

Education Methods and Innovation for the Learning of Projection Mapping

Qinglian Guo, Hiroshi Nagase, Minoru Nakazawa

Department of Information and Computer Science

Kanazawa Institute of Technology

Ogigaoka 7-1, Nonoichi, Ishikawa-ken, Japan

kaku@infor.kanazawa-it.ac.jp

Abstract – There are a great numbers of students who are interested in projection mapping, while as few books or teaching materials on projection mapping. To start an education program of projection mapping, teachers are required to have not only knowledge about computer graphics but also developing skills on computer animation, graphic design and video edition. They must provide expensive projectors, and safe environment so at their students can learn through practicing that are considered necessary for the education.

With the strong support of our university, we have been able to carry out a projection mapping education program for three years since 2013. We have constructed out a serials of original education methods for students learning projection mapping with practicing and demonstrating. In this paper, we would like to introduce our experience, present education methods, and analysis the results, in order to provide useful information to educators and students who are interested in.

Index Terms – Education method, Learning and practicing, Projection mapping, Computer graphics, Animation, Design

I. INTRODUCTION

Projection mapping indicates the entitlement shows using projectors to display CG animations on the surface of a building. Audiences may view a fantastic virtual world formed by overlapping the CG animations with the building, while the animations varying in the rhythm of background music. Just like an event of fireworks, many people may watch a projection mapping show together and share the same feeling immediately. The show may be impressive to the audiences by combining virtual world the realities of the building.

Since 1960, projection mapping has appeared in Disneyland where movie equipment has been used. After 2000, digital projectors of high lightness get to be used, that is light enough to show the difference between white CG models and their gray shadows clearly. When such projectors were used in the beginning show of PEIJING Olympic in 2008 [2], projection mappings show got to be known.

In Europe, projection mapping is widely used in advertisements [3, 20, 17, 13], stages [1, 4, 25], and entertainments. It gets popular in Japan because of the amazing performances in Tokyo station [10] and Tokyo Disneyland [22] in 2012. In YouTube, now you we find various videos of extraordinary projection mapping shows done all over the world, not only projected onto buildings but also cars [7, 19, 25], sports shoes [15], fish pool in aquarium [12], and even human body [16, 6]. Projection mapping is expected to profit to sightseeing development and local community reconstruction [12, 22, 10, 3, 17].

In colleges, in spite of the increasing numbers of students anxious in learning projection mapping, however it is rather difficult to start a course or program to teach projection mapping. There are many challenges for both teachers and learners. Firstly, we need teach students a lot of basic knowledge and techniques including graphic design, computer graphics, image processing, animation, and video edition. We also need to provide projectors, computers, software, which are comparatively high spec and expensive. Furthermore, we need a just-sized building for your students to practice projection mapping and safe enough environment around the building for the students and audiences. Only with such essential conditions, we can start a program to teach projection mapping, and support the students to learn through practicing.

With the strong support of hardware and environment from our university, we started a special course for learning projection mapping for senior students since 2013. Fortunately, many of the senior students joined this course are possessed of the knowledge of computer graphics and animation because that in our university the courses related with computer graphics and image processing starts comparatively early from second-year. Meanwhile, they are positively desire for such a chance to ensure their knowledge, to increase their abilities, and to demonstrate the result of their efforts to the local people. These positive factors make it easy for us to concentrate on teaching and groping for effective education methods.

In 2013, we used small projectors of lightness $3000lm$ to project onto handmade architecture models, paying more attention on teaching students to create animation contents. Since 2014, we have extended to project onto a small building with $11m$ width and $12m$ height inside campus. For covering the building, we used two projectors of $7000lm$ lightness. For teaching students to use the devices, design content, and create content, we had spent six months with an average 8 hours worktime by every week. About 2 to 3 of the worktime is for creating the original content of 18 minutes long. In the annual festivals of *Kanazawa Institute of Technology of Koudaisai 2014* and *Koudaisai2015*, our students demonstrated their learning results successfully and shared enjoyment with many people taking part in the events (Fig. 1).

Through the experiences of three years, we have concluded effective methods of teaching students projection mapping. We have focused on teaching what are especial of projection mapping, what processes are included in projection mapping events, what factors profit the success of projection mapping, and mainly how to create contents. In this paper, we would like to introduce our experiences, present our education

methods, and analysis the education results. At first, we would like to emphasize the differences between the actions of professors' projection mapping and educational one, that we realized necessary to be discussed and summarized for constructing good education concepts on projection mapping.



Fig.1 Pictures show the projection mapping events *Koudaisai 2014* [11] and *Koudaisai 2015* [12], in the annual festival of Kanazawa Institute of Technology.

II. THE DIFFERENCE BETWEEN PROFESSORAL WORK AND EDUCATION ACTION OF PROJECTION MAPPING

Education actions differ from professoral work in many aspects, especially in purposes, scale, and human abilities.

A. Purposes

Professionors work for creating contents representing decided topics and carry out performances royally according to the custome's requirements. Their works must be comparatively high level to entertain audiences and to gain expected results of advertisement.

Education actions should put weight on learning, practicing and researching. We should encourage students to design contents based on their original ideas, since there is no necessary to limit them to any custom. Arrounding a topic, each student may propose an original idea depending on one's own developing ability, then he/she will be more positively involved in learning and creating. We should also make the opportunities for them to practice and to redesign their contents. We need to instruct students that their contents must be positive, follow the ideas commonly accepted in the world, and keep to the law.

In addition, we perceive researching, related with computer graphics, animation or projection mapping to be the most important of educational actions. For instant, we have been developing algorithms of digital kaleidoscopes that may

animate along the rhythm of background music (Fig.2-(a)). We also proposed a method of modelling and animation to be applied to any form of building (Fig.2-(b)). As shown in Fig.2-(c), we did experiments for finding values of rendering parameters that make 3D CG most easily to be seen, when these CG are projected onto window glasses. Such researches are necessary since most of those joining the program are four-year students, who do researches as the core and projection mapping as the applications. Meanwhile, researches have been proved effective to level up the education program and for students to gain basic abilities that may be used even in future.

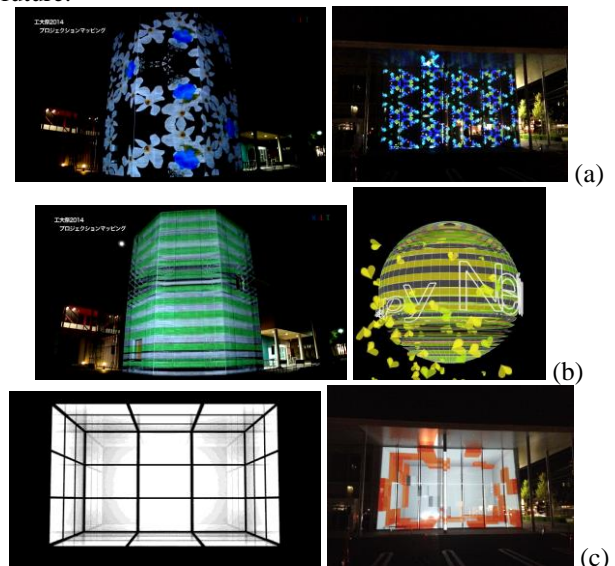


Fig.2 Researches we carried out during the education program of projection mapping, (a) on digital kaleidoscope, (b) on modelling and animation method, and (c) on rendering parameters and effects.

B. Scale

The scale of a projection mapping event depends on human power, time, and hardware. Students are all new in experience, limited in learning time, and in most cases provided with a few equipments. In contrast, professionors have remarkable abilities and rich experiences in developing contents. They also have financial background to prepare expensive equipments they need, only non much working time.

Professions often use over 10000lm high lightness projectors, each covering about 10mx10m area. To cover a big building, a number of such high lightness projectors are necessary. It is difficult for a university to provide many students the same environment. Through experiments, we find that projectors of over 7000lm can also do well enough, only when selecting buildings of white or gray colors. By this way, decreasing the cost for preparing projectors, we are still possible to provide students satisfied learning environment. Excepting projectors, we need computers with large memories and high speed graphics cards, audio equipment, connection devices, and electric power as well. For setting computers and projectors, we need desks, racks, or stands.

Professions usually have to finish a work within a short period, maybe two or three weeks, sometimes they may have to overwork for days. Educational actions should be given enough time for students feeling relaxed in learning and practicing, at least need half a year, or sufficiently ten months before doing performances.

We show them a syllabus at the beginning of a course. The syllabus must involve following 6 periods: learning related knowledges and skills, measuring and modelling the selected building, designing and creating contents, doing experiments of projection mapping in practice, adjusting and editing the contents, and final performance. For each period, we must make sure to educate students about the safety regulation of using equipment and doing outdoor experiments.

C. Human abilities

Professions are trained people who already have the abilities of developing CG animation, or usually a group of experts of different majors, such as design, music, computer graphics, painter, modeller, and video editors. They work together and turn out excellent results by individual giving full play to his/her ability bringing.

In comparison, students starting to learn projection mapping are rather weak-ability and have little head on design. They may learn and accumulate abilities, but need time and durability. Fortunately, students may have rich imaginations rising from free hearts and youth. When they are relaxed and encouraged, they may be most creative.

Still need students the teachers' clear instruction about what have to learn. There are editing software *AfterEffect* and 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.

III. THE DIFFERENCE BETWEEN CG AND 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 [8] 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 [21], 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 rhythmmed 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.

IV. OUR EDUCATION PROGRAM

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.

A. Planning of Event

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.

B. Selection of Building

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. 3) 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.3 In our projection mapping, we selected this small gray concrete building as a target, depending on the capability of the projectors we have.

C. Creating Projection 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.4): 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 part 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*.



We are ABBA



K. I. T.



Flowers of campus



One day in our campus



Books and strength



Delightful campus life

Fig.4 Our 14 minutes content has six parts: each uses different style of CG modelling and animation, but related with the same topic of campus life.

D. 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

E. 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 [11].

V. DISCUSSION ABOUT THE PROGRAM

From 2014 to 2016, 20 students, two of them are graduated and the others are 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 every year. For following questions, we got feedbacks from all of the 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.5, we got high evaluates of an average value of 2.2 for Query 1 to Query 8.

For the Query 5, there are students selected 1 or 2. We have to admit that some students are rather skillful in programming while the others are not and will like to learning more about using software.

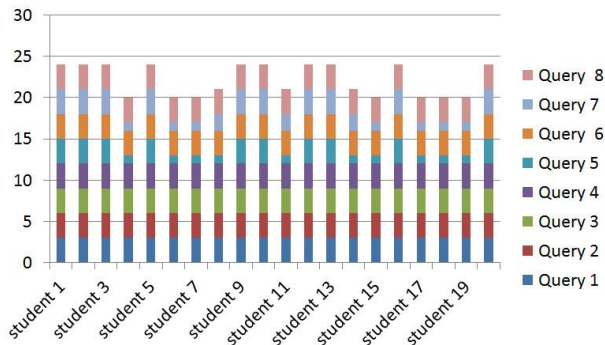


Fig.5 Feedbacks from the students who joined the course

For the Query 7, some students selected 2 (good) and other 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 planed 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.6, graduated students were patient and kind to the under-graduates, meanwhile, the under-graduates pay a lot respect to them. Graduated students and seniors are the core force of design and creation of the content, in spite of their busying, still spent time on teaching the lower-year students about computer graphics and using software.

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 ability for work, that they hope to be more capable of solving problems and making decisions, just like the graduated students do. We perceive 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, mapping, the two windows are not considered.

For the Query 2, our 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 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.



Fig.6 The activities of students when creating the content and practicing projection mapping

VI. CONCLUSIONS

Based on our explorations and experiences, we have summarized an original and effective program for teaching students projection mapping. In this paper, we have focused on the special features of projection mapping, the processes of carrying out projection and the discussion about our education program. In additional, we must mention another important factor that is the strong support we got from the university and

the people. For example, we got many photo pictures of precious books from the Library Center, and used these pictures in our contents. The staffs in the Audio/Video lab rent us audio equipment and come to teach the students how to use them. Many students did volunteer for guiding audiences in the event night. Without their support, we are impossible to do the final performance safely and perfectly. The understanding and supporting factor may be non-straight 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 [9, 14]. 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 [23, 5]. 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.

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