the head movement via a web camera and produces corresponding augmented virtual images, which are projected on the reflection holograms producing the combination of the projected virtual image of tangible AR and the reflection holograms stereo depth, synchronized with the head's movement.

In AHDP, the distance from the web camera to the user is about 45cm, and the tracked range of the user's head by the image center is 45 degrees both to left and to right. The web camera tracking the user's head will move within the tracking range. Since the user's head movement is tracked and the recorded viewing angles are known, the perspective of the graphical content can be updated to match the corresponding perspective recorded in the hologram.

If the user's head moves beyond the tracking range, the web camera will not be able to track it. The AHDP can double the tracking range. When the user approaches towards AHDP, the web camera starts to track automatically and the users can watch within the expanded scope with no restriction.

After obtaining the centralized positioning, it would be able to recognize the angular movement of the user's head. The interface design in Experiment 4 is based on the proposed interaction bidirectional communication. Figure 6 shows the TUI used in Experiment 4. Figure 6 a. shows the content of the interface. The operation control menu is divided into five items: classic aesthetics, literate's remarks, geographic allocation, historic context, and antique, to facilitate the follow-up examination of image qualities with detailed descriptions. Figure 6.c shows the historical background of the antique and Figure 6.d quotes and compares the other artifacts.

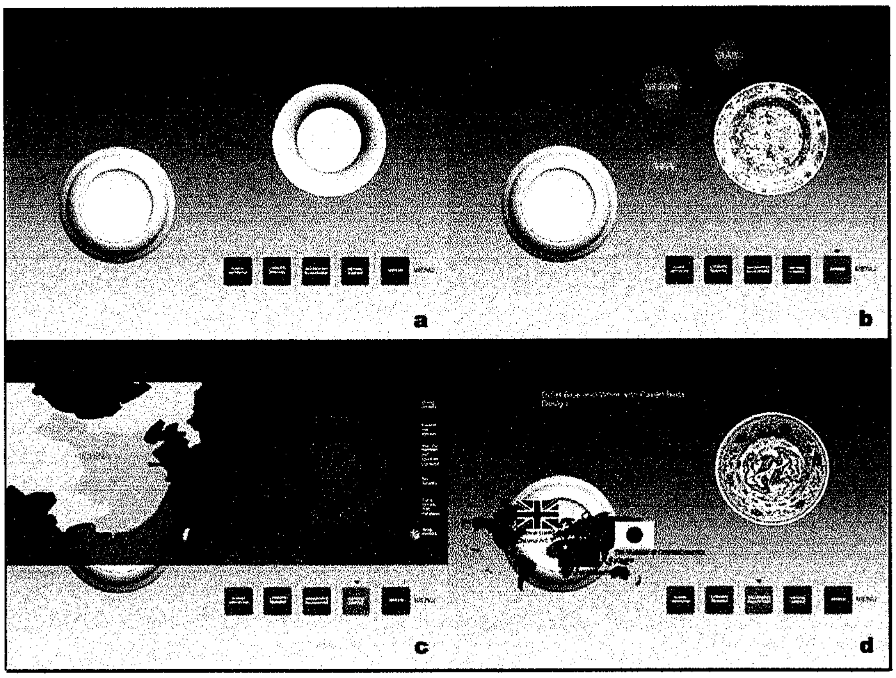

Fig. 6. Tangible user interfaces (TUI). Figure 6 a shows the content of the interface. The operation control menu is divided into five items: classic aesthetics, literate's remarks, geographic allocation, historic context and antique, to facilitate the follow-up examination of image qualities with detailed descriptions. Figure 6.c shows the historical background of the antique and Figure 6.d quotes and compares the other artifacts.

3 Augmented-Holograms Display Platform Results and Discussion

In our experiment, AHDP was established through many steps of experiments to describe functionality of platform; Experiment 4 is the final display platform. Our platform utilizes reflection holograms and transmission holograms in Bimber's study [15]; both of these are optical holograms. Light source comes from behind in transmission holograms; Bimber used it on the combination of 3-D graphical element in order to provide an acceptable trade-off between quality and interactivity. Under the comparison, the reason of our preferring reflection holograms is because the augmented virtual image presenting of tangible AR utilizes back projective method; furthermore, TUI adopts the instinct operation. Thus we selected reflection holograms.

The augmented virtual image of tangible AR in the platform uses 3-D object in reflection holograms as main body to augment virtual image over this 3-D object; backside projection augmented method was used to recover misshaped area of artifacts in museum. We captured user's head movement through web camera; then we observed the depth of 3-D object in reflection holograms through user's head movement. Augmented virtual image was projected according to the 3-D depth of reflection holograms through user's head movement.

Through AHDP which combines reflection holograms and tangible AR, user can use TUI to judge information and obtain sensory feedback; tangible operation can also promote usability.

4 Conclusions and Future Work

Our main aim to perform such experiments is to explore the development possibility of combining reflection holograms and tangible AR. Further practical applications of AHDP may be artifacts recovery by using the holograms perspective depth and promoting the tangible AR to recover artifacts to their original appearances. Holography is used to record artifacts retrieving methods and reconstruct the artifacts by making up their incomplete parts with AR. Figure 7a shows the object recovery to its original state by using modeling technology. Figure 7b shows the reconstructing of surface textures. Figure 7c shows the final results of artifacts interaction in reflection holograms with augmented images.

When exploring the current developments of AR, we are convinced that the interaction of reflection holograms and tangible AR will result in a crucial leap in holography application development. The combination of reflection holograms and tangible AR has demonstrated its realistic, mass-informational and real-time interactive nature. AHDP has provided users with fun in a quality style to access and manipulate information. Undoubtedly, we could conclude that the future interface is not just a vision. The new technologies are out there already, waiting for us to explore them. This paper foresees the combination of reflection holograms and tangible AR as a cross-disciplinary integration, with the two technologies slowing converging from their respective domains.

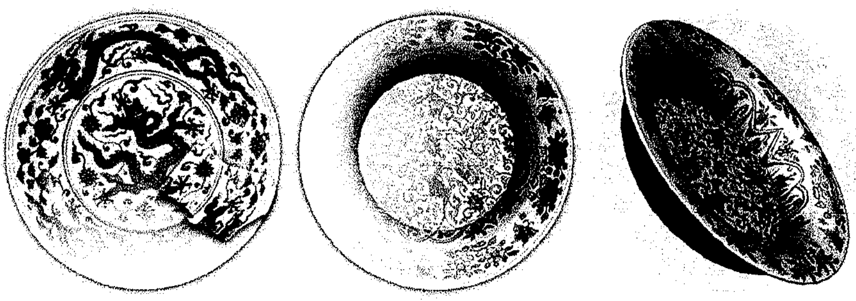

Fig. 7. Combination of reflection holograms and tangible AR applied to reconstruct artifacts at museums, in conjunction with the design of a multimedia user interface. Figure 7 b. c show the result of the current pretests. Figure 7 a shows the development of another direction.

The research of AR and holography should be started in the lab and synchronized with cross-field studies. This combination will bring more realistic applications. In this experiment, we conducted some experiments to enhance combination of reflection holograms and tangible AR and suggested methods to gain more space of diversification in the interface external design and operational mode. This powerful combination can work efficiently in the 3-D and virtual reality world when the user is not constrained by the physical device and able to move their head freely as shown in the previous experiments.

With the progress of science and technology, we should design an interface with better quality. In our paper, we tried to give special consideration to the user and machine interaction. We found that both 2-D and 3-D are help for users. The combination of reflection holograms and tangible AR with user and machine interaction is valuable to be developed in the future.

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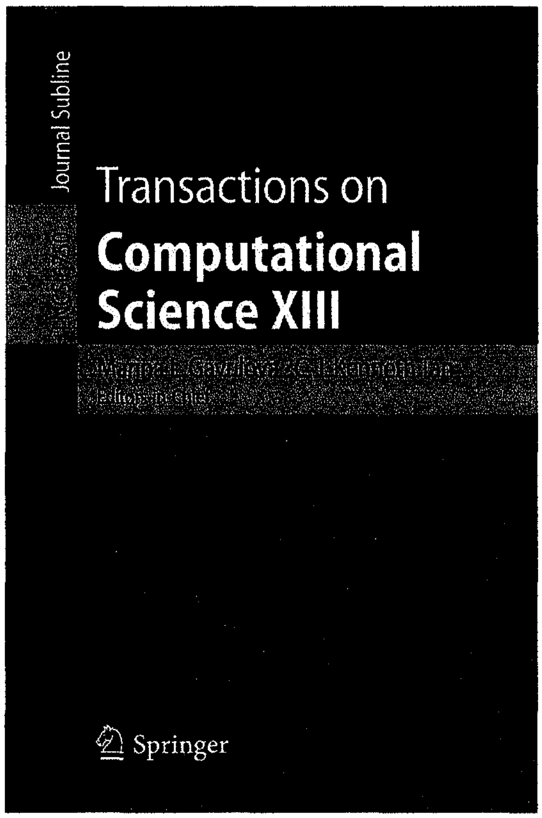
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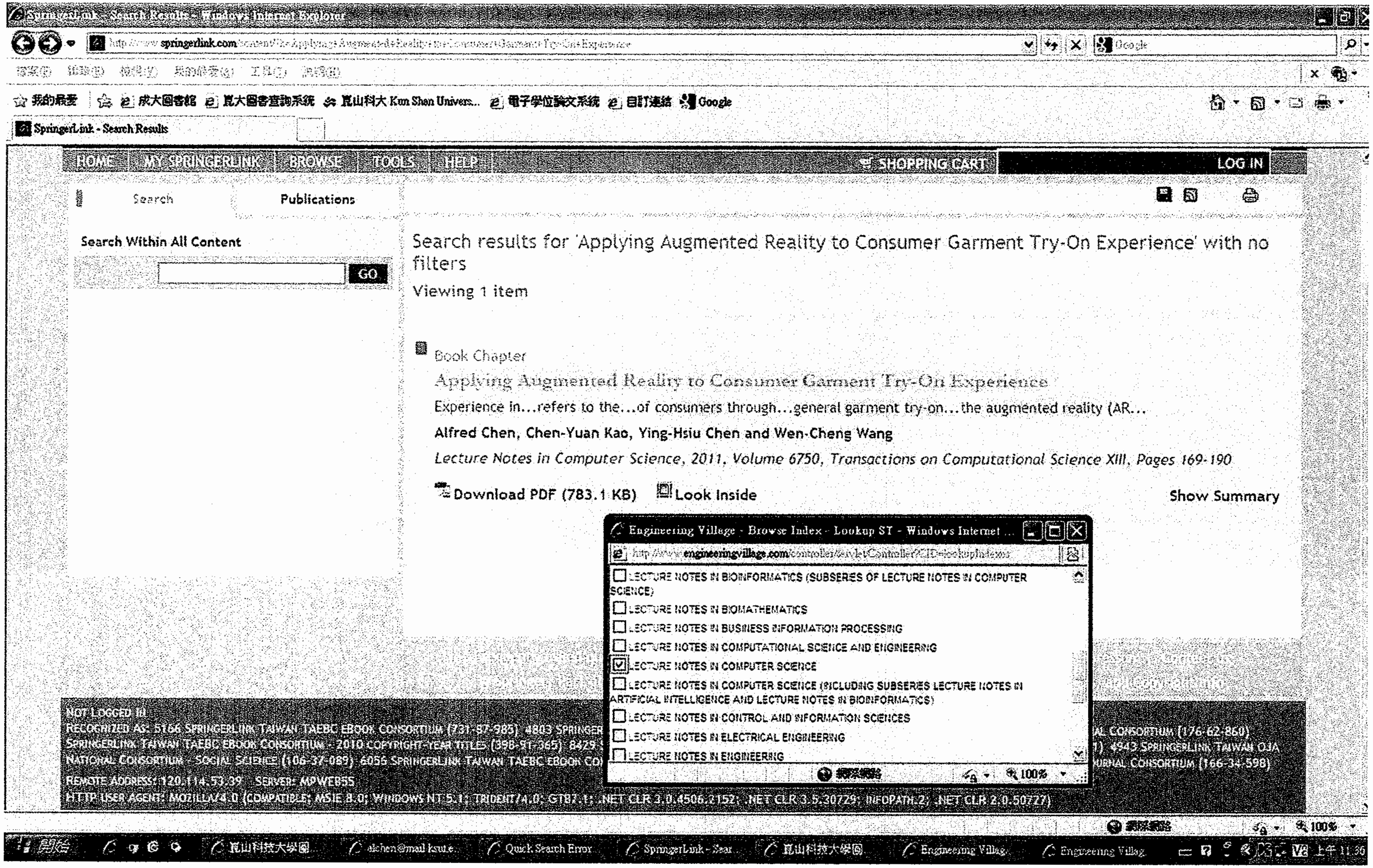
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