Low-cost Projection Mapping Technique for 3D Objects

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ABSTRACT

This study presents an alternative approach to display traditional multimedia with Projection Mapping—a technique which allows pictures and videos to be projected onto 3D objects to create more excitement and engagement among the audience. A framework for the low-cost projection mapping was achieved in this work. Simple and complicated geometric objects were experimented with suitable videos. The audience felt engaged and were satisfied with the outcomes of this project. From the survey of 79 audiences, their overall satisfaction was 4.37 out of 5. Low-cost projection mapping could also assist in other useful applications such as providing technical training or studying guidance.

Index Terms— *Projection Mapping, Multimedia, Digital Media, AR, 3D*

1. INTRODUCTION

Projection mapping has been popular and widely used internationally in festivals, concerts, and other activities. The principle of making projection mapping is to create computer-generated augmented reality objects and project those images onto three-dimensional objects such as boxes, buildings, and landscapes. This technique generates excitement among the audience because it could turn irregularly shaped objects into a display surface instead of a white flat screen for normal video projection. An object is spatially mapped on the virtual program which mimics the real environment it is to be projected on using specialized software. When such technique is used, it creates extra dimensions, optical illusions, and notions of movement onto static objects.

The inspiration for this low-cost projection mapping project stemmed from the annual "Haunted House" festival. Each year, the undergraduate students majoring in Information Technology at Naresuan University host this extra-curricular activity as an outreach to local school kids for entertainment. The IT students would dress up as ghosts and ghouls to scare the young attendees. Creative multimedia technology could and should be incorporated with traditional methods to help those youngsters to be inspired about computer technology. For this reason, projection mapping was selected for this study to help make the annual Haunted House more interactive, exciting, and inspiring.

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This paper contains the following information: background of the technology in Section 2, the proposed framework in Section 3, experimental results in Section 4, and the conclusion in Section 5.

2. LITERATURE REVIEW

Projectors have been used to display still and moving images. The most common type of projector used today is called a video projector which is an optical device that projects still or moving images onto a flat surface such as a projection screen.

Projection mapping refers to the technique that uses a normal projector to project images on any surface. By mapping the images with the contours of the object, this technique can turn such an object into a dynamic visual display. Instead of using a boring flat white screen, projection mapping can be used to bring buildings and objects to life --- creating immersive environments and providing audiences with exciting interactive experiences [1]. This is why projection mapping is gaining more and more popularity in advertising, merchandise launch events, live concerts, and even weddings.

Typical contents of projection mapping feature a mixture of computer animation and computer effects. To map these images onto any surfaces, a variety of different methods can be employed to achieve the desired effect. Nonetheless, projection mapping always involves a combination of creativity and complex planning.

Narita [2] created a methodology for dynamic projection mapping onto deforming non-rigid surfaces using a deformable dot cluster marker with a high-speed technique for tracking non-rigid surfaces. The speed of the mapping must be sufficiently high such that a human does not perceive any misalignment between the target object and the projected images. To achieve this, a high-speed technique for tracking non-rigid surfaces is needed. A high-speed projector was used to perform the dynamic projection mapping onto a deformed sheet of paper and a T-shirt with a speed sufficiently high that the projected images appear to be printed on the objects. While Narita's research is mathematically and computationally intriguing, this study was not planned to use non-rigid surfaces for projection mapping. And more importantly, the limited funding is a major concern. Walt Disney Imagineering and Disney Research Zürich published research on projection-based augmented reality (AR) in Disney Theme Parks [3]. The study presents the motivation and methodology on how to build a projector- camera toolbox to create spatially augmented 3D objects and interactive spaces that enhance the experience of the Disney theme park guests. Their projection-based AR typically uses one or more projectors arranged around an object or distributed throughout a 3D space. The images displayed with multiple projectors can be independent of one another or blended together. To achieve the most dramatic visual impact, the images should be precisely aligned with physical objects, especially on the surface features. This way the projected images can copy the colors and features of the surface to yield high dynamic range (HDR) results.

Again, with limited funding this study was not able to acquire more than one digital video projectors. However, the technique of precisely mapping the features to get the most HDR and dramatic visual impact was followed in this study, manually.

Projection mapping is also used locally in Thailand. The "Projection-Mapping on Models for the 3rd Arbhorn Exhibition", developed by Chingchuang [4], used the projection mapping technique creatively to light up mannequins and human models with digital images. The technique was used in that exhibition for advertising the show attractions and impressing the participants as shown in fig. 1. Despite the similarity, the images used in that exhibition were static while this project aimed to create dynamic moving images for 3D objects.

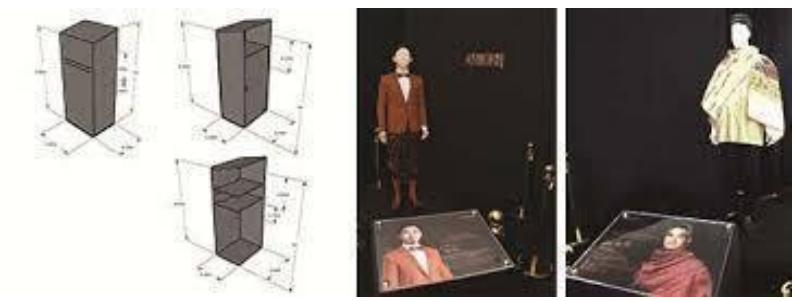


Fig. 1. preparation of the 3rd Arbhorn Exhibition [4].

Aleksandersen [5] helps artists, programmers, advertisers, and event organizer understand the psychology and allure of using projection mapping for as a marketing tool in a book, "The Marketers' Guide to Projection Mapping" --- how to catch the audience's attention and leave lasting impression of the products through this form of multimedia. The materials in the book stress the importance of projection mapping as an immersive media that would enhance the audience's experience for this study.

Projection Mapping Central [6] is an excellent community resource for projection-mapping related materials. The website is a good starting point for novices to learn and be inspired by this technology. It is an equivalent to GitHub or Stack Overflow for projection mapping.

3. DESIGN AND IMPLEMENTATION

A. Framework

As mentioned in the previous section, projection mapping involves a combination of creativity and complex planning. This study proposed a framework of how to easily achieve projection mapping on a budget as shown in fig. 2.

The first step is to start from finding a suitable 3D object. This could simply be a box, a tiered cake, or a mannequin. These physical objects should be light color, e.g., nude or white.

After acquiring the desired object and setting it at the display location, the distance and point of view must be set. This will determine the audience field of view.

Next, we could proceed with generating computer graphic images in software such as Adobe Photoshop and Adobe After Effects. Both allow editing and adding animated effects to these images. To ensure that the generated images would be precisely mapped to the physical objects, an actual photograph of the object in the scene which the audience would see is recommended. Otherwise, the created images might not be mapped with the model perfectly, as will later be discussed.

Finally, the software for video mapping can be used with the projector to display the computer generated images onto that physical object. There are several tools to choose from [6]. This project uses MadMapper [7] because it offers an easy to use interface as well as extensive tutorials.

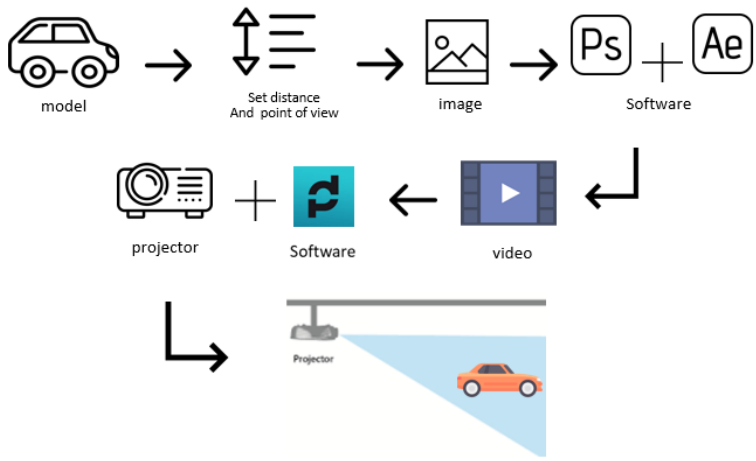


Fig. 2. Projection mapping framework.

B. Implementation

The first projection mapping video created for this projection was inspired by a projection mapping of a wedding cake found in [7]. It was a perfect starting point to learn and test our projection mapping framework. Instead of a two-tiered wedding cake, two white boxes stacked on top of each other were used. Several animations were created for this 3D object. An example of it which was displayed at the most recent Haunted House activity is shown in fig. 3.

Fig. 3. Simple animation with projection mapping on two boxes.

After experimenting with simple 3D objects, the attention was turned to something more complicated to create a more exciting experience. A car model was selected because it is similar to a square box yet contains multiple corners and angles for interesting illusion.

A car model and animation was created without carefully measuring distance and angles of the object. Thus when projecting the computer graphic image onto the car, the projection did not fit the model perfectly, as shown in fig. 4. This was due to the disproportions of the physical object and the created image.

Fig. 4. Misaligned projection mapping

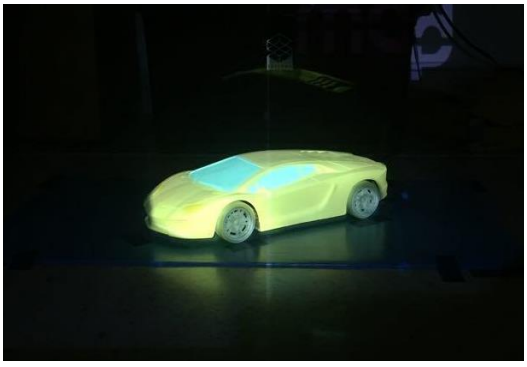


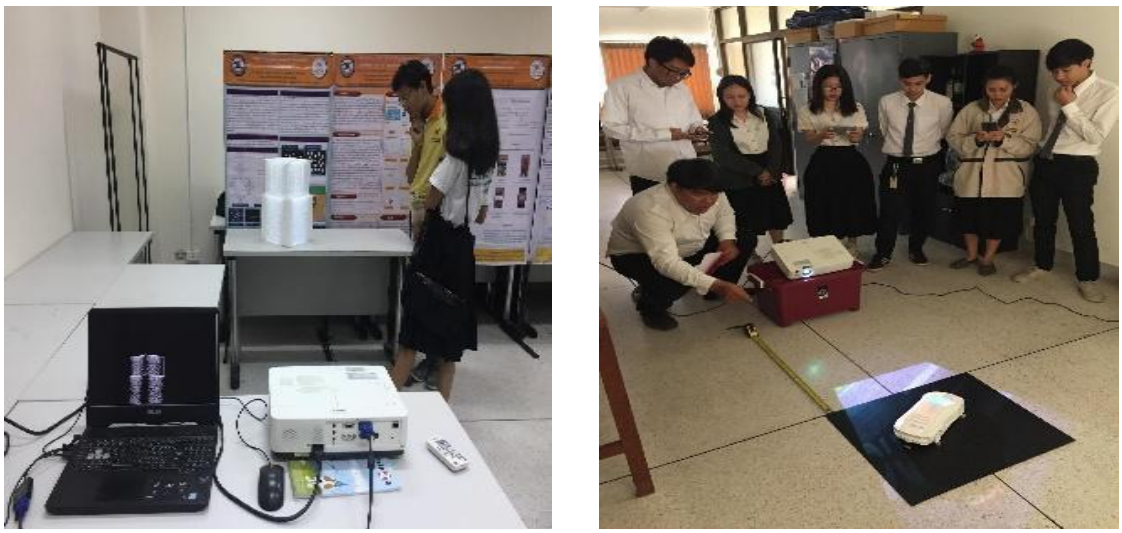
Fig. 5. Projection mapping precisely registered on the physical object.

After carefully following the proposed framework and the recommendation by precisely setting the audience's distance as well as point of view, and taking several reference pictures from the point of view, Adobe Photoshop was used to create the car's components and Adobe After Effects was used to create animation and render it into a video. MadMapper perfectly projects the images onto the car model as shown in fig. 5.

The main contribution of this work was to propose and verify the simple projection mapping framework. By following each step, a video could be mapped to a 3D physical object.

4. TESTING AND RESULTS

Video images displayed on physical objects using the proposed projection mapping framework were shown to the audience at the most recent Haunted House event. After they have been viewed, the audience's feedback was requested via a questionnaire on Google Form. Fig. 7 shows the fellow IT students viewing the projection mapping videos to give comments and suggestions before deploying at the actual event.



(a) (b)

Fig. 6. Suggestion gathering before deployment of (a) video projection mapping on boxes, and (b) on a car.

The obtained questionnaire results from the target audience shows a valuable insight on how to improve this low-cost projection mapping project. Seventy-nine school children and college students answered the survey. The summary of the questionnaire is shown in Table 1 with the overall satisfaction of 4.37.

Table 1. Summary of the questionnaire on projection mapping (5 being most significant).

Questions	$\bar{x}$
1. How much do you like the projected images on the 3D objects?	4.49
2. How interesting are the videos?	4.30
3. How appropriate are these videos?	4.38
4. How clear are the image and video quality?	4.34
5. Should the video be reused?	4.49
6. Were you entertained?	4.67
7. How appropriate were the audio tracks used for the videos?	3.95
Overall satisfaction	4.37

Furthermore, the comments and suggestions provided in writing and verbally were recorded and summarized in Table 2.

Table 2. Summary of comments and suggestions at the end of the test.

Positive	Negative
- Very cool.	- When viewed from different angles, the projected image does not match the car model.
- Good.	
- Enjoyed the animation.	- The background image was hard to see clearly.
- This should be used for something more useful.	

The two negative feedbacks can be addressed as follows. The projection mapping works under certain conditions, i.e. from the correct viewing angle. This problem was to be expected. The second comment could be fixed by using lighter shade of background.

As for the last positive feedback, projection mapping has been used in industry [9], [10]. The development of a mixed reality, both virtual and augmented, assistance system permits real-time support in manual operations and helps shorten the training time for assembly jobs.

5. CONCLUSION

This study presents easy to follow steps for creating projection mapping videos and an immersive experience for the viewers. A framework for the low-cost projection mapping was achieved in this work. Simple and complicated geometric objects were experimented with suitable videos.

The audience felt engaged and were satisfied with the outcomes of this project. Future of this could be to create an AR training assistance system using projection mapping technique.

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