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Interactive Spatial Augmented Reality Book on Cultural Heritage of Myanmar

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Abstract

Myanmar, also known as Burma, has a rich cultural heritage, and its historical tourist attractions well known around the world. Therefore, we designed and developed an interactive spatial augmented reality (iSAR) book on the cultural heritage of Myanmar. This iSAR book has total of 18 pages with rich media content including videos, animations, audio, and images featuring the cultural heritage of Myanmar in a digital format. In addition to virtual content, navigational features such as virtual buttons and touch-based hand gestures were implemented using Leap Motion and VVVV. Therefore, the developed iSAR book allows virtual content and navigational features to merge seamlessly into a physical book. Five participants were recruited to evaluate the prototype iSAR book, and interviews were conducted to gather their feedback based on its immersive qualities. Thus, the developed iSAR book on Myanmar effectively shares the cultural heritage of Myanmar, and ultimately allows users to explore and gain more insight into the country.

Index Terms: Cultural Heritage, Interactive, Projection Mapping, Spatial Augmented Reality

I. INTRODUCTION

Museums and cultural exhibits play an important role in showcasing and preserving a country's cultural heritage. However, museums and cultural exhibits have failed to attract visitors, and there has been a decrease in interest from the public owing to advancements in technology that allow information to be instantly retrieved without having to visit the museum. Instead of passive buildings simply storing and exhibiting objects in a museum, with the advancement of technology, museums can transform and have an active role in sharing new knowledge such as the creation of platforms providing entertaining education for children of all ages, and a trusted source of information or learning for adults. Modern approaches involving technologies such as spatial augmented reality (SAR) using projection mapping are being implemented in developed countries (e.g., in the National Museum of Zurich) [1] to recapture the interest of the public. However, less developed countries such as Myanmar have yet to implement such technologies. This paper presents an interactive SAR (iSAR) book as way to offer an entertaining and educational platform for the public to learn about the cultural heritage of Myanmar and indirectly promote economic growth through tourism.

SAR has become a popular way to enhance the experience and interaction of virtual content for multiple users in the real world without requiring a wearable device such as a hand-held or head-mounted display [2, 3]. Owing their advantages, there are various fields widely applying SAR technologies, such as industrial design, education, art, and entertainment [4]. SAR is usually carried out using projection mapping techniques by superimposing a virtual content onto the real world through a projector creating the illusion that it is a part of this world. This approach is limited to sta-

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tionary uses and offers a more immersive and authentic user experience. Projection mapping by itself does not allow for user interaction, and only projects pre-defined videos or images onto an object. To improve the user interactions, we use navigational features such as virtual buttons and touch-based hand gestures as modalities that allow multiple users to interact with the virtual content in a physical book.

II. LITERATURE REVIEW

Technological advancements have motivated researchers to design and create new forms of cultural heritage information for the public. A collection of interactive projection mapping applications has been made available, as summarized in section A. To improve the engagement of multiple users, various modalities and projection mapping toolkits and/or SDKs are available for the design and support of different interactions. A review of the input modalities is presented in section B, and section C summaries the projection mapping toolkits and SDKs available for the development of SAR.

A. Related Studies

Interactive books developed by iart [5] exhibiting works by Paul Gauguin at the Foundation Beyeler have motivated other museums and cultural exhibits to widely apply a book framework to convey information through physical books painted using light (projection mapping), the content of which is tangible (interactive), and thereby supporting rich media through interactions with users. This framework offers a new platform and experience for museum visitors to learn about culture and has attracted many new visitors, providing a new and fresh experience in introducing the ancient world through technology. Table 1 compares the media content of seven related studies [1, 6-11] aiding in the dissemination and education of cultural heritage. The types of media supporting such virtual content include 3D models, images, animations, video, and audio. Among them, 3D models are mainly used in 3D projection mapping applications where the virtual content is projected onto a 3D real-world object [6, 10, 11] for enhancing the user experience with a realistic effect. Most SAR applications have at least two types of media working in cooperation in the design and development of virtual content.

Table 1. Comparison of media usage on various projection mapping applications related to cultural heritage

Author(s)	3D Models	Images	Animation	Video	Audio
[1]	x	✓	✓	✓	✓
[6]	✓	x	✓	x	x
[7]	x	x	x	✓	✓
[8]	x	x	✓	x	✓
[9]	x	✓	✓	x	✓
[10]	✓	x	✓	?	✓
[11]	✓	x	✓	x	x

B. Input Modalities

SAR applications require interactivity when offering dynamic content to support the entertaining education of cultural heritage. Common interactive features include virtual buttons, hand gestures, and the use of dynamic pages, such as fiducial marker tracking for users to interact with a real object or virtual content. There are various input modalities in iSAR applications offering interactivity. Table 2 shows a comparison of the various input modalities, features, and capabilities that researchers can choose when designing an iSAR application.

As a limitation, a normal 2D web camera does not support depth information, which greatly impacts the accuracy of the 3D tracking. Therefore, it becomes challenging to differentiate various hand gestures such as a hover or tap for selection. Thus, 3D cameras such as Microsoft Kinect [12, 13] and Leap Motion [14] are becoming popular. Microsoft Kinect and Leap Motion offer reasonable features and can be used in designing and implementing iSAR applications. However, the official drivers of Microsoft Kinect version 1 do not offer the tracking of individual finger movements and only track the movements of the entire hand. This results in a larger trigger area for a physical book. A Leap Motion

Table 2. Comparison of various input modalities for interactive projection mapping or iSAR application

Input Modal	Sensing Capability	Gesture Recognition	Usable Range (from Sensor)	Accuracy
Touch Screen	Touch, Depth	Possible	Must touch screen	High
2D Web Cam	Presence, Color	Possible	0.3–1.6 m	Low
Microsoft Kinect	Distance, Touch	Possible	0.8–3.5 m ~57.5° horizontal view ~43.5 degrees of vertical view -27 to +27 tilt	Medium
Leap Motion	Distance, Touch	Possible	1–20 in 150° field of view	Medium to High
Touch Board	Distance, Touch	Impossible	Either touch or through proximity from zero to 5 in	High

device was tested, the results of which showed that it allows the tracking of individual fingers and offers greater precision in smaller areas. In addition, a touch board [15] uses conductive ink and is used as an input capture method when touched or within the proximity of the user. Thus, the use of this touch board will require conductive ink to be painted on various areas of the book for triggering an interaction.

C. Toolkits and SDKs for iSAR

The development of iSAR has resulted in the introduction of numerous projection mapping toolkits and interactive SDKs including Lumoplay [16], Paper Augmented Reality Toolkit (PapARt) [17], VVVV [18], TouchDesigner [19], and OpenFrameWorks [20].

Lumoplay is a platform for developing interactive experiences using projections or touchscreens. For projections, it supports inputs from a touchscreen, a normal 2D webcam, or a 3D camera such as Microsoft Kinect. Lumoplay is commonly used for games or marketing purposes. The application provides a manual calibration for the projector location by manually clicking on the edges of the display covered by the projector. However, because it is designed for simple plug and play use and is targeted to the general public, the features are extremely limited and basic.

PapARt is a software development kit (SDK) for the development of interactive projection mapping and AR applications. For normal AR applications, a normal webcam can be used; however, for interactive projection mapping applications, a depth camera for the object and hand tracking are required along with a projector to project onto the surface. The cameras are pre-calibrated using intrinsic parameters to enable an extrinsic calibration based on how the cameras are placed. PapARt uses ARToolkit and OpenCV as its tracking libraries. PapARt also calibrates the projector to enable projection mapping, and is built as a processing library. It is a programming language and integrated developing environment for creative programmers. In addition, it is open source and free to use.

VVVV is a general-purpose toolkit with a special focus on real-time video synthesis and the programming of large media environments with a physical interface, real-time motion graphics, audio, and video. It is also an open-source program that relies on the community's contributions through add-ons. It is an ever-growing platform and acts as a hub suitable for various projects involving motion graphics, projection mapping, computer vision, and other uses. TouchDesigner is a visual development platform that provides the tools to create real-time projects and rich user experiences, and is suitable for creating interactive media systems, architectural projections, and live music visuals. OpenFrameWorks is also an open-source tool kit and was developed for creative coding. It makes the development process easier by wrapping common necessary tools such as OpenGL, GLEW, GLUT, libtess2, and Cairo for graphics; rtAudio, PortAudio, OpenAL, and Kiss FFT or FMOD for audio input, output, and analysis; FreeType for fonts; FreeImage for saving and loading images; Quicktime, GStreamer, and videoInput for video playback and grabbing; Poco for a variety of utilities; OpenCV for computer vision; and Assimp for the loading of 3D models.

III. iSAR BOOK on MYANMAR

A. iSAR Book Design and Setup

The developed iSAR book uses a 2D flat surface of a book page, and interactive 3D models were created, allowing the user to rotate a 3D view of the model. Furthermore, the user can also control the directional lighting of the 3D model by swiping their finger left and right. The iSAR book application contains an image gallery, videos, 3D model, audio, and animation to provide an immersive user experience, which an ordinary book cannot offer. Furthermore, the videos, audio, and images are dynamic and can be controlled and triggered by the user through virtual buttons. Finally, 360° images are added with user control through hand gestures.

A major aspect of the project is the tracking of the hands and fingers to enable the book to act as a "touchscreen" and for the projections to respond dynamically to these hand movements. A leap motion is placed between the user and book, and by facing the book, when the user's finger is within its tracking range, it will return the finger coordinates to the VVVV. Fig. 1 shows a sketch of the environmental setup for the iSAR book, Leap device, and projector. Therefore, the iSAR application supports direct interactions between the user and book, unlike in the case of ISO CAM [6], which uses a touch sensitive table to indirectly control

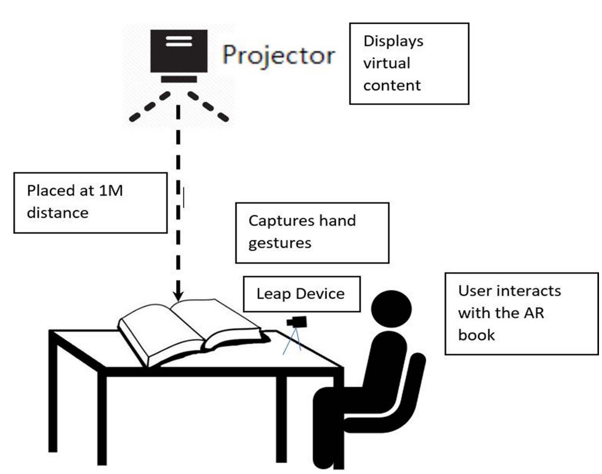

Fig. 1. Environmental setup of iSAR book for cultural heritage of Myanmar

the projection.

B. Interaction on Physical iSAR Book

The design of the physical iSAR book acts as a key component in this project, with the virtual content projected onto it in a complementary manner. These projected areas are left blank to enable dynamic content to reflect the cultural heritage of Myanmar. The book was designed through sketches and using Adobe InDesign. The iSAR physical book contains text and images. The fiducial trackers are detected using reacTIVision, which is a computer vision framework. The AR application displays the animation and virtual video content through the projector. Furthermore, sound and music are played through the AR application. The Leap sensor is used to capture hand gestures through the Leap SDK.

The left side of Fig. 2 shows the actual pages 2 and 3 of the iSAR physical book, with text and images as static information on page 2, and a blank page on page 3 showing the area where a virtual map of Myanmar is projected along with cultural points of interest. Fiducial trackers are printed on the top-right side of each pair of pages as markers. The user's hand movements are tracked using the Leap Motion sensor, and when a user touches a point of cultural interest, a video regarding the site will play on page 2 of the blank area. Page 3 displays a map with hotspots that can be triggered when pressed. When the hotspots are triggered, related videos of the triggered place of interest will be played on the page 2. The right side of Fig. 2 shows the integration of virtual content into the physical iSAR book where the user points a finger to trigger the cultural attraction, and video is then superimposed onto page 2.

The same design is applied on the remaining pages according to the order of the storyline of the cultural heritage site. Pages 4 and 5 showcase six groups of traditional instruments from Myanmar. When a user presses on one of the instruments on page 5, the sound of the relevant instrument is played. Musical notes jump based on the tune of the song. The animated notes are projected onto the printed lines of an empty page of sheet music, to allow for a seamless integration of the virtual and real-world content. On page 4, a video of a puppet show is also added. However, to avoid an interruption, the sound is muted when a user presses a musical instrument on page 5. Pages 6 and 7 showcase the world's largest book and the Kuthodaw pagoda. A video of the Kuthodaw pagoda is automatically played on page 7 once it is flipped. The ancient city of Bagan is shown on pages 8 and 9 using a 3D model of the interior of Khayiminga temple, which was downloaded from SketchFab [21].

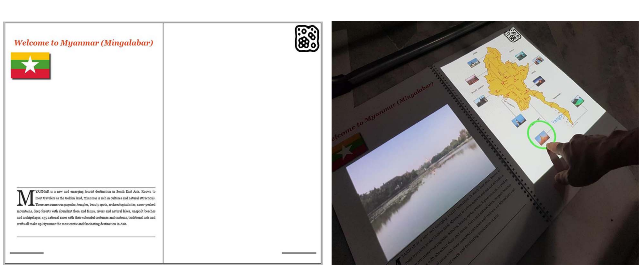

Fig. 2. Example of pages 2 and 3 of the physical iSAR book of cultural heritage in Myanmar

Pages 10 and 11 showcase the wonderous highlights of Myanmar through a printed image gallery and a virtually projected image gallery, respectively. The virtual image gallery contains virtual buttons that can be triggered to view the enlarged image as well its relevant text. Both the enlarged image and text are dynamic. Popular delicacies from Myanmar are highlighted on pages 12 and 13. On page 13, two videos about Jaggery are played. However, only one has audio. It also contains virtual texts regarding Jaggery. The 360° image extends on pages 14 and 15 to showcase Mandalay Palace and allow a wider viewing experience. Furthermore, the user can use a hold and drag gesture to rotate the view. By tapping on the arrows on the ground, the user can travel to the next 360° image available in the area, similarly to Google Maps Street View. The final two pages (16 and 17) showcase an overview of the Golden Land iSAR Book. The book cover is displayed in the scene and when the user touches the book, it opens up, playing an overview video of the book.

IV. DISCUSSION AND CONCLUSION

A. Environment Setup

The design of the environment is an important factor in this iSAR book. Because the target environment is a public exhibition and/or museum, the projector and Leap motion device use a stationary setup. From the experiment setup, the Leap motion device was placed 55 cm from the starting top edge of the book after testing to maintain the finger tracking. However, it was found that the coordinates shift when the finger is further from the Leap motion device. To allow the Leap sensor to effectively detect and track a user's finger when touching the book, the Leap sensor was elevated from the ground by 9 cm. Similarly, the placement of the projector is also important because the projections should not be obstructed by the user interacting with the book. Therefore, the projector is mounted at the top, 1 m from the AR book. The webcam is mounted at a height of 30 cm from the surface of the book, focusing on the Fiducial markers.

B. VVVV challenges using 3D Models

Loading the 3D models with textures proved to be a challenge because there is a limit on the texture size in a 32-bit

VVVV. The 64-bit VVVV cannot be used because it does not support fiducial trackers. Therefore, the original 3D model downloaded from sketchfab had to be resized from 8192 × 8192 to 4096 × 4096. The 3D model was then loaded in Blender to retexture and map the newly resized texture onto it. It was then exported as a collada file (.dae) to be loaded into VVVV. The 3D model is loaded into VVVV using the ColladaFile node and placed into the mesh node which returns the mesh and FileTexture into the PhongDirectional node. This is then grouped together with the axis node, which displays the directional arrows of the axis to be displayed in the renderer.

Another challenge is in controlling the view of the 3D model, because mapping the leap input values directly into the camera view matrix of the camera (transform orbit) node proved to be inaccurate. Therefore, the cursor (system) node was applied to impersonate a mouse cursor. The x and y outputs of the leap tracking patch was mapped into the x and y coordinates of the cursor (system) node and the Z bang output was used to impersonate a left click.

To control the directional lighting based on the user's hand movements, a light (directional) node was added into the PhongDirectional. The x output from leap tracking patch was set as the input for the yaw rotation of this light (directional) node. However, if the user's finger is not currently present in the scene, the model will be pitch black because the yaw value of the lighting (directional) node will be null owing to the finger not being currently detected. Therefore, an AvoidNIL node was added to provide a default value if the LeapTracking patch provides a null output for the x-axis. Furthermore, a damper (animation) node was added to slow down the changing of the yaw rotation value. This allowed for a fading light animation effect.

C. Immersive Evaluation

The system testing and user feedback on usability [22] showed evidence that the projection mapping application and the physical AR book were interactive and fully functional. This work is further evaluated based on the immersion of the virtual contents on the physical book. User testing is conducted to gather valuable feedback on the immersion of the iSAR book. In this user testing, five volunteer participants were recruited and asked to explore the iSAR book application. They were allowed the freedom to explore and learn about Myanmar through the iSAR book. To test the feeling of immersion from the users, the participants were asked to rate their answers accordingly on a Likert scale of 1 (strongly disagree) to 5 (strongly agree).

The questions shown in Table 3 were modified from Regenbrecht and Schubert [23] to better fit the current context, and Fig. 3 shows the mean score for each question. Although the findings from Q1 and Q2 showed that the majority of the participants seemed to experience the virtual content as immersive, however, Q3 and Q4 showed the sense of tangibility still needs to be improved, and the differences noted by the user between the real and virtual content should be minimized.

Table 3. Questions for immersion evaluation

No.	Question
Q1	Was viewing the virtual content just as natural as viewing the real word?
Q2	Did you have the impression that the virtual content came from a real book (physical book)?
Q3	Did you have the impression that you could have touched and grasped the virtual content?
Q4	Did you notice a difference between the real and virtual content?

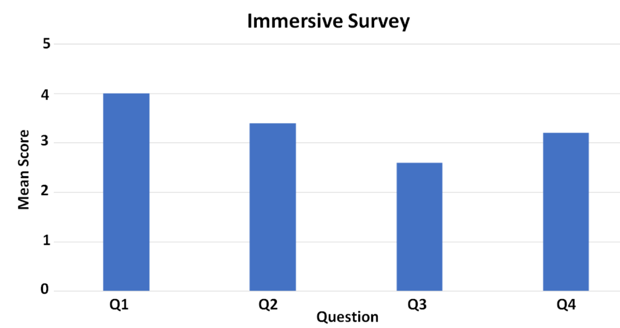

Fig. 3. Mean score for immersion survey of five participants

D. Conclusion

The proposed interactive projection mapping application can be further improved using a higher resolution projector with higher lumens. This will greatly improve the visual quality of the projected virtual content. Furthermore, the use of a rear projection projector will reduce the effect of shadows being cast by the user's hands onto the AR book. In summary, the interactive projection mapping application used in the iSAR book was found to be effective at enhancing the cultural heritage of Myanmar while providing an interactive and immersive experience for users.

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