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Article

Design and Implementation of Museum Educational Content Based on Mobile Augmented Reality

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Abstract: In the digital age, museums are becoming increasingly integrated with media technology. The interactive mode of museum education brought about by new digital communication technology can increase the audience's participation and interest in museum education content. This paper attempts to use Mobile Augment Reality (MAR) technology to design museum education content under the guidance of the principle of abstraction hierarchy from the theory of education optimization. With the help of MAR technology, museum education content can move up and down at different levels of information abstraction. The purpose is to help the audience move between perceptual knowledge and rational knowledge and improve their ability to understand. The evaluation results show that this style of interactive teaching content can promote visitors' understanding, thinking and interest in the cultural content of museum exhibits. It is also can helps visitors use a more professional-level vocabulary and more detailed descriptions about the cultural content of museum exhibits. The design and implementation method detailed in this paper has a certain guiding value for museum education development as well as utilization of MAR technology.

Keywords: Mobile Augmented Reality (MAR); museum education content; abstraction hierarchy principle

1 Introduction

Education is one of the functions of museums. Museums were originally specialized institutions for the collection and study of valuable cultural relics and collections. These artifacts and collections are displayed and exhibited for people to enjoy [1]. Since museums contain the essence of civilization. The education of the public through museums can promote the public's understanding and recognition of culture, thus achieving the goal of cultural confidence. At present, "museum fever" has become a global phenomenon. However, since the majority of the public facing museums are non-professionals, it is still quite difficult for people to properly understand the history, culture and aesthetics of collections.

With the rapid development of the digital age, digital technology provides technical support for the digitization of museum education content and enriches the interactive form between the museum and the public. A growing number of museums are embracing new digital media technologies, such as interactive screens, virtual travel and social media. There have been many studies that have discussed how museums have adopted these new technologies to increase public interest and experience. Although edutainment is important, how to use interactive digital media technology to effectively promote public understanding of collections should also be an important topic that museum education should study.

Augmented reality (AR), an advanced representative of digital media technology, can enhance user cognition by overlapping virtual objects in rich formats in the real world [2]. Based on this technical feature, the application of augmented reality in museum exhibitions is favored by researchers and practitioners. But in many examples of museums using augmented reality, many of the applications focus on entertainment, emphasizing the use of augmented reality to enhance the performance of collections, with the goal of stimulating the public's senses and arousing public interest [3,4].

This study attempts to enhance the educational content of museums on the basis of entertainment and experience. The research on the combination of educational optimization theory and mobile augmented reality technology features can really promote the public's cognition and understanding of museum education.

2 Theory and Technology

2.1 Educational Resources in Museums

The characteristics of museum educational resources are discussed as follows. The first characteristic of these resources is sociality. Museum education belongs to the category of social education resources. Sociality is reflected in the fact that all members of society can visit museums and receive the offered museum education. Therefore, the scope of museum education objects is broad and includes professional and nonprofessional education objects.

The second characteristic of these resources is that they are both tangible and intangible. Tangible museum educational resources are usually physical resources, which are also relatively common educational resources in museums. The public needs to experience physical resources through their senses to acquire relevant knowledge. In contrast, intangible museum education resources refer to the various types of information and knowledge attached to tangible museum education resources, which are sometimes displayed in the form of text or picture boards or are transmitted orally by guides.

As the original knowledge base of each educational object is different, the efficiency of acquiring knowledge and information through museum educational resources is also different. For the educational resources of tangible museums, the nonprofessional public is not able to extract the correct information from the objects through visual observation. For intangible museum education resources, the nonprofessional public often has difficulties reading and understanding the information provided.

2.2 Educational Optimization Theory—Abstraction Hierarchy Principle

The famous communication scholar Wilbur Schramm and his student Professor Yu Yalu summarized the optimization principle of the educational communication effect in their work "Media, education, modernization: theory and practice of educational communication [5]. The abstraction hierarchy principle is one of the important education optimization theories.

The abstraction hierarchy principle holds that educational communicators must be able to move up and down at different levels of abstraction when disseminating teaching content and remain within a scope of abstraction that the audience can understand. At the same time, the abstraction points are supported by concrete examples. Concrete examples are the foundation of an abstraction point, and the cognition of abstraction depends on these concrete examples. Without abstraction, the content of acquired educational information cannot be condensed into knowledge and ability. The abstraction hierarchy principle takes into account the advantages of the vividness of concrete examples and the essential and profound advantages of abstraction points. Concrete and abstract examples are interrelated and permeate each other. The abstraction hierarchy principle can help tourists' perceptual knowledge become rational knowledge and thereby help them grasp the essence of cultural content.

In the cone of experience theory proposed by American educator Edgar Dale [6], the middle of the cone is closely related to museum education, such as visiting exhibitions and taking outdoor tours, as see Fig. 1 below. The closer one moves toward the upper part of the cone, the more abstract the information becomes. Symbolic information is located at the top of the cone, where the more abstract information is located. In addition, experiences in which direct contact with the real item itself is made, in which a purposeful experience is engaged in, etc., are located at the bottom of the cone, indicating that they are the most concrete.

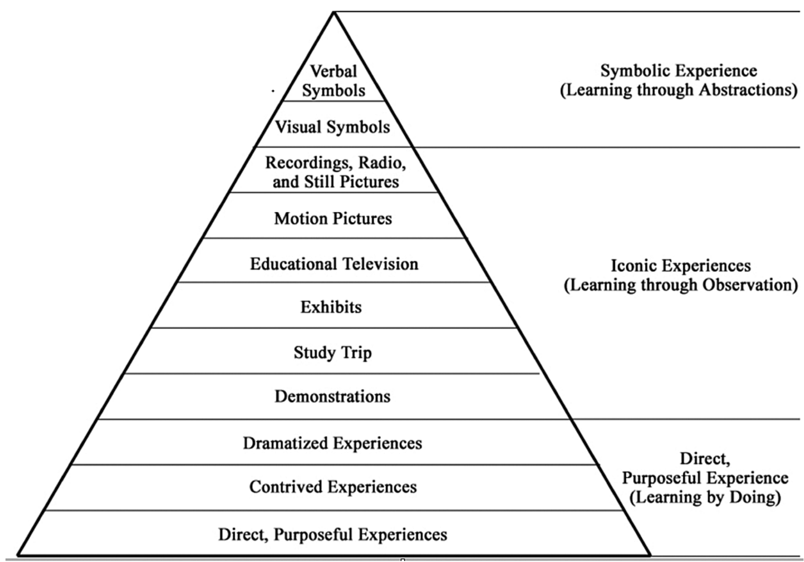

Figure 1: Dale- cone of Experience [6]

The design of museum teaching resources based on the principle of abstraction hierarchy depends on the type of audience and the specific knowledge base. Depending on the nature of museum education resource, the design should try to fit an abstraction level that the audience can understand and that is within their scope of knowledge to help guide tourists to effectively absorb educational communication content. By following this approach, the museum's educational resources would be designed and developed in multiple levels of "abstract-concrete" examples that are used to strengthen the educational communication effect through the mutual connection, supplement and contrast between different levels of abstraction for each resource.

2.3 MAR Technology

2.3.1 Classification of Augmented Reality System

According to different display technologies, augmented reality systems can be divided into head-mounted display devices, such as helmet-mounted displays (HMDs) or Google Glasses; space-aligned display devices, such as projection devices; and handheld devices, such as tablet computers or mobile phones [7–9]. Handheld devices are minimally invasive, socially acceptable, emergent and highly mobile.

They are a good substitute for the helmet-mounted display device and space-aligned display device systems. There are several types of handheld devices available for the MAR platform, i.e., tablets, ultraportable personal mobile computers (UMPCS), and mobile phones. MAR platforms based on tablets, laptops or custom PC hardware are often equipped with backpacks filled with hardware, and while they offer more computing power and input options than do PDA devices or phones, they are relatively bulky and much more expensive. Mathias Mohring et al. from Bauhaus University in Germany proposed the first AR system that runs on a mobile phone [10], which can detect different markers and correctly integrate the optical tracking of 2D/3D graphics into an interactive rate real-time video stream. Disadvantages to this system include the low resolution of the video stream, small memory capacity and slow processor speed.

In the context of the current rapid development of mobile technology and devices, emerging smartphones and tablets have integrated cameras, GPS, fast processors and advanced dedicated graphics-processing hardware. A report from Deloitte suggests that smartphone penetration in developed countries will reach 90% by 2023. Widely used mobile smartphones have brought the mobile convenience of devices to AR technology, and people can engage in the AR experience either indoors or outdoors without being restricted by heavy hardware [11]. Therefore, MAR technology based on smart phones is a hot topic in current research and application development.

2.3.2 Discrimination of Augmented Reality Concepts

Augmented reality (AR) and virtual reality (VR) share the word “reality” and many similarities in the initial stage of development. For example, The Sword of Damocles was a milestone in the development of both VR and AR. Virtual reality, mixed reality and augmented reality are all technical concepts related to the augmentation of reality.

Through the “virtual continuum” proposed by Paul Milgram, people can clearly distinguish the four concepts of the real environment, an augmented reality, an augmented virtually and a completely virtual environment [12]. In the real environment, the proportion of virtual components is zero. In an augmented reality, a virtual environment/object is used to explain and enhance the real environment/object. In an Augmented Virtuality, means add a real object to virtual environment/objects. Interpretation, explanation, and enhancements of virtual environment/object are purpose. In complete virtual environment, the proportion of real objects is zero.

The small figures in Fig. 2 illustrate these four terms. Fig. 2(a) is a completely real environment that can be seen directly by the naked eye or perspective equipment. Fig. 2(b) superimposes virtual icons of location information on a real environment video captured by a mobile phone camera. Virtual information enhances people’s understanding of the real environment (road), which belongs to the augmented reality. Fig. 2(c) shows that the virtual computer-generated 3D characters jump in the real environment (on the piano keys in the room), which enhances the authenticity and interestingness of the virtual characters and belongs to the Augmented Virtuality. Fig. 2(d) shows a fully virtual digital scenario.

2.4 The Advantages of Use MAR Technology to Develop Museum Educational Content

MAR technology supports almost all types of digital media, including 3D models, 3D animation, vector graphics, plane images, 2D animation, text, digital video, digital audio, and particle effects [13]. The rich media types supported by MAR technology can provide not only experience of observation (such as picture, animation etc.) and abstract experience (such as chart, text etc.) individually located within the cone of experience but also services to a larger extent for “The experience of doing” (such as interaction). It completely cover the three levels of the experience cone that ranging from concrete to abstract.

Therefore, using MAR technology supports development of museum education content can point to generalizing abstraction as well as specifically, visualization, practical. It satisfies the requirement of using the principle of abstraction hierarchy which is move up and down the different experience hierarchies of abstraction; or blend of different hierarchies, So that the visitor can have a more three-dimensional access and understanding of educational content.

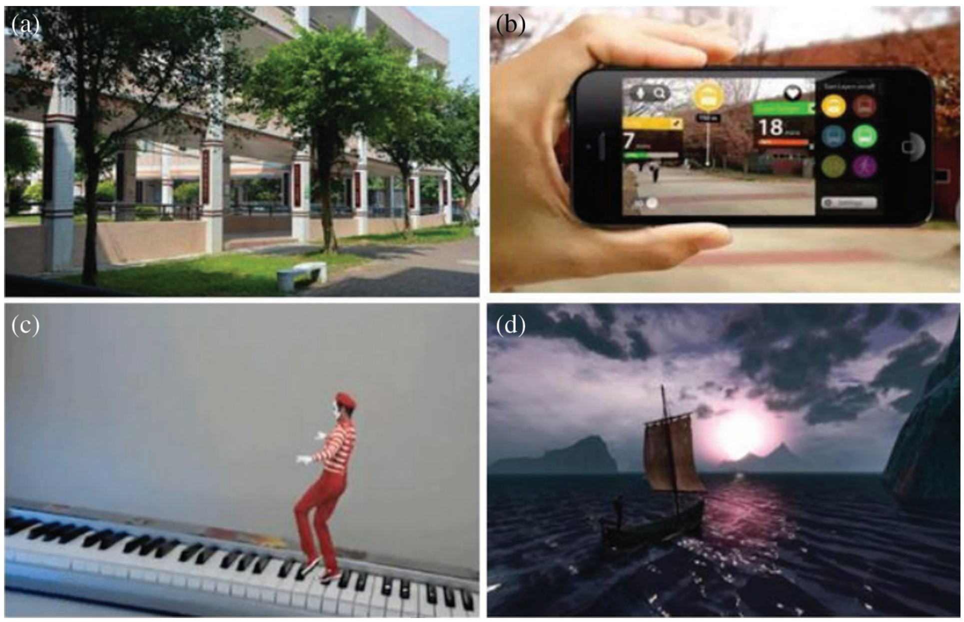

Figure 2: Real, augmented reality, augmented virtuality, virtual

3 Methodologies

3.1 Three-Dimensional Registration Technology Based on Computer Vision

The main workflow of the MAR app is as follows. First, the app collects video images of real scenes through the device camera provided by the phone. Then, the program processes and recognizes the real scene video stream, and the registration information is obtained through tracking technology. Then, the real-time rendering technology effectively combines the virtual objects in the virtual object database with the real scene with the help of registration and tracking information. Finally, through the mobile phone screen, real-time output is obtained.

It can be seen from the main workflow of the MAR application that 3D registration tracking technology is the core key technology of MAR application, which can detect, identify, track and complete the registration of virtual and real scenes in real time.

3.1.1 Identification Technology

3D registration tracking technology can be classified into sensor-based devices, computer vision-based devices and hybrid types. Among them, 3D registration tracking technology based on computer vision can be divided into recognition methods based on labels and natural features, as shown in Fig. 3. The tag in Fig. 3(a) is a set of black and white square markers, and the QR code can also be used as a tag. The mark-based identification method requires the markers to be placed in advance. This method has the advantages of fast identification speed and high stability and is often used in indoor MAR systems. The representative open source SDK is ARToolkit. Fig. 3(b) is a recognition graph for MAR application in the teaching of mechanical drawing [14]. The image in the textbook of mechanical drawing is directly used as the recognition graph. This method is an image recognition approach based on natural features without the need for additional markers. Photos, printed pictures and natural features in real scenes (such as hands and planes) can all be used as recognition methods based on natural features, as shown in Fig. 3(c) and Fig. 3(d). The disadvantages of the recognition method based on natural features are related to the fact that the natural scenes that need to be identified are complex, which sometimes leads to long periods of time consumption, low real-time degree and calculation errors. In general, MAR technology supports multiple identification types, such as tags, natural images, cylinders, intelligent terrain, 3D objects, and text recognition.

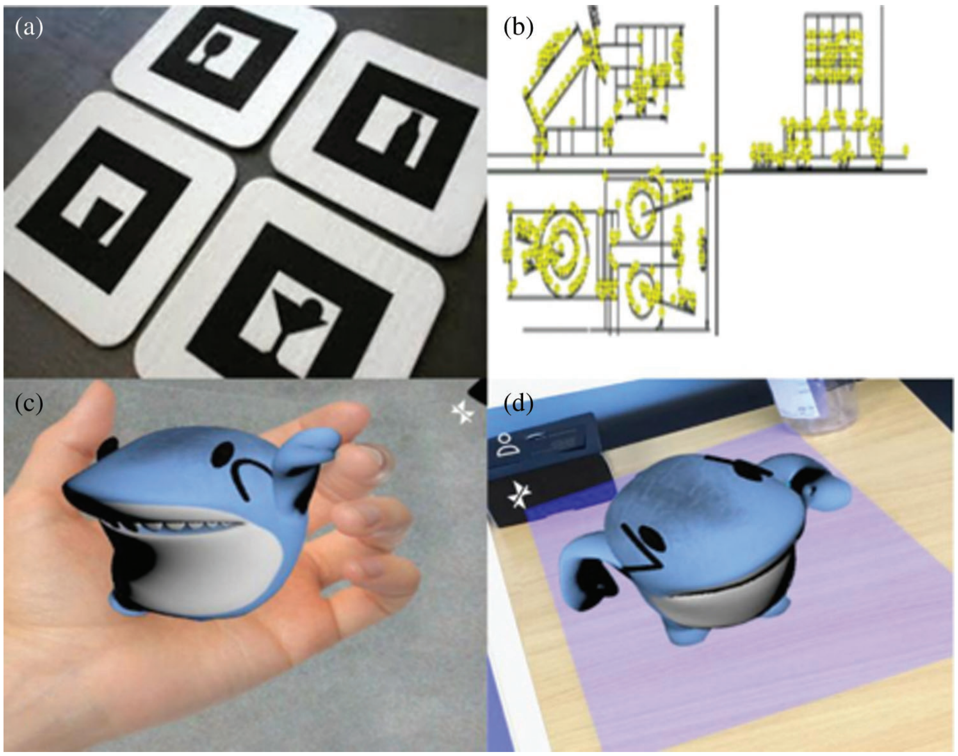

Figure 3: Identification Technology based on different ways

3.1.2 Registration Technology

For the target recognition method based on computer vision, the following registration and tracking process is used: the spatial position and shape of the target object is tracked through the mobile phone camera. The transformation matrix is calculated for the real world coordinate system W, the camera coordinate system C, the imaging plane coordinate system O and the pixel coordinate system O1 by the coordinate transformation algorithm.

The coordinate that the virtual object needs to display is obtained through the transformation matrix. The virtual and real objects are seamlessly fused and displayed on the mobile phone screen. The transformation process of different coordinate systems is illustrated by the following examples based on natural feature recognition:

1. The transformation between the real world coordinate system and the camera coordinate system, where $W(X_w, Y_w, Z_w)$ represents the real world coordinate system; $C(X_C, Y_C, Z_C)$ represents the camera coordinate system; $W(X_W,\ Y_W,\ Z_W,\ 1)^T$ is the coordinate of any point in the real 3D scene described by the secondary equation, and $C(X_C,\ Y_C,\ Z_C,\ 1)^T$ is the three-dimensional coordinate of a point in the camera coordinate system described by the homogeneous equation. The R_{WC} matrix and the T_{WC} matrix represent the rotation and translation components between the real world coordinate system and the camera coordinate system, respectively.

$$C(X_C,\ Y_C,\ Z_C, 1)^T = \ R_{\ WC} T_{\ WC}\ W(X_W,\ Y_W,\ Z_W,\ 1)^T \tag{1}$$

2. The conversion between the camera coordinate system and the imaging plane coordinate system, where O (x, y) represents the imaging plane coordinate system, and f is the distance between the camera imaging plane and the focal plane.

$$x = fX_C\ /Z_C,\ \ y = fY_C\ /\ Z_C$$

$$Z_C \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_C \\ Y_C \\ Z_C \\ 1 \end{bmatrix} \tag{2}$$

3. The transformation between the image plane coordinate system and the pixel coordinate system, where O1 (u, v) represents the pixel coordinate system, and u and v represent the number of rows and columns of a certain pixel in the digital image array, respectively. In addition, $o1(u,\ v, 1)^T$ describes the coordinates of a point in the digital image pixel coordinate system with a homogeneous equation; $\lambda = Z_C$ represents the scaling factor of the transformation from the image plane coordinate system to the camera coordinate system; and K is the internal parameter of the camera, including focal length, image plane transverse and the size of pixels in the vertical direction.

$$\lambda o1\ (u,\ v,\ 1)^T = KR_{\ WC} T_{\ WC} W(X_W,\ Y_W,\ Z_W,\ 1)^T \tag{3}$$

3.2 Selection of MAR SDK

A software development kit (SDK) is a toolkit used for software development. The MAR SDK is a set of tools and libraries to help developers to develop MAR applications. Currently, it is commonly to develop MAR applications based on the MAR framework or the MAR SDK. Common augmented reality SDKS include ARmedia (Italy), Aurasma (UK), Metaio (Germany), Vuforia (USA), D'Fusion (France), ARToolKit (USA), Kudan (Japan), Wikitude (Austria), etc. [15]. Although China's augmented reality SDKs started late, they have also developed rapidly in recent years, representative of which are EasyAR, Liangfeng HiAR, Taixu AR, etc. The Tab. 1 lists the properties and features of these SDKs.

3.2.1 Unity

Unity is a cross-platform game development engine. By 2018, Unity was extended to support game development on 28 platforms, including PC Windows/MacOS and Linux platforms, PlayStation, XBox, Wii, 3DS and Nintendo Switch, as well as iOS, Android and other mobile device platforms, including next-generation multimedia platforms such as ARKit and Oculus Rift.

Unity provides many out-of-the-box features and tools used for creating interactive 3D content and can handle graphics, lighting, animation, audio, shades and other features of the rendering work [16]. Unity also provides extensive learning documentation and APIs, as well as a community of developers and designers. Unity supports two major programming languages (JavaScript and c#) and allows plug-in creation. Unity also supports the importation of 3D models and animations from other 3D modeling software. Based on the above mentioned extensibility of Unity and its other development advantages, MAR application development combining Unity and AR SDK is a common technical route at this stage. Common AR SDKSs that are compatible with Unity3D include ARToolKit, Vuforia, EasyAR, Wikitude, etc., as shown in Tab. 2. Vuforia was integrated into Unity in 2017, enabling Unity developers to create and build cross-platform AR applications directly from the Unity editor. The other three AR SDKs or libraries provide Unity plug-ins for MAR application development.

Table 1: Features and properties of common MAR SDK

Name	Type	iOS	Android	WIN	3DRecognition	Features
ARmedia	Free/Commercial version	Yes	Yes	Yes	Yes	–
Aurasma	Free/Commercial version	Yes	Yes	No	No	–
D'Fusion	Only Commercial version	Yes	Yes	Yes	No	–
Metaio	Free/Commercial version	Yes	Yes	Yes	Yes	Add watermark
Vuforia	Free/Commercial version	Yes	Yes	Yes	Yes	Cloud recognition
ARToolKit	Open source	Yes	Yes	Yes	No	Extensible
Kudan	Free/Commercial version	Yes	Yes	Yes	No	Support without net
Wikitude	Free/Commercial version	Yes	Yes	Yes	Yes	Base on LBS
EasyAr	Free/Commercial version	Yes	Yes	Yes	Yes	Support many people interact
Hiar	Free/Commercial version	Yes	Yes	Yes	Yes	Support facial recognition
Taixu AR	Free/Commercial version	Yes	Yes	Yes	No	Support recording screen

Table 2: The AR SDK or library which can be used for Unity3D plug-in

ARToolKit	Vuforia	EasyAR	Wikitude
Support simple black square tracking, plane image tracking, camera calibration, single or stereo camera, camera position/direction tracking and other functions.	Support to identify image target, cylinder target, VuMark target, Vuforia ground plane; Provide virtual buttons, Support local database or cloud storage.	Support flat image target, video playback, transparent video and streaming video, while support QR code recognition, cloud recognition and multi-target tracking and other functions	Support image recognition and tracking (offline and cloud), SLAM (simultaneous localization and mapping), real-time tracking and 3D object recognition, extended tracking and other functions.

3.2.2 EasyAR SDK

Since this project experienced the acquisition and interruption of services of multiple augmented reality development tools during the study period, the researchers took Vuforia and EasyAR as tools for experimental development and comparative study in consideration of learning cost, development cost, feasibility of experiments and development stability. Research findings: 1. The official documents and communities of Vuforia are all in English, but due to its early entry into China, it is easy to learn from both literature experiments and online Chinese courses. 2. EasyAR is the first AR engine put into application in China released by Shanghai Inner Vision Information Co., Ltd. in 2015. Official documents and communities can provide localized services, but due to its late entry into the market, EasyAR is less experimental than Vuforia in research and online tutorials; 3. The development process of Vuforia and EasyAR combined with Unity is similar. Based on the development experience of Vuforia, EasyAR is easy to get started; 4. Both of them have excellent target detection and tracking capabilities, and the

Vuforia target recognition and virtual content load stability are slightly better than EasyAR; 5. The system compatibility rate of EasyAR is as high as 95% and the whole platform supports IOS, Android, Windows and MacOS. 6. EasyAR supports HD video and transparent video playback function, which conforms to the study on the characteristic functions of MAR application in this experiment; 7. The final release of Vuforia free included watermarks (company information), and the basic version of EasyAR met the experimental requirements.

3.3 Construction of the MAR Application Development Environment Based on the Android Platform

Android is an international mainstream operating system based on Linux open source architecture; it is widely installed in mobile devices and is led and developed by Google (Google) and the Open Handset Alliance. In other words, Android is a software stack based on mobile devices, including the Linux kernel layer, the system runtime layer, the application framework layer and the application layer. The Android system architecture from low to high is described as follows. The Linux kernel layer is dependent on the Linux2.6 kernel and is used as the abstraction layer between the hardware and software stack. The system runtime layer contains the program library and the Android runtime library, which can be used by different components of the Android system, such as WebKit, SSL, and SQLite. The Android runtime provides a set of core libraries, enabling Android developers to use standard Java programming language to write Android applications. The application framework layer provides many high-level services to applications in the form of Java classes that developers can use in their applications, including activity management, content provision, resource management, and notification management. The application layer is the layer that connects directly to the user. Users can find all Android applications or write applications to install in this layer.

In the specific development, EasyAR SDK combined with Unity is adopted, and the final project file is released to the Android platform through Unity packaging. Therefore, in this project, in addition to Unity and EasyAR SDK, the MAR application development environment based on the Android platform should be installed and configured with the Android Software development tool, Android SDK (Android software development kit), and the Java development tool, JDK (Java development kit). The specific process is shown in Fig. 4.

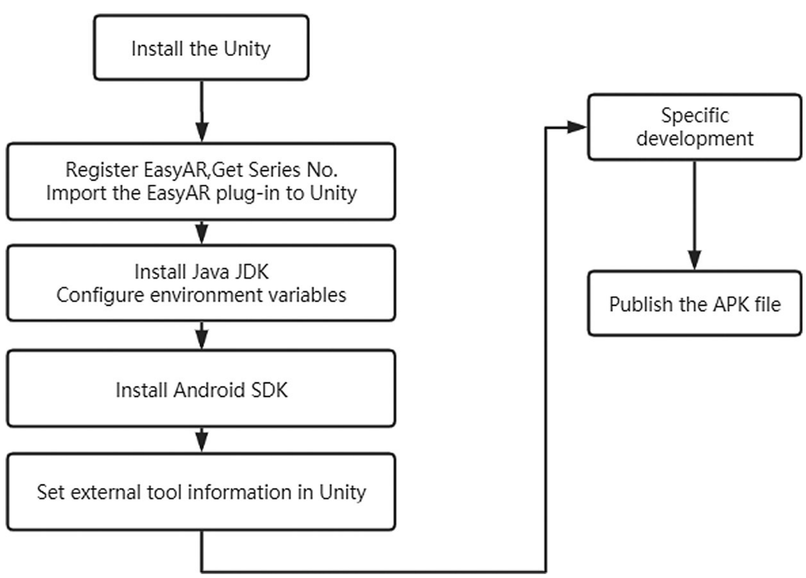

Figure 4: MAR application development process based on Android platform

3.4 The Framework Design of Interactive Educational Content for Museums is developed by Using the Abstraction Hierarchy Principle and MAR Technology

This paper describes the framework design for the development of interactive educational content for museums by using the abstraction hierarchy principle of educational optimization theory and MAR technology. As shown in Fig. 5. First, the objectives of museum education are set based on the agreement of the museum education team and the visitor representatives. Second, the abstraction level of the exhibits in the original museum is judged. Then, rich information types supported by MAR technology are selected to express, supplement, enrich and refine museum exhibits with digital information types at different levels of abstraction, Finally, the interactive educational content of museums is formed.

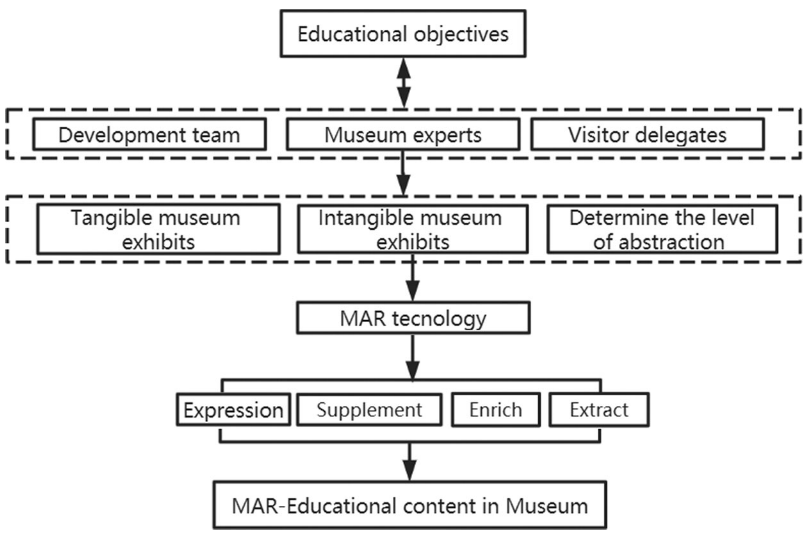

Figure 5: Framework design

4 The Development Process

4.1 GY-MAR Project Introduction

The GY-MAR project explores the design and practice of museum education content based on MAR technology in relation to the Ancient Kiln Folk Customs Museum. This museum, which is located in Jingdezhen, China, covers an area of 83 hectares and is the only one with ceramic culture as the theme; in addition, the museum is a national 5A-class tourist scenic location, a national cultural industry demonstration location, a national popular science education location, a productive state-level nonmaterial cultural heritage protection demonstration location and a classic ceramic culture scenic location.

In recent years, the development of the Ancient Kiln Museum has also been present in the trend of actively embracing science and technology, resulting in the establishment of the Ancient Kiln Museums' official website (http://www.chinaguyao.com/index.html), public WeChat numbers (Chinaguyao), official microblogs (Jingdezhen ancient kiln), and other information platforms. During the investigation of the Ancient Kiln Folk Custom Expo Area and through the introduction of researchers, relevant persons in charge of the scenic area expressed their strong interest in the application and integrated development of MAR technology and believed that this exploration conforms to the development needs of the times. The researchers, with the help of the persons in charge of the museum, also applied for admittance to the museum to conduct investigations, interviews and later on-site evaluations during the study period. During the investigation, the researchers also learned that there are currently 20 professional guides working every other day at the Ancient Kiln Folklore Exposition Area. This scarcity of professional guides contradicts the huge flow of tourists. The GY-MAR project can thus serve as a complementary way to resolve such conflicts and attract visitors in an innovative way by providing them with rich and understandable cultural content and more interaction with the attractions and exhibits.

4.2 GY-MAR Project Development

With the help of experts and staff at the Ancient Kiln Museum, the designers chose six spots (including a rest area) as design reference points, i.e., understanding the kiln God's story, visiting the imperial kilns and their architecture, watching the handmade porcelain process, appreciating the firewood porcelain boutique, and listening to porcelain music, as the education content for tourists.

Fig. 6 is an introduction to the porcelain-making process found in the Ancient Kiln Museum. The overall design of the board is exquisite and echoes the style of the ancient kiln itself. The cultural information on the board includes the name and explanation of the porcelain-making process, as well as the corresponding English introduction. The information type uses a text and picture format. The text messages on the boards are professional in their wording and expression; they are similar to classical Chinese and contain obscure characters. While people feel that cultural information is profound, there are related problems that are difficult for the general public to understand. Since both the picture and the text belong to the information type found at the top of the cone of experience, the information is more abstract. Therefore, according to the cultural content of the porcelain-making process, the designer reproduced a corresponding short video with the help of the experts at the museum. Thus, when visitors point their mobile phones at the presentation board, the video content will overlap with the presentation board. Because the short video message type is located in the middle of the cone of experience, the message is less abstract than the text and pictures. Therefore, the museum designers are able to express the same educational content through the two different levels of abstraction information types. On the one hand, visitors can better understand the porcelain-making process, which is the main educational purpose of the presentation board. On the other hand, the presentation can also establish a connection between the porcelain-making process and the professional expression of ceramic culture on the display board, such as the understanding of obscure characters and an appreciation of classical Chinese, to enhance the depth of cultural education.

Figure 6: Introduction to the porcelain making process

The original exhibit in Fig. 7 is a porcelain painting of Tong Bin, a legendary figure related to the ancient kiln. The painting contains a full-length portrait of Tong Bin. Due to the picture's limitations, the introduction of the kiln god Tong Bin is located at the bottom of the porcelain plate painting and is relatively brief. The designer produced an animated video based on mouth shape animation for this porcelain plate painting. Through MAR technology, when viewers point their phones at the porcelain paintings, Tong speaks and tells the visitors his story. In this case, the mouth animation video embedded in the porcelain plate painting expands the information expression space of the original carrier. The museum's educational content is thereby enriched with more specific forms of information expression.

Figure 7: The kiln god-Tong bin

The original exhibit in Fig. 8 is a 20-inch powder enamel plate with five dragons. The pictures on the porcelain plates are exquisitely designed with intricate designs.

The designers designed short text notes for the exhibits. When viewers point their mobile phones at the porcelain plates, the text labels overlap on the plates. Through MAR technology, the relatively specific graphic information is extracted and condensed by using the text information type with a higher level of abstraction to guide the esthetic appreciation of the tourists. This process helps the tourists move from perceptual knowledge to rational knowledge.

Fig. 9 is an explanatory booklet about ancient kiln exhibits, including some pictures and text descriptions of the exhibits located in the Ancient Kiln Museum. The designer produced some interactive 3D model for the brochure. When viewers point to a picture of an exhibit in the brochure via their mobile phone, a simulated 3D model of the same exhibit overlaps the picture. Viewers can interact with the exhibits in detail by rotating, zooming in and moving about. This experience of interacting directly with the exhibits is located in the middle and lower part of the cone of experience, which can compensate for the higher-level abstraction image and text information types that are available on the booklets.

5 Evaluation

The researchers recruited 38 subjects after a recruitment notice was issued by a university adjacent to the Ancient Kiln Museum and supported by a research tourism company in the city. The researchers offered qualified subjects a ticket to the Ancient Kiln Museum and a coupon worth 50 yuan to be used at the company's "self-service pottery" in return for their participation. The recruited subjects were randomly assigned to either an experimental group or a control group, which consisted of 19 members each (6 males and 13 females), while maintaining a balanced gender distribution. The researchers provided the experimental group with mobile phones installed with the GY-MAR app during the tour, demonstrated the use method of the GY-MAR app, and asked the experimental group participants to use the GY-MAR app when visiting the Ancient Kiln Museum, while the control group was required not to use these mobile phones. In addition, the researchers verified that the subjects had never previously visited the Ancient Kiln Museum to avoid the influence of a previous experience. Due to the control of equipment uniformity and the need for interviews, these subjects were scheduled to visit the Ancient Kiln Museum at different times, and the participants completed the questionnaire and interview after their visit.

Figure 8: Highlight the appreciation key of dragon dish

Figure 9: Interactive ceramic 3D model

5.1 Evaluation of Knowledge Gain and Learning Interest

Q1. This visit to the Ancient Kiln Museum gave you a new understanding of ceramic culture for all or some of the six designated scenic spots (Numbers 1–6 are marked successively from "strongly disagree" to "strongly agree"; please check the corresponding option).

Q2. This visit to the Ancient Kiln Museum aroused your interest in regard to learning more about all or some of the six designated scenic spots (Numbers 1–6 are marked successively from "strongly disagree" to "strongly agree"; please check the corresponding option).

In terms of the results for the above two questions, the subjects in the experimental group scored higher than those in the control group, with average grades of 25.34 and 23.71, respectively, as shown in Tab. 3. The score difference between the experimental group and the control group was statistically significant, with p values of 0.001 and 0.018, respectively. In other words, the subjects in the experimental group reported that they had learned more and were more interested in further learning than the control group. Therefore, the researchers believe that the reported increase in knowledge and interest in learning is a change brought about by the GY-MAR application.

Q3. During this visit to the Ancient Kiln Museum, you have done a lot of thinking about the cultural information provided in the exhibits (Numbers 1–6 are marked successively from "strongly disagree" to "strongly agree"; please check the corresponding option).

The results of the control group and the experimental group on this question were as follows: The control group had an average score of 3.26, and the treatment group had an average score of 4.10. As shown in Tab. 3, the difference was statistically significant, with p value equals 0.008.

Table 3: Data analysis result (1)

Question Number	Control Group		Experimental Group		Z Value	P value
	Mean Rank	Sample Size	Mean Rank	Sample Size	Mann-Whitney U test	
Q1	13.66	19	25.34	19	−3.366	0.001*
Q2	15.29	19	23.71	19	−2.435	0.018*
Q3	14.76	19	24.24	19	−2.758	0.008*

* $p < 0.05$

5.2 Evaluation of Knowledge Retention and Knowledge Application

Q4. Did you leave the museum with a deep impression about the six designated scenic spots you visited today?

Q5. If yes, please describe this impression and explain why you were impressed.

Overall, the exhibits impressed most of the participants, accounting for 68.4% of the participants in the control group and 89.4% of the participants in the experimental group. As shown in Tab. 4, the impression reported by the experimental group was slightly higher than that reported by the control group, but the difference was not statistically significant (P = 0.116).

The experimental group and the control group showed a variety of responses to the Question 5, which described how the participants thought about what they had seen and heard. From the descriptions provided by the experimental group and the control group, as shown in Tab. 5, the researchers found that the experimental group showed a stronger level of recall and reflection and provided more detailed and professional descriptions of the cultural content of the museum, such as stories that exactly matched the content of the GY-MAR application, than did the control group. Some examples are listed in the table.

Table 4: Data analysis result (2)

Result of selection	Control Group	Experimental Group	Fisher exact test
			P value
Yes	13 (68.5%)	17 (89.5%)	0.116
No	6 (31.5%)	2 (10.5%)	
Total	19 (100%)	19 (100%)	

Table 5: Data analysis result (3)

Control Group
Porcelain making is very interesting.
How fast the woman drawing the old camellia cup is!
This is the first time I've seen such a beautiful dragon dish!
Today, I finally observed the value of hundreds of millions of chicken jar cups.
There are so many exhibits in the ceramics exhibition hall, I was dazzled.
Experimental Group
Combined with the text description on the wall in the Ancient Kiln Museum and the crafters' demonstration animation in the GY-MAR app, I not only understood what the "li-pi" process was like but also had a clearer understanding of the text description, which inspired me a lot.
The naming rule of ceramic products is a combination of the name of age, color pattern and shape. Through the GY-MAR app, I learned how to appreciate ceramics. In the Ancient Kiln Museum, I observed many shapes, such as olive bottles, garlic bottles, plum bottles, jade pot springs and gourd bottles. In the future, I will be more professional when introducing porcelain to others.
It was the first time that I observed the characters on the wall of the Ancient Kiln Museum speak directly, which impressed me a lot in regard to Tong Bin. When I was young, I observed in a story book that the craftsman threw fire to produce such exquisite porcelain.
The original kiln god was a person who was dedicated to ceramics; these artisans created a brilliant ceramic culture.
The original name for Jingdezhen was "Changnan"; Changnan is China!
Jingdezhen produces tea as well as ceramics, and the camellia is the city flower of Jingdezhen; therefore, the old camellia bowl is famous as well.
Blue and white porcelain was produced in the Yuan dynasty from the steamed bread kiln, while the porcelain for daily use made from the dragon kiln, the colorful cup with chicken pattern design made from the calabash kiln, and the egg-shaped kiln were invented in Jingdezhen during the Qing dynasty. The change of kiln brought about changes in ceramics, and the development of kilns brought about the development of civilization.

6 Conclusion

This study attempted to use MAR technology to design museum education content under the guidance of the abstraction hierarchy principle based on the theory of education optimization. With the help of MAR technology, museum education content can move up and down or blended at different hierarchies of abstraction.

This paper presents a framework for developing museum educational content using MAR technology under the guidance of the abstraction hierarchy principle. And the concrete realization presented is based on the education content design of the Ancient Kiln Museum of China. It provides a development idea and solution for similar development work in the future. The evaluation confirms that the educational content of museums developed through the methods described in this paper can enhance visitors' understanding of, interest in and thinking about the cultural content presented in museums. Moreover, through the statements provided by visitors after visiting the museum, it can be found that visitors who use GY-Mar APP can use more professional terminology and provide more detailed cultural content than visitors who didn't.

As MAR technology is still in the rapid development stage, the development process of MAR application is relatively complex which requires professionals in various fields to complete together. All these have led to high development and experimental costs. Therefore, there are still some limitations in this study. For example, the experimental period is not long enough and the sample size is not large enough. In the process of effect evaluation, although the scores of some factors in the experimental group were higher than those in the control group, it could not show statistically significant differences. This may have had an impact on the accurate assessment of educational outcomes. In the future, researchers will seek opportunities and financial support for cooperation with scenic spots and universities. Large-scale sample data can be obtained for further study through the demonstration application in the scenic spot.

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