Designing and Developing an Interactive Projection Mapping AR Book on Cultural Heritage of Myanmar

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Abstract

The projection mapping technology is used to design and develop an Augmented Reality (AR) based book of the cultural heritage of Myanmar. The proposed interactive AR book contains 18 pages designed using Adobe InDesign to introduce the culture and heritage of Myanmar including the World largest book, traditional musical instruments, and various Myanmar delicacies and cuisine. Leap Motion device and VVVV toolkit are used to design and develop the AR contents which ultimately blends the virtual contents to the real world.

Keywords- Projection Mapping; Spatial Augmented Reality; Leap Motion; AR book; Cultural Heritage

1. Introduction

Augmented Reality (AR) has become a popular and high potential for enhancing user's perception and interaction with the real world. AR provides the display of computer-generated sensory inputs or information onto the physical view of the world in real-time [1,2]. Most current AR technologies are experienced through hand-held or head-mounted displays, thus requiring the user to see through the device to view the virtual contents which overlay onto the real world. However, to truly create an immersive experience, the virtual contents should be viewable directly in the real-world using projection mapping and spatial augmented reality (SAR) techniques [3, 4]. Projections will superimpose on the real world through a projector creating the illusion as if it is part of the real world.

Projection mapping is a technique that displays the projections on top of 2D or 3D real-world objects or surfaces. It is then designed and mapped, create an illusion as if the virtual contents are part of the real world itself. Projection mapping by itself does not allow for user interaction, as it only projects pre-defined videos or images on to the object. In order to make these projections respond accordingly to the user, we can capture user inputs through various input capture techniques such as 3D cameras that can capture depth information. It is commonly used by advertisers, marketing, art shows and in events. This allows a more immersive and authentic user experience; however, it is usually limited to stationary uses only. Nevertheless, it is suitable for this project as the application will be used in a stationary setting such as a public exhibition or museums. Furthermore, traditional augmented reality methods are less ergonomic as it can be quite cumbersome for the user to hold handheld displays or to operate around with the head-mounted displays.

Museums and cultural exhibits are responsible for preserving a country's cultural heritage. However, in recent years, there has been a drop of interest from the public. Modern approaches involving technologies such as SAR projection mapping are being implemented in developed countries (eg. in the National Museum Zurich) [5] to recapture the interests of the public. However, less developed countries like Myanmar have yet to implement such technologies. Myanmar is well-known for the introduction of Buddhism into Southeast Asia for the last two thousand years ago, with rich cultural heritage and many tourist attractions which are not yet well known to the world. Therefore, this project is beneficial to enhance knowledge of cultural heritage as well as to promote tourism in Myanmar.

Thus, this project aims to design and develop a projection mapping application on the AR book for an immersive and interactive experience. After conducting a thorough literature review on previous projection mapping techniques and AR experiences, it was decided to opt for a fiducial tracker-based AR application and project the AR virtual contents on top of the physical book.

2. Literature review

2.1. Previous works of interactive projection mapping applications

By reviewing previous related works of interactive projection mapping especially in the field of culture and heritage, it helped to define the requirements and strengthen the aim and purpose of the goal. As the results on previous works can show the impact and benefits of these interactive projection mapping applications. Table 1 shows the comparison of the common features in existing applications, it also provided a better idea on the design phase, as in what features to include or exclude for this project.

Table 1. Comparison of various projection mapping applications

Name of Projection Mapping Application	Author	3D models	Image Gallery	Animation	Video	Audio	Interactivity			
							Virtual Buttons	Hand Gestures	Dynamic Pages	Audio Visualizer
National Museum Zurich - The Interactive Books of the Exhibition 'Ideas of Switzerland' [5]	iART	×	✓	✓	✓	✓	✓	×	✓	×
PARACOSM-the projection mapping picture book [6]	mrokacheke	×	×	×	✓	✓	×	×	×	×
Interactive Projection Book [7]	C. Sun	×	×	✓	×	✓	×	×	✓	×
Interactive Book of Alexander the Great [8]	Vasilis Athanasiou	×	✓	✓	×	✓	✓	×	✓	×
Interactive Projection Mapping in Heritage [The Anglo Case] [9]	G. Barber et al.	✓	×	✓	✓	✓	✓	×	×	×
IsoCam: Interactive Visual Exploration of Massive Cultural Heritage Models on Large Projection Setups [10]	F. Marton et al.	✓	×	✓	×	×	✓	✓	×	×
A SAR-based Interactive Digital Exhibition of Korean Cultural Artifacts [11]	Y. Y. Lee et al.	✓	×	✓	×	×	×	✓	×	×
Interactive Projection Mapping on AR Book	**Proposed work**	✓	✓	✓	✓	✓	✓	✓	✓	✓

2.2. Various input captures

Table 2. Comparison of different input captures for interactive projection mapping

Input Capture	**Sensing Capabilities**	**Gesture Recognition**	**Usable Range**	**Accuracy**
Touch Screen	Touch, Depth (if pressure sensitive)	✓	Must touch the screen	High
2D Web Cam	Presence, Colour	✓	- 0.3 m to 1.6 m from the sensor	Low
Microsoft Kinect [12]	Distance, Touch	✓	- 0.8 m to 3.5 m from the sensor - horizontal angle of vision is 57.5 degrees - vertical *field of view* is 43.5 degrees, with -27 to +27 degree variable tilt	Medium (1.3 mm resolution)
Leap Motion [13]	Distance, Touch	✓	- 1 to 20 inches - 150 degree field of view	Medium – High (resolve movements of 1/100 mm)
Touch Board [14]	Distance, Touch	×	Either touch or proximity sensor from 0 to 5 inches	High

Table 2 shows various input capture techniques suitable for interactive projection mapping experiences. Based on the findings, the Microsoft Kinect and the Leap Motion devices [12] were initially found most appropriate for this project.

A major aspect of the project was 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. The Kinect was originally used to track these hand movements however the Microsoft official drivers that come with Kinect v1 do not offer for individual finger movements rather it only tracks the movement of the entire hand. This resulted in a large trigger area for the physical book. The leap motion device was then tested as it allowed for individual finger tracking and more accurate precisions in a smaller area. The leap motion is placed between the user and the book. It is placed facing the book so when the user's finger is within its tracking range, it will return the finger coordinates to VVVV toolkit.

3. Design and Development of Interactive Projection Mapping on AR Book Application

The application is designed by taking inspirations from previously existing works and further enhanced and tuned to fit the aim which is to enhance the cultural heritage of Myanmar. The application process has been described using the flowchart shown in figure 1.

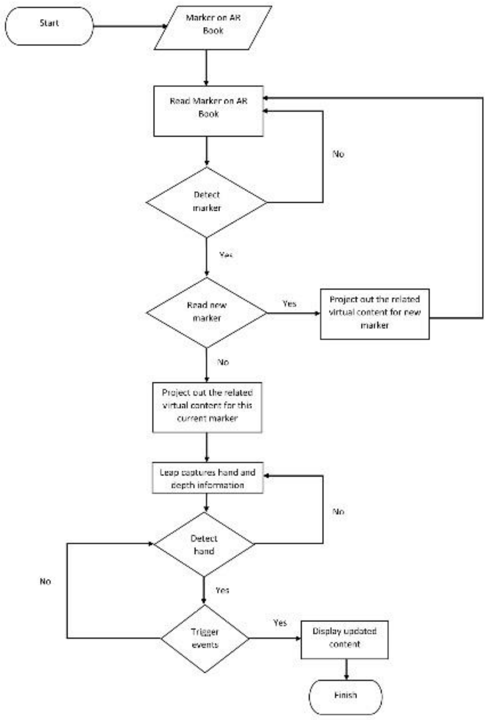

Fig 1. Flowchart of the application process

3.1. Detection and tracking of the user's finger

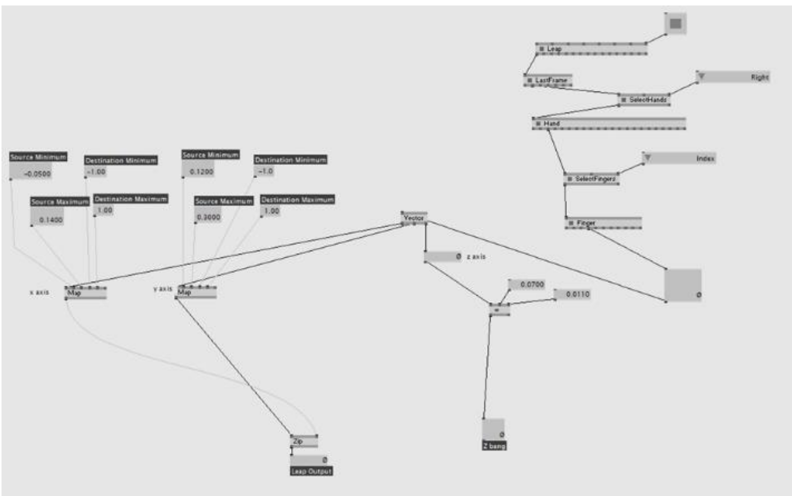

Fig 2. Screenshot of the Leap Tracking patch

The Leap Tracking patch was one of the core components of the project as it accepts the raw input from the leap device and returns the coordinates of the hand and finger positions. The Leap node connects to the leap device and the Last Frame node selects the latest frame from it. The Select Hands and the Select Fingers node both allow to filter which hand or finger the output coordinates are generated from. As shown in Figure 2, the coordinates being generated are from the Index finger of the right hand. The x and y coordinates are both passed into the Map node, which maps the coordinates from a source minimum and source maximum to destination minimum and destination maximum. The source minimum and source maximum are determined through manual calibration by placing the user's finger on the edge of each side of the book. The destination minimum is -1 and the destination maximum is 1 because this is the minimum and maximum coordinates of the VVVV renderer. Therefore, these mapping nodes simply converts the raw coordinates of the finger as received from the leap device into the ratio of -1 to 1 of the renderer.

The coordinates from the z-axis are compared with a value derived through manual calibration by touching the surface of the book. As the z-axis represents the depth, this axis is used to determine and differentiate between a touch and a hover. Therefore, if the coordinates of the z-axis equal the value determined by touching the surface of the book, VVVV will return true in the form of a bang, else it will remain false. An epsilon value is also added in the = node, this acts as a range of deviation from the exact value allowing for VVVV to return true whenever the value is within this range.

3.2. Fiducial Tracker

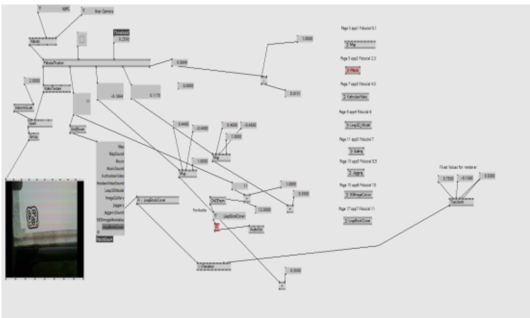

Fig 3. Screenshot of Fiducial Tracker patch

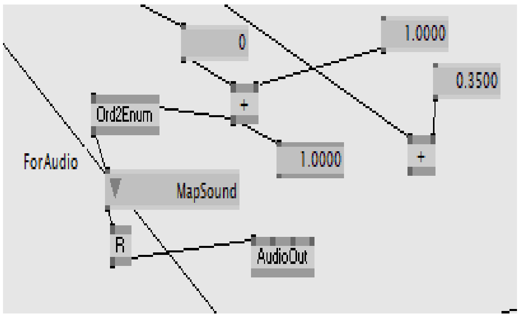

Fig 4. Screenshot of the Audio data receiver

To allow for the dynamic changing of patches when a book page is flipped, the fiducial tracker patch was created. Each page is identified by a fiducial tracker that is printed on the top right-hand corner of each page on the physical book. As shown in figure 3, the Fiducial Tracker node accepts the webcam video stream. The threshold of the Fiducial Tracker node can also be adjusted to filter out the blacks and the whites. The outputs of the Fiducial Tracker node are Fiducial ID, X and Y coordinate locations of the Fiducial Tracker and its orientation. The X and Y coordinates can be used to map the renderer to display the projection based on the location of the Fiducial Tracker by using the mapping nodes.

The Fiducial IDs are used to uniquely identify the pages and determine which scene to load. The Fiducial IDs are converted into an enumeration using the ord2enum node, which allows the dynamic switching between the patches that send the scene using the s node (sender) to be received by the r node (receiver). The renderer accepts this scene and displays it. The audio data for each scene is sent using another s node as the renderer only accepts visual data. Therefore, the audio data was identified by another fiducial ID. However, using this technique will require each page to have 2 fiducial trackers printed on each page. Thus, a workaround as shown in figure 4 was implemented by using another r node and adding 1 to the fiducial ID which was returned by the fiducial tracker node. This r node only returns the audio data which is received by the AudioOut node. The AudioOut node plays the audio data through the speakers. Each of the patches was also stored in sequential order to load the patches without having to open them individually.

3.3. Virtual Buttons and trigger areas

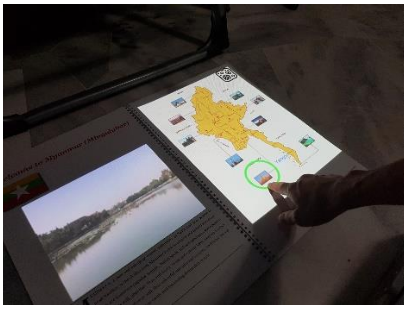

Fig 5. The map with trigger hotspots triggering the related video

For the user to interact with the AR book, virtual buttons and trigger areas were defined. Figure 5 describes how the virtual buttons are defined to trigger the relevant videos of the hotspots. The X and Y coordinates of the finger are compared with the X and Y coordinates of the hotspots. The epsilon value is set to a fixed value representing the range of acceptance. The Z axis is used to check if the finger is touching the book. Lastly, all these 3 logical comparisons go through an AND node which returns true only if all 3 conditions return true. The output is a Boolean spread of 6 rows, which will return true or false for its respective spread. This allows for the detection of which quad is being triggered.

3.4. Animated Audio Visualizer

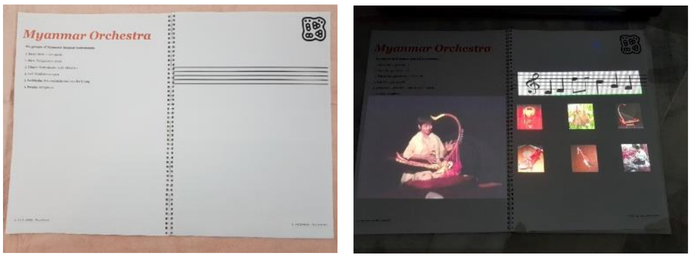

Fig 6. Side by side comparison of the physical book and the virtual contents projected onto the book.

Figure 6 showcases the six groups of Myanmar traditional instruments. When a user presses on one of the instruments, the sound of the relevant instrument is released. An audio visualizer was also added through animation. The musical notes jump based on the tune of the song. The animated notes are projected onto the printed lines of the empty musical sheet, to allow for seamless integration of the virtual and the physical world. On the left side, a video of a puppet show was also added. However, the sound is muted as it will interrupt the triggered sounds when a user presses a musical instrument.

3.5. Image Gallery, 3D models and 360-degree image

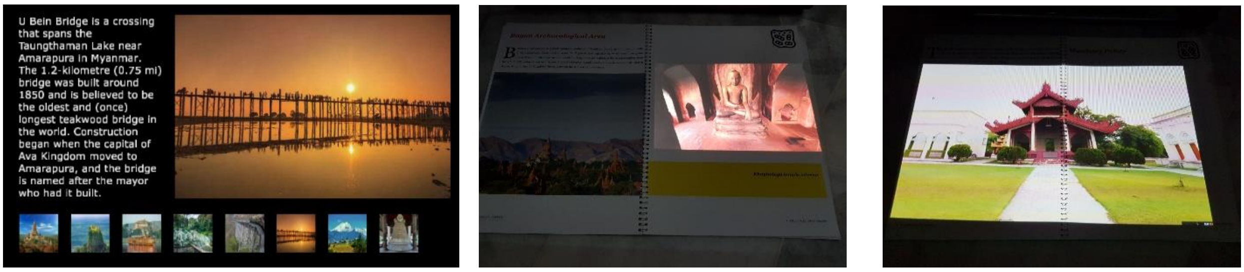

Fig 7. Image Gallery, 3D model and 360 degree image

Figure 7 showcases a few pages from the AR book including the wondrous highlights of Myanmar through a printed image gallery on the tenth (10) page and a virtually projected image gallery on the eleventh (11) page. The virtual image gallery contains virtual buttons that can be triggered to view the enlarged image as well as its relevant text. Both the enlarged image and text are dynamic. The 3D model of the Khayiminga temple interior was downloaded from SketchFab [15]. The model texture was rescaled and retextured due to VVVV 32bit texture limitation. The user is able to interact with the 3D model, through hand gestures by sliding their finger left or right to control the directional lighting of the 3D model. The user can drag and swipe whilst touching the surface of the book to rotate the view of the 3D model. The 360-degree image of the Mandalay Palace extends on both pages, to allow for a wider viewing experience. Furthermore, the user can use the hold and drag gesture to rotate the view. By tapping on the arrows on the ground the user can travel to the next near 360-degree image available in the area, similarly to Google Maps street view.

4. Testing

The output of the physical book, as well as the virtual contents of the AR app, were tested, and feedback was collected from users to further modify and improve the proposed work.

4.1. System Testing

Stress tests such as its performance under different lighting conditions, distance, speed of tracking and detection capabilities were examined thoroughly to enable for further improvement of the setup environment to fit the optimal environmental conditions for the application. It was found that the detection speed and recognition accuracy was dependent on the lighting conditions and the webcam’s input. The detection and recognition both performed best in moderate lighting conditions. In very low light it was found that the webcam could not detect the fiducial tracker. Whereas, in bright lighting conditions it was found that the reflection affected the webcam’s recognition accuracy. The distance of the webcam until the fiducial tracker was recognized was also tested. It was found that the webcam could start detecting the 2x2 inch fiducial trackers at 76cm. The tracking capabilities of the leap motion device were tested using the default Leap motion visualizer. The maximum range for it to start detection was at 33cm and the maximum distance until the finger tracking was lost, was at 73cm. The field of view (FOV) for depth was 120 degree and FOV for width was 150 degree.

4.2. User Testing

The quantitative feedback was analyzed by calculating the mean score of pre and post knowledge ratings on the selected 5 topics namely, World Largest Book, Types of Myanmar musical instruments, Places of interest in Myanmar, Jaggery and Ancient Bagan. The post-test knowledge rating means scores were increased for all topics. To verify their claim of rating a short multiple-choice quiz was conducted. The findings supported the quantitative ratings. A survey for immersion was also tested using the pre-defined questions. The findings are overall positive therefore achieving the aim of the project for capturing an immersive and interactive experience. Lastly, a few questions regarding the usability of the interactive projection mapping application were asked to the participants. The results show that the accuracy is overall accurate; however, some found it difficult for the leap device to detect their hands immediately and required some training but afterward, they became more used to it and were able to interact with the AR book. Manual recalibration also increased finger tracking accuracy.

5. Conclusion

The AR book offers interactive images, audio, videos, 3D models, 360-degree images, animation, and audio visualizer. The system testing and users’ feedback on usability and immersion showed evidence that the projection mapping application and the physical AR book were interactive and fully functional. The results showed that most of the participants perceived positively on the Interactive projection mapping application on AR Book. They also believed that the projection mapping application was able to facilitate their understanding of the culture and heritage of Myanmar.

The current interactive projection mapping application can be further improved by using a higher resolution projector with higher lumens. This will greatly improve the visual quality of the projected virtual contents. 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. The accuracy of finger tracking can be improved by testing different input devices. In addition, to increase calibration speed the calibration process can be made automatic by using the checkerboard detection technique. The performance of the interactive projection mapping application can be greatly increased by using a more powerful computer with better graphics, processing power and memory. Refactoring of the VVVV code to make it more memory efficient and rewriting some modules to support dx11 may also aid in the performance increase.

In summary, the interactive projection mapping application on AR book was found to be effective to enhance the cultural heritage of Myanmar whilst providing an interactive and immersive experience to the users.

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