Augmented Reality Museum Visiting Application based on the Microsoft HoloLens

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Abstract. Immersive technologies such as the Augmented Reality (AR), which attaches the virtual information to the real environment, are extending the research space and attracting various domain experts including museum experts. Applying the AR technology in the 3D relic information visualization and helping visitors to visit the museum are also hot research issues. Current museum solutions are mainly based on the website, smart phone and Virtual Reality (VR) technology, AR museum applications are also mainly deployed on the smart phone. In this paper, an AR museum application based on the Microsoft HoloLens is presented, and the Microsoft HoloLens is a kind of head mounted device (HMD). Besides, multiple user interaction forms are supported in this solution, such as gaze, voice command, voice speech and hand gesture. Evaluation about this solution has also done, and the conclusion can be drawn that most participants appreciated this solution in clear interface and completion aspects.

1. Introduction
As is known to all, museums play a significant role on displaying cultural collections and spreading the rich culture. In these years, internet and technologies also have a great development. How to adapt to the development of the new situation and better provide the public with diversified and personalized service content have become important topics in the construction of digital museums [1]. Recently, museum experts also present the “museum plus” issue and want to help the transition development of the museum [2]. And how to popularize the cultural treasures to public has attracted more and more researchers' attentions. Besides, it's shown that multitude possible digital object types of relics in museum can be divided into text, image, audio, video and 3D model [3, 4]. Now there are various ways to visualize and show this relic information, such as web-based museum systems, mobile phone applications and virtual museums applied the VR as well as AR applications in phones. Besides, VR and AR as two immersive technologies, offer an ideal presentation medium for museums and other cultural heritage institutions [5]. AR adventures for museums and cultural travels seem to have demand potential and AR seems to add values to the museum and cultural travel experiences [6]. With the interaction forms developing, museum experts pay more attention on them [7], and immersive technologies are the host issues. They can change the traditional visiting form from only watching and listening to the expositor to a new form that visitors can observe the real relic, hear the explanation, scan and operate the virtual relic information.

In the museum, the visualization effect of the relic information is closely related to the visitor's visiting experience, influencing the effect of spreading the traditional culture and historical knowledge. Through the conversation with museum experts and the on-site museum visitors’ questionnaires, museum experts’ and visitors’ needs are collected and summarized to get the application tasks. And
in this paper, the AR solution is used the client/server framework, and the evaluation process is done after the completion of all tasks to evaluate this solution in clear, satisfaction and completion aspects.

2. Related Work
In recent years, immersive technologies such as VR and AR have a massive emergence, becoming one of the forefront research fields in human-computer interaction and information visualization areas. Besides, with more attention focused on Chinese traditional culture, finding the suitable approach to display the relic information and transmit the full knowledge to visitors are becoming more necessary.

There are many traditional and existing approaches to show the cultural relic information of museums, including web-based systems, mobile applications, large-screen displays, virtual museums [8, 9, 10, 11]. Matevitsi proposed a system that facilitated virtual museum development and usage, Wojciechowski described an AR interface for visualizing and displaying digital representations of cultural relics in virtual museum exhibitions. Besides, the increasing development of the AR technology has raised audience expectations and advanced the use of mobile and wearable AR in museums. Meier provided an AR museum guide in the six-month exhibition on Islamic art, getting detailed description of the museum’s motivation for using AR [12].

As it can be seen, AR as one immersive technology has broken the limitation of traditional display form. Despite of its rapid development, there still are much limitations about immersive solutions in cultural information visualization and display, for the device mobility or display forms and so on.

3. AR Museum Application

3.1. Task Analysis
Task analysis is an important part in an application research, on-site visitor questionnaire, observing visitors’ behaviours and consulting the museum experts are be done in this research. Then tasks can be summarized and extracted and they are listed in the following.

[T.1] Support the mobility to accommodate visitors' random movements in the museum.
[T.2] Display basic text descriptions of cultural relics.
[T.3] Display virtual models of cultural relics and allow visitors operate these models through various user interactions.
[T.4] Record visitor operations on the virtual information to collect visitor data for future data analysis.

3.2. Microsoft HoloLens
Microsoft HoloLens is the first cable-free holographic computer device made by Microsoft, which runs on the Windows 10 system. Compared with other immersive devices, it does not need cables and handsets, nor does it need to be connected to a computer. The HoloLens device includes an independent central processing unit (CPU), a graphics processor (GPU) and a holographic processor (HPC), it also equips with several kinds of sensors to get environment information from the real world. As an attracting immersive device, its various interaction forms are also an important part for developers and researchers. The device supports three kinds of user interaction forms, they’re gaze, hand gesture and voice, because it has no cable restriction, device movement can also be seen as a kind of interaction form in this application.

During the process of the device movement, the camera position can be detected, user interactions can also be designed basing on the movement. Gaze is the basic interaction form in the HoloLens device, it can be seen that a laser line is emitted from the middle of the wearer's head and collides with the virtual object in front of the device camera. In addition, there are two states of virtual objects in the immersive system, getting focus and losing focus, which mean that the wearer is gazing on the virtual object or not. Hand gestures include click gesture, navigation gesture and manipulation gesture, which are widely used to complete various user interactions. The click gesture is similar to the mouse click operation, and the cursor is equivalent to the mouse pointer. The click gesture takes effect only when
the cursor is targeting on virtual objects. Navigation gesture and manipulation gesture are composite gestures, users can start the navigation and manipulation gesture by click gesture, hold this pose and move their hands in an imaginary normalized three-dimensional cube. Offsets in each direction of X, Y or Z axes can be detected and they are all in the range of -1 and 1. The device can also detect and recognize voice commands and speeches, commands are phrases composed of several simple English words that represent users’ actions, and speech contents are longer than voice commands.

3.3. System Overview
In this paper, this AR application uses the client/server framework, the client is deployed on the Microsoft HoloLens and the server is the Photon Server, which has several features such as running autonomously, load balancing, modifiable SDK and so on, the server construction shows as the Fig.1 (a). Based on tasks in the Task Analysis, visitor behaviors in this application can be divided into three parts, setting personal information, recognizing relic and scanning relic information, the process of the application can be seen in the Fig.1 (b). And functional views such as the Personal Setting View, Info View and Info Detail View are shown in the Fig.2.

![Fig.1 System Construction of the Application.](image)

It’s shown from the Fig.1 (a) that visitors can set the personal nick name and sever settings in the Personal/Server Setting View, then the client is connected to the sever side through clicking the connect button. The Relic Recognition process uses the Vuforia SDK, which is an AR plugin in the Unity. Before using it, visitors should scan the real relic through the specific android scanner to get relics’ features. After connected to the server, the application enters the scanning mode, once the target relic appears in the field of the HoloLens camera, it can quickly recognize the relic identity. After knowing the relic identity, the relic virtual model and its virtual text information can be shown in the visitors’ views.

3.4. Application Interfaces
Views in this application are mostly designed as 2D panels, they’re used to convey and show text information to visitors.

**Personal Setting/Server Views:** It can be seen from the Personal Setting Views in the Fig.2 (a) that they guide visitors to input some personal information and server parameters after the application initializing successfully. The Keyboard View shown in the Fig.2 (b) is used to help users input text context and it’s also designed like the real keyboard to fit visitors’ using experience.
Info View: The Info View in the Fig. 3 (a) shows the description title list of the relic that the current visitor is observing now, the list may include the historical meaning, making technical and other relic text description titles. Each title has its different lightness and click number that is collected from the previous visitors’ interactions, showing in the brackets, and the bigger the value is, the larger the lightness is.

Info Detail View: It can be seen from the Fig. 3 (b) that the Info Detail View shows the detail context of one description title in the Info View. Visitors can switch from the Info View to the Info Detail View through corresponding user interaction.

3.5. User Interactions

Immersive technologies are totally different from traditional desktop systems and mobile applications on the user interaction forms, different immersive devices also have their own interaction forms. Microsoft HoloLens supports three kinds of forms, they are gaze, hand gesture (click, navigation and manipulation) and voice (voice commands and speeches). In different views of this application, different user interactions are designed basing on these interaction forms to support visitors understand relics deeply and get an excellent visiting experience.

Personal/Server Setting Views: User interactions in these Personal/Server Views include clicking buttons and inputting text through clicking on the Keyboard View, and main interaction forms are gaze and click gesture. Virtual buttons in these views have two statuses: getting the focus and losing the focus, when buttons get the focus, their sizes will become larger; when buttons lose the focus, their sizes will become normal, and these interactions can emphasize users’ candidate choices. Clicking interactions in these views are different from each other, they may be connecting to the Photon Server (left of Fig. 2 (a)), joining in a session (left of Fig. 2 (a)) and inputting text content (Fig. 2 (b)).

Info View: Interaction forms in the Info View include movement, click gesture, navigation gesture and voice commands. Visitors are randomly moving when they’re visiting the museum, the Info View can get the position of the device camera and always moves as the user moves, keeping appearing in the front of the camera and the user. Sometimes, this movement interaction may influence users scanning the text content, “Start/Stop Following” voice commands can be used to stop and restart this following interaction. When this following interaction is stopped, the position of the Info View is fixed and this view can’t move as the user moves. Besides, clicking on one description title in the list
will lead to the switching from the Info View to the Info Detail View, and the detail process is that the
Info View will hide and the Info Detail View with corresponding description context will show in the
application. What’s more, there may be too many description titles in the Info View, and some titles
may hide in the bottom of the list. In this case, users can scroll down the title list through navigation
gesture to scan the full list.

**Info Detail View:** User interaction forms in the Info Detail View are movement and voice
commands. The following interaction of this view is similar to the following interaction of the Info
View, and this interaction can be started and stopped through “Start/Stop Following” voice commands.
Besides, users can also switch this view to the Info View through the “Info View” voice command.

### 4. Evaluation

User evaluation is an important part to evaluate this application, so 30 participants are invited to join
in the evaluation process. The evaluation process can be divided into three parts, adapting to the
immersive device, experiencing the application and filling in the network questionnaire. The
questionnaire can be divided into three parts, personal information, cognition aspect and completion
aspect of core functions in the application.

Personal information of 30 participants may influence the evaluation result, and their information is
shown in the Table.1. It can be seen from the Table.1 that participants can be divided into several
groups according to different classification standards, like gender, the highest academic degree, the
age degree, immersive device using experience and so on. The questionnaire result can also show
these standards’ influences to the evaluation result.

**Table.1 Personal information of participants in the evaluation process.**

| Classification Standard       | Option   | Frequency | Percentage (%) |
|------------------------------|----------|-----------|----------------|
| **Gender**                   |          |           |                |
| Male                         | 20       | 0.6667    |                |
| Female                       | 10       | 0.3333    |                |
| **The Highest Academic Degree** |         |           |                |
| Junior School                | 4        | 0.1333    |                |
| High School                  | 4        | 0.1333    |                |
| Bachelor                     | 6        | 0.2       |                |
| Master                       | 12       | 0.4       |                |
| Doctor                       | 4        | 0.1333    |                |
| **The Age Degree**           |          |           |                |
| 18-25                        | 17       | 0.5667    |                |
| 26-30                        | 3        | 0.1       |                |
| 31-40                        | 4        | 0.1333    |                |
| 41-50                        | 6        | 0.2       |                |
| **Have Contacted Immersive Device Before or not** | Yes | 6 | 0.2 |
|                              | No       | 24        | 0.8            |
| **Interested in Immersive Device Applied in Museum Visiting** | Yes | 28 | 0.9333 |
|                              | No       | 2         | 0.0667         |

In the evaluation, cognition degrees of views are divided into four levels, they are *not confusing &
very clear*, *slightly confusing & relatively clear*, *slightly clear & relatively confusing* and *very
confusing & not clear*. These levels have their corresponding scores, 1, 0.75, 0.5 and 0.25. The
cognition result can be seen from the Table.2 that the average score of each view is larger than 0.9, it
can be concluded that all views are clear enough for most participants in the evaluation. Besides,
gender and immersive device using experience can also influence the cognition result, the average
score of male participants is larger than the score of female participants, and the average score of
participants who have contacted immersive devices is lower than the score of those haven’t contacted
immersive devices. It can be inferred from the text comments in the questionnaire that female
participants have less interest in immersive devices than male participants and participants who
haven’t contacted immersive devices are more interested in those have contacted before, so in the
opinion of these participants more interested in immersive devices, each aspect in the application is more excellent, and it may lead to score difference to a certain degree.

The completion degrees of views can be divided into four levels, bad completion, weak completion, simple completion, good completion and perfect completion, whose corresponding scores are 0.1, 0.3, 0.5, 0.7 and 0.9. Participants evaluate the completion aspect of core functions in this application and the result is shown in the Table 3. It can be seen that average scores (0.8 and 0.833) are both in the level between Good Completion and Perfect Completion. Besides, completion degrees female participants scored are larger than male participants scored. It can be known from the text comments in the questionnaire that male participants have more suggestions and ideas about the core functions, who think that more prompt information is needed to lead a better using experience.

Table 2 Clear & Confusing result of views in the application.

| View                    | Degree | Score | Gender | Contacted immersive device or not |
|-------------------------|--------|-------|--------|-----------------------------------|
|                         |        |       | Female | Male | Yes | No |
| Personal/Setting View   | Slightly Clear | 0.5 | 1 | 1 | 0 | 2 |
|                         | Relatively Clear | 0.75 | 2 | 4 | 2 | 4 |
|                         | Very Clear | 1 | 7 | 15 | 4 | 18 |
|                         | Average Score | 0.9167 | 0.9 | 0.925 | 0.9167 | 0.9167 |
| Relic Info View         | Relatively Clear | 0.75 | 4 | 6 | 3 | 7 |
|                         | Very Clear | 1 | 6 | 14 | 3 | 17 |
|                         | Average Score | 0.9167 | 0.9 | 0.925 | 0.875 | 0.9271 |
| Relic Info Detail View  | Relatively Clear | 0.75 | 2 | 3 | 2 | 4 |
|                         | Very Clear | 1 | 8 | 17 | 4 | 20 |
|                         | Average Score | 0.9583 | 0.95 | 0.9625 | 0.9167 | 0.9583 |

Table 3 Completion result of core functions in the application.

| Core Functions            | Degrees        | Score | Gender | |
|---------------------------|----------------|-------|--------|---|
| Support Visitors’ Movements | Simple Completion | 0.5 | 0 | 2 |
|                           | Good Completion | 0.7 | 2 | 4 |
|                           | Perfect Completion | 0.9 | 8 | 14 |
|                           | Average Score | 0.8333 | 0.86 | 0.82 |
| Display relics’ text information | Weak Completion | 0.3 | 0 | 1 |
|                           | Simple Completion | 0.5 | 1 | 2 |
|                           | Good Completion | 0.7 | 2 | 1 |
|                           | Perfect Completion | 0.9 | 7 | 16 |
|                           | Average Score | 0.8 | 0.82 | 0.82 |

5. Conclusion
It can be concluded from the evaluation process that this application gets a good result on the completion aspect and cognition aspect. Most participants are interested in this application and show great appreciation on it, they think views in the application are clear enough to get relic information, and this application have successfully completed its tasks in the Task section. As it should be, some participants give some suggestions about this application to make it better.

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