



How to Collective Design-and-Fabricating a Weaving Structure Interaction Design-Six Experiments using a Design-Fabrication-Assembly (DFA) Approach

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Abstract

This paper, through six experiments, practiced the design and manufacture assembly process. Our experimental theme starting with Responsive Carrier Component Envelope (RCCE) fabrication (Teng-wen Chang, 2019), and then weaving structure-based (Dong Yan, 2016; Huang, Wu, & Huang, 2017) interaction design experiments. Since the interactive device features are customized for small batch production, there is no person who specializes in prototyping. Decentralized fabrication is targeted at a small number of customizations that meet the needs of users involved in the design and the manufacturing process. Digital fabrication technology and network technology allow component-based installation to be fabricated in different locations at the same time and combined in different locations as planned. Users can work with different teams or in different regions to meet the needs of local users. Therefore, our research team will work with other teams to conduct experiments through the method of decentralized fabrication. However, the component-based installation requires a large number of people to help with the assembly phase. Therefore, it is necessary for the team members to understand the method and process of assembly. It is a problem to a novice design fabrication team to let the team members participate and understand the project. Finally, we proposed a two-dimensional design model of communication media for the component-based installation to help the design team to fabricate and assemble the prototype. The iterative design of the communication media tools in this study is still in progress.

Keywords: *Collective design, weaving structure interaction design, design, fabrication, assembly*

1. Introduction

A component-based installation is composed of components, its characteristics are that each component can be fabricated and assembled from different regions, and the fabrication of components is a repetitive manner. The development of today's digital technology provides designers with parameters and generation design capabilities. Due to the new trend in the design and construction of the building, it is necessary to propose a form that can be adapted (Huang, Yan, Luo, & Li, 2016). They proposed a new design and construction of the braided structural system, and its design and construction is completely based on the digital platform. This paper, through the different experiments, mainly practiced the design and fabrication assembly process.

Since the interactive device features are customized for small batch production, there is no person who specializes in prototyping. Decentralized fabrication is targeted at a small number of customizations that meet the needs of users involved in the design and manufacturing process. Digital fabrication technology and network technology allow component-based installation to be fabricated in different locations at the same time and combined in different locations as planned. Users can work with different teams or in different regions to meet the needs of local users. Therefore, our research team will work with other teams to conduct experiments through the method of decentralized fabrication.

Novice members in a multidisciplinary team issue in a component-based interaction design process. Due to novices not being trained, they often encounter the following problems: (1) it is necessary to understand the expertise in each field to complete the prototype implementation. This is a threshold for prototyping; (2) they usually used to use the breadth search method to find a solution, as they find solutions to problems by try error, but the time of prototyping can't be discussed and designed for a long time; and (3) when communicating with team members, the idea cannot be clearly described.



However, the component-based installation requires a large number of people to help with the assembly phase. Therefore, it is necessary for the team members to understand the method and process of assembly. It is a problem to a novice design fabrication team to let the team members participate and understand the project.

Any design into the fabrication process, since all participants used to use the diagram to communicate with each other, diagrams are the major medium for the communication cross DFA. Such as architectural diagram, engineering diagram, mechanical Exploded diagrams etc. The symbol and component description has certain logic and rules and can be understood, so for the novice design team, using diagram is an appropriate way to integrate fabrication process. Although, we intend to build a general model, there is still limitation and scope that arises during the experiments. The two-dimensional design model of communication media proposed by this study can be used in component-based interactive installation design based on given representation between design and fabrication. In our project, such representation exists in Rhino/Grasshopper implementation that is connected to the physical environment.

2. Objectives

This study will propose a two-dimensional design model of communication media to help the novice design team at the fabrication and assembly stages of prototyping.

3. Materials and Methods

3.1 Step

First, standardized design-fabrication-assembly cyclic process was utilized for finding the requirement for media. Furthermore, through the experiment to find the needs of the communication media, the design method and process of generating images are proposed to help the process of the manufacturing phase to the assembly phase of the media design cycle. Finally, analyze and discuss the advantages and weaknesses of the two-dimensional communication media characteristics proposed in this study.

3.2 Scope and limitation

There are many types of interactive design devices, and we must limit the features of the device and the team's team to narrow the scope. The main content of this research is to help the design team.

3.2.1 Interactive device features:

- i. The device must consist of components.
- ii. The device is a combination of hardware and software design.
- iii. The device must contain an interactive design.

3.2.2 Staff

- i. The field must include design and engineering staff
- ii. The number of people needs to be 3~5 people

3.3 Method and Research Steps: Six Experiments

The research methods and steps: (1) 6 experiments are conducted for testing the collective design process proposed; (2) testing the collective design process for component-based interaction design; (3) integrating fabrication with assembly process to be a valid design process; (4) exploring needs for a communication media for assembly and rapid prototyping-design cycle. Customizing different targets and set up experiments in six experiments, each with different exercises.

3.3.1 Exploration Stage: finding the characteristics of DFA

i. Experiment one:

In this experiment, we expect the characteristics of collective design process and how to implement a component-based installation in such collective matter. So we participate in the 2016 Makerfaire exhibition in Shenzhen, China, the team is comprised of three teams from an architecture team from Perth in order to confirm the prototype implementation process, the research team was mainly



responsible for the manufacturing and assembly process, which was designed by the Australian construction team. In the process, we select the three-dimensional files of the design team for the appropriate materials of the components, such as the original with multiple angles, we use three-dimensional printer to produce. At the manufacturing stage, we use three-dimensional printers and laser cutting machines for component production and testing. During the assembly phase, we tested the robustness of each component after assembly and set up the assembly steps. We spent 20 days testing and manufacturing components and assembling components in 12 days. Finally, we learned that the decentralized manufacturing process is mainly divided into: (1) design phase: design device prototype (2) manufacturing phase: test device components and production (3) assembly phase: component assembly and testing. The manufacturing phase will return to modify the design due to the test, as shown in the process of No. 3 in Figure 1, the assembly phase will also return to modify the design due to the test, as shown in Figure 1 No. 2. The retrospective method is modified to be designed as a decentralized manufacturing feature, so the prototype production process needs to be continuously communicated to reach a consensus. After experiment 1, we defined three stages in the decentralized manufacturing process. We expect that the communication method of number 1 and b in Figure 1 of the Design-Fabrication-Assembly (DFA) approach can be helped by communication tools, so that the whole can achieve a loop. We want to know more about the communication between the stages to see if there are tools to help, so our next experiment goal is to test the communication tools.

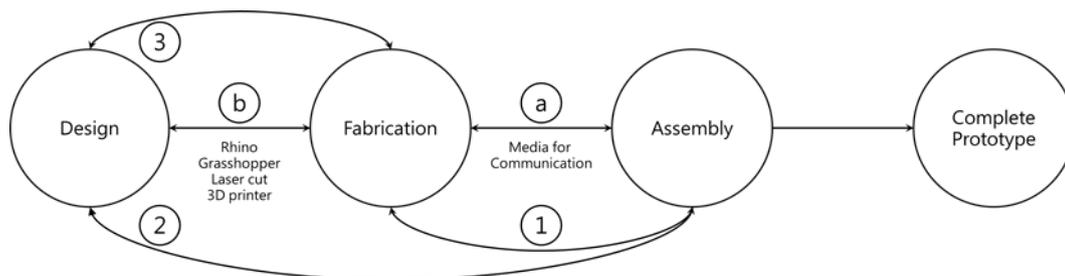


Figure 1 The forces acting on the particle in the rotating fluidized bed reactor

ii. Experiment two:

In this experiment, we hope to test the communication tools for communication at each stage of DFA. So we conducted a workshop experiment at the CAADRIA 2017 conference at Xi'an Jiaotong-Liverpool University, Suzhou, Jiangsu, China. Two teams from Idea Factory, YunTech, Taiwan and School of Architecture, Tsinghua University, China participate in this experiment. Five participants participated in the workshop. Test cases are two folds: one is to integrate the design phrase into collective design process, and another is to investigate how non-skillful collaborators participate in such dynamic but chaotic design process. In the process, we spent 20 days testing and manufacturing components, assembly components in 5 days. We assign work to the participants and lead them to manufacture and assemble. After this experiment, we learned that the assembly method and sequence cannot be clearly explained if only the verbal instructions are used during the assembly process. Here we confirm the need to communicate media to facilitate communication between the manufacturing and assembly phases, namely the communication tool numbered a in Figure 1. We test the communication tools of DFA communication at various stages. Figure 1 number b communication tool belongs to the field of design computing. Its tools are converted from virtual models to entities to verify, but there is still a lack of simulation tools in the process of design to manufacturing. If there is a simulation tool, it will be more complete. This study found that there is currently no communication tool with the number a in Figure 1, so the communication tool from the manufacturing to the assembly stage is a problem. In the next experiment, we considered that the interactive device consisting of components required a large number of components to be assembled during the assembly phase, so many people involved. However, these participants did not participate in the whole process, and they were not clear about the way the components were made and the way they were



assembled. So we will try to integrate the various professional teams, each team is involved in the prototype production, are familiar people.

3.3.2 Implementation Stage: four experiments

i. Experiment three:

Integrating professionals from all teams is the goal of this experiment. We conducted experiments at YunTech, Yunlin, Taiwan, two teams from Idea Factory, YunTech, Taiwan and School of Architecture, Tsinghua University, China participate in this experiment. In the process, we graphically represent the light bar grouping and all wire wiring sequences according to the requirements. However, the following problems occurred: (1) we failed to check the direction of the light bar, so we could not achieve interactive design and lighting effects; (2) a large number of components need to be assembled during the assembly phase, so it is necessary to help, and although there are light bar grouping methods and all wire wiring sequences and directions, the way the components are fabricated is not clear for helpers who are not involved in the whole process; and (3) the team consists of Taiwan YunTech idea factory and China Tsinghua School of Architecture. We have not unified the component manufacturing and component assembly steps, so we cannot distribute the work to the helpers smoothly. We spent 27 days testing and manufacturing components and assembling components in 5 days. We learned in this experiment: (1) the direction information of the wire can help the component production and wiring sequence are correct; and (2) the series connection can help the same group of light strips to have different effects, but the program needs to be customized according to the fragment of the lighting design. And put forward the following requirements: (1) need to set the time to check the component direction; (2) description of component manufacturing methods; and (3) Unit manufacturing and component assembly steps are uniform. In order to solve the communication problem between design and manufacturing, we plan to practice simulation tools.

ii. Experiment four:

This experiment goal is to implement simulation tools and communication tools in the fabrication-assembly phase. We conducted workshop experiments at Rangsit University, Thailand (Huang, Williams, Luo, Wu, & Lin, 2018). Two teams from Idea Factory, YunTech, Taiwan and School of Architecture, Tsinghua University, China participated in this experiment. There are 20 students involved, but their participation time is very short. We tried to reduce the number of teams to three and see if we can still experiment. We join simulation tools to solve communication problems between design and manufacturing. In order to solve the manufacturing-assembly communication problem, we tried to design the component assembly diagram. We spent 25 days testing and manufacturing components and assembling components in 3 days. We found that the simulation tool can let the engineers understand the lighting design and can clearly complete the lighting effect, as shown in Figure 2. The component content map and component assembly diagram design of this experiment can already help the component manufacturing and assembly stage, and its expression can be understood by the participants, but because the symbol of the male position is not similar to the real shape and is not unified, there will be the situation of misjudgment occurred. In addition, because the site information is not clear, the power supply line design is not perfect. Finally, we propose the following requirements: (1) the male symbol in the component manufacturing diagram is designed to be similar to the real shape; (2) the design of the male symbol in the component assembly diagram must be uniform; and (3) when the site information is not clear, we can increase the flexibility of the device layout design. Since the communication between the design and manufacturing phases can be effectively solved by the simulation tools, we plan to delve into the communication tool requirements of the manufacturing-assembly phase.

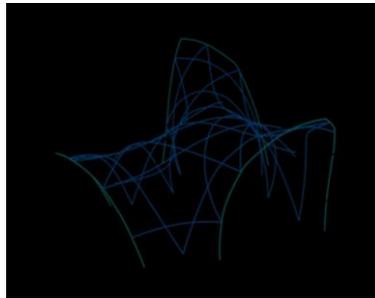


Figure 2 The lighting simulation

iii. Experiment five:

In this experiment, we explored the requirement for communication tools in the fabrication-assembly phase. We conducted a workshop experiment at the CAADRIA 2018 conference at Tsinghua University, Beijing, China. Two teams from Idea Factory, YunTech, Taiwan and School of Architecture, Tsinghua University, China participated in this experiment. Ten students were involved in the experiment. We tried to do it if we have a small number of raw lots, and tried to change the structural design of the braided structure. This component manufacturing and component assembly diagram is fully understandable and can successfully shorten the prototyping process under structural design changes. The simulation tools in this study have been able to reach communication, so if we want to generate new simulation methods, we can repeat it again. The interactive device consisting of components is characterized in that components can be disassembled, so we can ask the cooperation team to assist in the welding of the light bar in China to achieve: (1) saving transportation costs, and (2) shortening manufacturing time. We spent 20 days testing and manufacturing components and assembling components in 3 days. We learned: (1) the design of the symbolic symbol of the component is similar to the real shape and can be integrated to help the component manufacturing and assembly stages; and (2) The different chips of the light bar cause the light bar program field to be different. Finally, in design-manufacturing and manufacturing-assembly, we have effective communication tools to aid prototyping. In the process of debugging, we do not have a clearer process, so the debugging process for each experiment takes a lot of time. So in the next experiment we plan to make the debugging process clearer and allow prototyping to be completed in time.

iv. Experiment six:

Customizing clear debugging process is the goal of this experiment. We conducted experiments at LuXun Academy of Fine Arts, Shenyang, China. Two teams from Idea Factory, YunTech, Taiwan and School of Architecture, Tsinghua University, China participated in this experiment. In this experiment, there was no raw hand to help, and it was confirmed by skilled hands in the debugging process. We spent 14 days testing and manufacturing components and assembling components in 3 days. It is divided by the skilled hands of the team. We learned that a clear debugging process can help prototypes complete in time. In addition, since the site information is not clear, the position and surface of the device cannot be confirmed. Therefore, we can design the position of the power supply line point that can be changed, so that each button station position can be the assembly point of the device, meaning that all power lines will pass through. The frame components are concentrated at this point, and each face can be the closest to the main power supply, so that the design of the device can be unrestricted (increasing device-oriented design flexibility). Finally, because we use decentralized manufacturing methods and teams are working in different regions at the same time, there is an extreme demand for project monitoring. We need online and specific project control methods. Therefore, in the next experiment, we expect to add software control for the prototyping process.

3.3.3 Comparison of experiments

The following is the comparison of each experiment, including (1) team staff number (2) novice number (3) assembly time. In the team staff number comparison, we originally needed 5 people to complete the project. Finally, we could complete the prototype only by 3 people. In the novice number comparison,



we hope the number of novice less than 5 in the previous experiment and we would have the ability to increase it in the further experiment. In the comparison of assembly time, we also successfully accelerated the assembly time. Please see Table 1, Table 2, and Table 3.

Table 1 Introduction to Experiment 1 and Experiment 2

Title		Dynamic Cloud	Potato Chips
Experiment number		1	2
Photo			
Team staff number	5		5
Novice number	0		5
Assembly time	10 days		5 days
Finish date	2016/10/23		2017/04/04
Location	Shenzhen, China		Xi'an Jiaotong-Liverpool University, Suzhou, Jiangsu, China
Objective	Finding the characteristics of DFA.		Testing the communication tools for communication at each stage of DFA.

Table 2 Introduction to Experiment 3 and Experiment 4

Title		Tutu	Stargate
Experiment number		3	4
Photo			
Personnel number	5		3
Novice number	10		20
Assembly time	5 days		3 days
Finish date	2017/09/01		2017/10/03
Location	YunTech, Yunlin, Taiwan		Rangsit University, Thailand
Objective	Integrating professionals from all teams.		Implementing simulation tools and communication tools in the fabrication-assembly phase.



Table 3 Introduction to Experiment 5 and Experiment 6

Title	Stargate 2.0	Stargate 3.0
Experiment number	5	6
Photo		
Personnel number	3	3
Novice number	10	0
Assembly time	3 days	3 days
Finish date	2018/05/15	2018/10/01
Location	Tsinghua University, Beijing, China	LuXun Academy of Fine Arts, Shenyang, China
Objective	Exploring the requirement for communication tools in the fabrication-assembly phase.	Customizing clear debugging process.

3.3.4 Iterative process for media refinement and requirement analysis

i. Communication media iterative design

This study analyzes the needs through various experiments and develops communication media at various stages. Table 4 shows the iterative design of the component manufacturing diagram. The manufacturing requirements of this component are: (1) description of component manufacturing methods; (2) the male symbol needs to improve the correlation; and (3) it is necessary to check the component orientation at the time. In this study, the component manufacturing method is described in the component manufacturing diagram. The first version is numbered 1 in Table 4, and the sign of the male position is not similar to the real shape, so there is a misjudgment. The second version is number 2 in Table 4, and the production logic is the same as the first version, and the following changes are made: (1) the male and female heads use symbolic symbols similar to the real shape; and (2) join the check box as a component check the record.



Table 4 Iterative design of component fabrication diagram

Number	Component fabrication diagram	Image communication results
1	<p>C-019</p>	<p>The symbol be used to indicate the male of the wire is not similar to the actual shape. It cause identification error.</p>
2		<p>This diagram can be understood by the participants. The check box provides a check record for the components that had been inspected.</p>

ii. Table 5 is the iterative design of the component assembly diagram. The assembly requirements of this component are: (1) light bar grouping method (2) all wire wiring sequence and direction (3) component manufacturing and component assembly steps are unified (4) device direction (5) Sensor position (6) Position and contents of the take-up box (7) Avoid misjudgment of the male position (8) Increase the flexibility of the device placement design. In this study, the component assembly method is described in the component assembly diagram. The first version is numbered 1 in Table 5, and the light bar grouping manner is unclear, which makes the assembly and debugging process difficult. The second version is numbered 2 in Table 5. The design of the male symbol in the component assembly drawing must be uniform. This version of the light bar and the power cord male are represented by different symbols to cause misunderstanding. The third version is numbered 3 in Table 5. This version successfully smoothed the assembly process and the debugging process without causing errors.



Table 5 Iterative design of component assembly diagram

Number	Component assembly diagram	Image communication results
1		<p>Unclear distinguishing LED strips group make it difficult for the component assembly and installation debugging process.</p>
2	<p style="text-align: center;">Big door</p> <p style="text-align: center;">Small door</p>	<p>The design of the male symbol in the component assembly diagram must be uniform. In this version, the male of LED strip and the male of power line are represented by different symbols. It would cause misunderstanding.</p>

4. Results and Discussion

4.1 How the collective design process helps the component-based rapid prototyping design process

Decentralized manufacturing is targeted at a small number of customizations that meet the needs of users involved in the design and manufacturing process. Digital manufacturing technology and network technology allow device components to be fabricated in different locations at the same time and combined in different locations as planned. Users can work with different teams or in different regions to meet the needs of local users. An interactive device consisting of components is characterized in that components can be disassembled and need to be completed in a short period of time, while decentralized manufacturing can help this type of interactive device, because the cooperative team can simultaneously manufacture in different locations, achieving: (1) Saving transportation costs; and (2) Shorten manufacturing time.

4.2 Which characteristics of media proposed is required for the smooth of assembly

In the component fabrication section, using the checkbox can help the checking record. The component content map provides the material to be prepared, and the symbol design used to resolve the direction of the component needs to be similar to the real shape. In the component assembly part, the component position indication and directivity are extremely important. The wiring sequence can help the process. The color can be used as the basis for component grouping. The expansion map and point information can help the device direction identification. The relative component length and bending angle can help the identification of components. If you can design the power lines gathering points for the



installation, you can increase the flexibility of the installation placement design. The following is the two-dimensional design model of communication media proposed by this study. The design guideline for diagram includes component fabrication and component assembly. As shown in Figure 3 and Figure 4. The novice design team can refer to the steps in the design guideline to create a diagram. We did not reject three-dimensional design model, because three-dimensional technology takes time.

The three-dimensional model is difficult to give immediate assembly instructions for the user. It is hard to use the three-dimensional model for assembly on site. For example, participants need to assemble the components using both hands, and there is no extra hand to use the three-dimensional model when assembling the components. We currently find some limitations in the two-dimensional design model and we will try to propose a three-dimensional design model in the future. The target users of the three-dimensional design model of the communication media are participants in the entire project process.

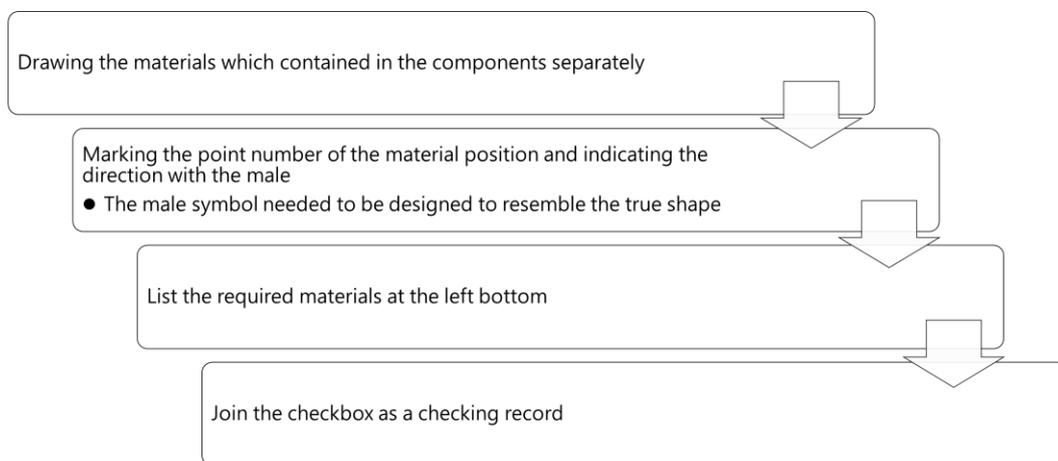


Figure 3 The design guideline for component fabrication diagram

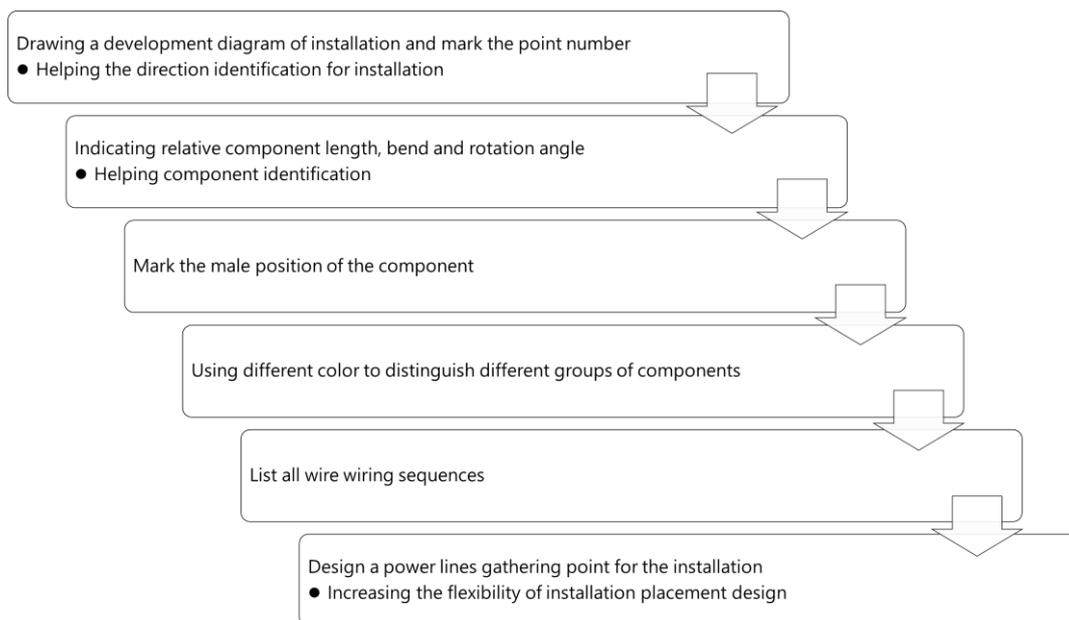


Figure 4 The design guideline for component assembly diagram



5. Conclusion

This study was first standardized design-fabrication-assembly cyclic process through the first experiment. Through the six experiments, the following objectives are carried out in sequence: (1) finding the characteristics of DFA; (2) testing communication tools for DFA communication at various stages; (3) integrating people in various team professional fields; (4) practice simulation tools and manufacturing-assembly the communication tools of the stage; (5) discuss the communication tool requirements in the manufacturing-assembly phase; and (6) the custom-defined debugging process. In the process of analysis and discussion, the characteristics of communication media are communicated, and the design method and process of generating images are proposed and confirmed and realized. Finally, we proposed a two-dimensional design model of communication media for the component-based installation to help the design team to fabricate and assemble the prototype. The iterative design of the communication media tools in this study is still in progress.

6. Acknowledgements

The series of experiments in this study was done by many people, thanks for their help.

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