From Learning to Practicing
– Our Education Methods of Teaching Projection Mapping

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There are increasing numbers of students who are anxious to learn how to make projection mapping. However, to teach students projection mapping, we have to teach them a lot of basic knowledge and techniques about design, computer graphics, image processing, animation, and video edition. We also have to provide software, projectors, computers, buildings, and environment, only with these can we support the students to learn through practicing that is considered necessary for the education.

With the strong support of our university, we have been able to carry out projection mapping projects in our research lab or on our campus since 2013. Because there are courses of computer graphics and image processing starting comparatively early for sophomores in our university, many senior students of have possessed of the basic knowledge necessary for doing projection mapping. Meanwhile, they are desire for such a chance to ensure their knowledge, to promote their abilities, to demonstrate the beauties of CG animations, and to share enjoyment with local people. Through the experiences of the two years, we have constructed out original and effective ways of teaching students projection mapping. In this paper, we would like to introduce our projects, present our education methods, and analysis the results, in order to provide useful information to educators and students who are interested in.

Keywords: Education, Learning and Practicing, Projection mapping, Computer graphics, Animation

1. Introduction

Projection mapping indicates the entitlement shows using projectors to display moving images on the surfaces of buildings. In a specified view direction, audiences watch moving images overlapping with a building, varying along the rhythm of a backgrounding music and demonstrating a beautiful fantastic world. Audiences can be a lot of people watching the show together and sharing the same feeling immediately. Just like watching fireworks, no matter young or old, people would be excited with projection mapping events, which combines virtual images with the realities of architectures.

Since 1960, Projection mapping has already appeared in Disneyland with using of movie equipment. After 2000, digital projectors of over 10000lm lightness get into the market, being able to show the difference between white 3D CG models and their gray shadows clearly. Such high lightness projectors are used in the beginning show of PEIJING Olympic in 2002, impressing
people by the fresh images projected on walls and making projection mappings popular.

In Europe, projection mapping is widely used in advertisements, stage effects, and entertainments of tourist. It gets popular in Japan because of the amazing visual performances in Tokyo station and Disneyland. Nowadays, in YouTube, we can find various videos of extraordinary projection mapping carried out all over the world. Not only buildings but also cars, sports shoes, models, and even jellyfish room in aquarium are used as objects of projection mapping. It is expected that projection mapping can make profits to develop sightseeing and to harmonize local communities.

In our university, there are increasing numbers of students who are anxious to learn how to make projection mapping, however, it is practically rather difficult to start a course to teach projection mapping. Firstly, we need teach students a lot of basic knowledge and techniques including design, computer graphics, image processing, animation, and video edition. We also need be able to provide the software, projectors, computers, buildings and even environment, in additionally, these projectors and computers are usually highest spec and very expensive. Only under such condition, we can support the students to learn through practicing that is considered necessary for learning projection mapping.

With the strong supporting of hardware and environment from our university, from 2013, we started to teach students projection mapping as a special course of graduate research. Fortunately, many senior students of the media information department here are possessed of the knowledge necessary for doing projection mapping, since computer graphics and image processing related courses are started comparatively early from second-year in our university. They are desire for such a chance to ensure their knowledge, to increase their abilities, and to demonstrate creation beauty of CG animation.

In 2013, Students used two small projectors of lightness 3000lm to project animations of computer graphics onto handmade architecture models in our laboratory. From 2014, we extended to project onto a small building with 11m width and 12m height. For covering the building, we used two projectors of 7000lm lightness. For preparing hardware, designing contents, creating contents, doing experiments of projection, we had spent six months, and finally created an original content of 18 minutes. In the annual festival of Kanazawa Institute of Technology “Koudaisai 2014” on 3th Nov. 2014, we carried out the projection mapping shows successful meanwhile shared the enjoyment with many people. Fig.1 gives some scenes of the event.

Through the experiences of these two years, we have concluded effective methods of teaching students to carry out projection mapping. In this paper, we would like to introduce our experiences, present our education methods, and analysis the results. We will focus on teaching students about the special features of projection mapping, the processes to carry out projection mapping, and explain some factors that would benefit the success of projection mapping events. This paper is desired to be a good reference for other teachers and students.
2. Special Features of Projection Mapping

Most projection mappings are based on a principle that the locations of projectors, viewers, and object are constant. Even interactive projection mappings that change mapping images according to a live performance still keep the principle. For example, projection mapping on piano visualizes the player’s pressing keys in real time, while the location of piano, the projector hanged overhead the piano, and viewers surrounding the piano all unchanged. Only in limited cases, such as Box, they projected images on moving object to show the highest level culmination of multiple technologies including robotics, image processing, and 3D computer graphics.

Projection mapping contents are created by using computer graphics, image processing, and image editing. For every building, we need to construct its 3D graphics model based on its blueprints. But drawing the outlines of the model from the blueprints is commonly not enough. For example, to make an animation of building wall cracking into small pieces and falling down, we need model the wall with many polygons each of which corresponding to a crack of the pieces. This means that CG and projection mapping have some differences in purposes and emphasis. At the beginning of learning projection mapping, students should be educated about the following special feature of projection mapping.

- The aim of projection mapping is to entertain the audiences by using images and music. When creating contents, creators should have a definite idea about how to balance among modelling, animation, texture, and music, i.e., how to make these four factors in harmony. You may use very simple CG techniques, rather than higher level ones, but probably make the four factors in good harmony while expressing the concept of the event clearly.

- Projection mapping relies on the formations and shapes of buildings in great deal. Usually it is necessary to construct a 3D CG model of building according to blueprints, pictures, outlines, windows, beams and pillars. Only when these formational features are reflected in the 3D model, you can get the feeling of identification of CG with the real building.

- Since the locations of building, projectors, and audiences are constant, it is difficult to show three-dimensional images to the audiences who watch the building in a single specified direction. If you rotated a three-dimensional image to let see inside or backside, the image may be seen not merging with the building due to the rotation. For keeping the CG merge with the building meanwhile showing its inside or backside, we need to research and develop ways of
visualizations and animations.

- Projection mapping requires not only building structure-related dynamic animations, such as concrete wall breaking, glass window cracking, or pillars falling down, but also the movements that can be described as fantastic, fairytale-like, magical, or romantic. Despite of various possibilities, animation must be rhythmed with the background music. Animations depend on your needs of representation, your rhythm of music, your audience interests, CG techniques you use, and finally your imagination.

3. A program to educate students to do projection mapping

We have summarized an original education program to teach students about the methods and processes to do projection mapping. We divide the program into following sections, and describe what should be taught with explanations.

3.1 Planning of events

Based on the aim and purpose of an event, the building and the best position for the audiences should be selected firstly. Then it should also be decided where to set projectors, which will cover a range of the building and face the building in determined directions. As a leader or producer of the event, you must be sure at the budget of the project, since there are various costs, such as equipment, software, electric power, and staff, all must be estimated.

It would be efficient to have the architecture blueprints when generating the 3D model of the building. Select music, make drawing plan, decide color collection, all of these detailed things should be based on the building’s architecture, background history and local culture.

3.2 Selecting of buildings

For projection mapping, three-dimensional factors, such as windows, doors, pillars, or beams, are desirable to add interesting variations, however, you should avoid a building in which there are too much depth difference between the building wall and these factors, unless you will come cross the problem of impossible to focus the projectors and gaining a blurred projection mapping. If the distance between projectors and building is about $15m$, the uneven due to these factors to the wall should be at least not over $2m$.

Also, it is expected that the projectors’ view directions are similar with that of the audiences. The closer the two types of directions, the more perfect the images overlap with the real building. When it is impossible to put projectors in a position near the audience, you have to first create 3D images according to the audience view direction, add affine transformation based on the difference in the two directions, and then project the transformed moving images to the building in the projector’s direction.\(^{26}\)

In front of the building, there should be an open space for the audiences. Since there will be a gathering of people in public, big volume of music and high degree of lightness, you also have to consider about the influence on the normal life of surrounding inhabitants. If the gathering of audience would have influences on public traffic, you must furthermore be sure about the event would be allowed by the local government law and ordinance.

As our experience, we looked around our campus and considered about the possibilities of every
building as a target. Finally, we selected a small building, called “Eagle Gallery” (Fig. 2) based on the capability of projectors we have. We have only two projectors of 7000lm (EPSON-EB-G6350), and the area that can be covered by the two projectors is just the largest possibilities of the two projectors. For many cases, when selecting a building, you have to consider how many projectors you can use, and how large of an area your projectors can cover.

![Fig.2 We selected this small gray concrete building, Eagle Gallery, depending on the capability of the projectors we have.](image)

3.3 Preparing equipment and software

Professional creators usually use over 10000lm high lightness projectors, one of which can cover an area about 10mx10m area. To cover a big building, it usually needs a number of projectors, which usually leads to such a high cost. However, through our experiments, we find that projectors of over 7000lm can also do well enough, when selecting buildings of white or gray colors. A projector would be the half in price of that a 10000lm one. It may be a reasonable alternative for universities to provide to students to practice projection mapping.

Also, you need to have computers with large memories and high speed graphics cards. You need audio equipment, connection devices, and electric power as well. For setting computers and projectors, you have to buy desks, racks, or stands for students, and make sure to educate them about the safety regulation of using these equipment.

We used a MacBook Pro Retina connected with two the projectors. Each frame of images is 2000x2000 pixels in resolution. We divided each frame of 2000x2000 pixels into up-and-down two pieces and sent them to the two projectors individually.

You need a lot education time to teach students how to use software necessary for creating contents. There are moving image editing software AfterEffect, projection mapping software MadMapper, which are most recommended. 3D CG software Blender has a lot of functions for modeling and rendering. Graphics programming environments, such as processing and Unity, are high level tools for generating three-dimensional CG animations. For generating original textures and patterns, picture re-touching software PhotoShop and painting software Illustrator are also necessary.

3.4 Creation of projection mapping contents

When designing the contents, you may need to think over the purpose of the event, the history of the building and the culture of local audiences. When decide the length of a mapping content, you might consider under what kind of condition the audiences watching the show. Usually, the audiences watch the show, standing in front of building, that is different from sitting in cinema and seeing a two hours movies. Therefore, we think that a high peace animation with rich variation
would be more favorable and pleasing. Alike with other outdoor event, such fireworks or sports events, projection mapping should be limited to 30 minutes.

If you just project one-style images, the audiences must be tired in some minutes, i.e., you need to change the CG and animation methods continuously. We developed an effective method for contents constructing design: to divide the whole content into several parts, for each part use different styles of CG modellings, renderings, and animations. Our method of designing contents is similar to that of figure skating programs. A skating show is usually 4 minutes long, divided into two parts: the first part uses slow music to demonstrate skills, and the second uses fast one to demonstrate dynamics. The advantage of dividing the whole content into a number of parts is on representing the topic in different rhythm, letting the audience enjoy the changes but not care about time.

Our content is 18 minutes long, including 1 minutes of starting, and 3 minutes of authors list at the end, the actual length of the content is about 14 minutes. We have divided the 14 minutes content into six parts (Fig.3): each part depends on the topic of the festival in our campus, but uses individual music and CG animation method.

- **Architecture of Pop**: we used lines and polygons in liner formation to represent the architecture of the building, and used mathematical functions to add animation to the lines and polygons, ensuring the animation rhythmic with the music of “Lollipop” sung by The Chordettes.
- **K.I.T.**: we used Blender to create animation of white cubes and three-dimensional words, added dynamics motions cubes to show the variation of building wall, and applied physical collisions to the words to represent the campus markers and the messages of the festival.
- **Flowers of campus**: we used algorithm and programming to create animation of kaleidoscope from picture and paintings. Here, we used the pictures of the flowers in the campus and the paintings of children reading books in various relaxed poses.
- **One day in our campus**: From a large numbers of pictures taken continuously by each minute at a selected location of the campus, we were able to create a stop motion animation of the campus from morning to night. The one day is decreased to three minutes, in which we can see students walking in the campus, cloud moving over the buildings, and sun light changing it shadows.
- **Books and strength**: we used processing and OpenGL to create virtual books of computer graphics and animation of opening the books. On the books, we mapped the pictures of the pages of the precious books maintained by our library. We also created “birds of books” flying around to represent the strength that human beings getting from these books.
- **Delightful campus life**: we used Unity to create 3D CG animations of Hatsune Miku dancing inside a virtual building, while the blocks of the building wall moving rhythmically around Miku. This parts is a cooperation associated with three professional creators, Mr. Ramazu P who made the music, Mr. Tda who created the 3D CG model of Miku, and Mr. hino who designed the poses and motion of Miku dance for the music of Mr. Ramazu P.
3.5 Rehearsing
Through rehearsing in front of the real buildings, you can check and adjust the following points so as to connect the projectors’ images perfectly to one scene:

- The locations and direction of each projector
- The lightness of each projector
- Square area that each projector covers
- The condition of environment in lighting down
- The necessary no entry area in front of projectors
- Electric power
- Sound equipment and sound effect

3.6 Doing the performance
To coordinate and manage an event of projection mapping, manpower will be necessary through the whole processes, especially on the performance days. On our event day, it was raining in the morning, but turned to cloudy in the afternoon. We did the performance three times from 6 to 8 o’clock, using a lot of waterproof sheets to pitch a tent over the projectors.

A lot of audiences of local people, students, and OB/OG enjoyed the performance. Many of them had the experience of seeing live projection mapping for the first time and got very excited by the large size images and the hyper-beautiful CG animations. We have gotten so much kindness messages and advices from the audiences that we soon decided to do projection mapping for the festival next year one again.
A web video service company iHokuriku recorded our performance and distributed the video on YouTube before the day is over. We also put an edited video on YouTube in a week.  

4. Discussions

During the two years of 2013 and 2014, 12 students, 2 graduated students and 10 seniors, have taken part in our projection mapping course. We took a questionnaire survey to them about how they think about the course at the end of 2014. For following questions, we got feedbacks from all of the 12 students.

Query 1: Are you interested in the course before you taking part in?
Query 2: When you are taking part in the course, do you feel enthusiasm for it, and will work hard for gaining the aims?
Query 3: Do you understand the differences between CG and projection mapping?
Query 4: Are you able to use the software MadMapper and AfterEffect which are necessary for projection mapping?
Query 5: Are you able to use programming (Processing or Unity) to make CG animations for projection mapping?
Query 6: Do you think you have understood all the processes of doing projection mapping?
Query 7: Do you think the given period of time is appropriate for learning and practicing projection mapping?
Query 8: Are you satisfied with this course?
Query 9: What is the most remarkable thing you found of the course?
Query 10: What is the un-satisfied thing you found of the course?

For Query 1 to 8, the answer is one from four possible selections of points: 0 (no), 1(a little), 2(much), and 3(very much). For Query 9 and Query 10, we let students to write down their feelings freely. As show in Fig.4, we got high evaluates of an average value of 2.7 for Query 1 to Query 8.

For the Query 5, there are six students selected 1 (a little). We have to admit that some students are rather skillful in programming while the others are not good at programming and would like to learning more about using software.

![Fig.4 Feedbacks from the students who joined the course](image-url)
For the Query 7, seven students selected 2 (good) and other five students selected 1 (a little). As the teachers, we also felt that we might need more time for educating students to create contents. Since the course started on April and the performance day is at the beginning of November, there are only seven months for learning and creating. Before the performance day, students had a very hard one week working at night for editing the content and had to give up some planned animations. If we could manage to have one more month and put the performance day on December, students would have enough time for doing all what they had planned to do.

For the Query 9, what is the most excellent thing during the event, all the students mentioned team building activities. During the whole period of the course, we have paid attention to teach the students about the importance of cooperation with others. As show in Fig.5, graduated students were patient and kind to the under-graduates, meanwhile, the under-graduates pay a lot respective to them. Graduated students and seniors are the core force of design and creation of the content, in spite of their busy, still spent time on teaching the lower-year students about computer graphics and using software.

![Fig.5 The activities of students when creating the content and practicing projection mapping](image)

On the performance day, there are also many volunteers who come to guide the audiences and set the no entry lines. We all know that projection mapping involves various activities that are fun, learning skills, challenging, meanwhile, a great teamwork is one of the key factors associated with success.

For the Query 10, what do you find un-satisfied, many four-year students showed their expectations regarding the availability for work, that they hope to be more capable of solving problems and making decisions, just like the graduated students could. We can understand the difference in students, as the teachers, we also know about each’s strengths and weaknesses. We hope to make more opportunities for them to improve their problem solving and decision making abilities.

After the event, we also took a questionnaire survey from the audiences of students and staffs in our university.

Query 1: Which parts of our projection mapping content do you like more? (The answer could be multiple numbers from 1 to 6).

Query 2: Do you think learning and practicing is necessary for teaching students projection
mapping? (The answer is one of 0 to 3, which 0 (no), 1(a little), 2(much), 3(very much)).

For query 1, the feedbacks we received are mainly kindness messages describing that the projection mapping was beautiful and impressive, and most selected part 1, part 3, and part 6. Some people added the comments that they think the computer graphics and animations did not go very well with the building, since the building original has two small windows, but in our projection mapping, the two windows are not considered.

For the Query 2, we received highly evaluated feedbacks. People agree that we should motivate students to learn more and to practice more. In our content, the final 3 seconds are the list of names of all the people who take part in the creation and help the performance. By showing their name, we want to motivate them and let them care more about the issue of copyright. Such motivation not only committed to success in the event, but also has effects on the other students who will join the activity next year.

5. Conclusion

Based on our two years of exploration and experiences, we have summarized original and effective methods for teaching students who would want to learn about projection mapping. In this paper, we have focused on the special features of projection mapping, the processes and methods of carrying out projection and the discussion about our experience.

Here in addition, we must mention another important factor that is the supporting we got from the people in the university. For example, we got the photo pictures of the precious books from the Library Center, and used these pictures in our contents. The staffs in the Audio/Video lab rent audio equipment to us and come to teach the students how to use the equipment. Without their support, we are impossible to do the final performance with high quality background sound. This factor may be few related with education, but is indispensable to the success.

Furthermore, we got the strong supporters from outside of the university. Mr. Ramazu P who provided his original music, Mr. Tda who is a famous 3D modeler and created the 3D formation data of “Hatsune Miku”, Mr. hino who designed the animation of dance for the 3D model of Hatsune miku, along the music written by Mr. Ramazu P. We used Unity programming to connect their works together, and added the animation of dancing block wall behind the dancing Miku. Through the cooperation with professional creators outside the campus, we want the students to have a broad outlook, to know their insufficient, so as to educate the students keep be modest and desire to improve themselves.

There have been new productions doing projection mapping appeared. However, researches on the education methods of projection mapping are just starting. There are only a few materials useful for teaching and most of them are videos. No matter the target is a small model or a large architecture, no matter an artist or some students is doing the projection mapping, what would always be asked is the same questions, i.e., how to make projection contents, what kind of CG animation will be appropriate for many buildings? Since such concerns will be related with not only computer graphics, but also arts, music, and architecture, we need continuous our research and practices so as to find the good solutions.
Appreciations
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