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Kinetic Mirror Façade

conveying messages with daylight

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Abstract—In human history sunlight is seen as sanctity. In architecture daylight is always an important topic. There are many well-known examples using sunlight cleverly, not only for practical reasons but also for spiritual meanings. Daylight is everywhere. Through the artificial manipulation it could be emphasized to evoke the human senses.

This paper demonstrates the work on a kinetic mirror façade, which is able to reflect the daylight via mirrors in order to convey messages. Based on the approach the project also addresses the potential use of daylight in an interactive process outdoors. In others words, the project aims to explore the potential of architectural façades in conveying messages and the relationship of human and architecture from the perspective of human sense.

In order to adapt the changing solar conditions and reflect different information, the façade is divided into small panels. All the panels can rotate in three dimensions individually. The computational approach demonstrated in this paper uses simple geometric and formulas calculation of vectors and angles. In order to control the panels separately, the amount of servo motors will be set up in the installation.

The reflected image, which is composed by a great amount of beam spots will not have a high resolution like digital screen. It breaks the conventional reading custom. Since information is not be shown clearly, the human mind needs to reconstruct the images. This way human could get a different and abstract experience.

Kinetic façade; convey messeages; reflection; daylight; (key words)

I. Concept

A. Context

Media Façade, an application of electronic technology in Architecture is often associated with great display. The over-dimensional LED screen could reach a high resolution. and it is often used for animated advertisements. Using artificial light to convey information is a common and gaudy method. The bright façade in the dark is a sign of the metropolis. But what happens in the day? How to make use of sunlight, the clean and sustainable energy, in information transfer and furthermore the interaction between the architecture and human is the task which the project aims to explore.

In the childhood, it's common to play with mirrors. Children manipulate the mirror by rotating a specific angle to hit the right spot on their friends to attract them. The Gestalt Theory proves that the visibility of figure depends on the contrast with the background. Therefore even if the spot is small and feeble, it could be recognized [1]. In the simple play children can learn physics of light. One mirror has one reflect spot. What will the amount of mirrors bring out when they all rotate differently?

B. Design Thinking

The American architect Greg Lynn once introduced the concept "animation" in his book »Animate Form«. He thinks that an animate approach to architecture will subsume traditional models of statics into a more advanced system of dynamic organization [2]. On the premise of the safety of the building with static structure, it is possible to think about a kinetic structure on the façade.

Placing kinetic structures on each panel of façade can enhance the ability of transferring complex images. There are two parts of the mirror façade: mirrors part and mechanic part. To convey different messages, every single mirror which is controlled by two servo motors can rotate through the horizontal axis and vertical axis separately. Within the parametric computational environment by knowing the location and time the exact sun path can be calculated. As soon as the solar angle is calculated, the computer can calculates the rotation angle of each mirror according to the algorithmic principle and send it to the servo motors digitally.

II. PREVIOUS STUDY

One example, which inspired the work is stained glass which is usually seen in the old catholic church. The glass has its practical function that it uses the sunlight to tell biblical stories for the illiterate audience who could not understand the priest otherwise because he held the mass in Latin. In this way, the whole building and the interior became a tool for communication and manifestation of mankind's role on earth versus god. The usage of the daylight in the church is partly based on religious and institutional reasons but in addition to the pure conveyance of such motivated messages it also generates a very specific atmosphere. Before the industrialization being able to manufacture glass in larger quantities, sufficient qualities and larger panes was so to say high technology, which only a few experts were able to execute. It is hard to imagine the awe, which struck people by entering a church and experiencing the shear visual richness, which is probably comparable seeing the first time a 3D movie in an Imax theater or large LED screens on Times Square etc. However what inspired the work is the combination of today's technological possibilities, and the availability to everybody e.g. open source paired with a more direct but also intuitive way to convey messages and images like described in the church and child's play example. Everybody understands the basic principle and relation of the mirrors in relation to the sunlight and the necessary for their movement at a first glance but how the individual mirror contributes and the interplay of all of them to the whole image, which is the intelligence behind stays mysterious.

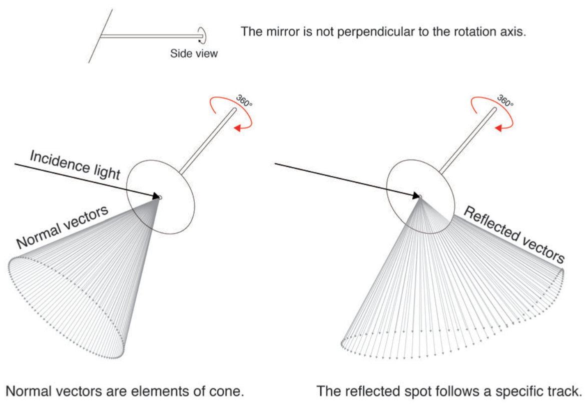

Figure 1. Analysis of 动/Mobility, ART+COM

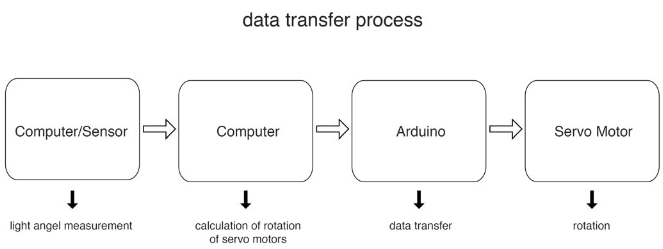

Figure 2. Digital control

One keystone of this project is making use of the changing daylight. From the review of other projects, the installation "动/Mobility" from design studio ART+COM that is exhibited in the Expo 2010 Shanghai is studied. In this installation, one hundred prosthetic hands rotate and the mirrors reflect the light and the beam spots are finally coming together to form the Chinese character "动" [3]. From the first glance, it is similar to the concept that is demonstrated in this paper. But there is much difference. First, the hundred hands only rotate around their own vertical axis. Second, the light source is a fixed spotlight. As the mirror that is hold by the hand has a specific angle to the vertical axis, the normal vector and furthermore the incidence angles changed when the hands rotates. But there is restriction. Although the mirror can rotate 3 dimensionally to a certain extent, the normal vector can only move on a conical surface and therefore the beam spot of each mirror can only move in a certain track (Fig. 1). In generally this system is not universal valid for every form. In other words, this system can only reflect limited images in limited range. Comparing to this installation, the project here has a more complex and dynamic system and more flexible operation to adapt the changing conditions, e.g. the solar angle, the position and the form of the reflected image.

III. DESIGN

A. *Digital Control*

The whole Installation is digitally controlled. When sun path and the image are known, the input will be evaluated and the rotate angles of each servo motor (Servo motor has a rotation range from -90° to 90°.) will be calculated, The whole algorithm is written in Grasshopper [4], a parametric plug-in for Rhino. And through Firefly [5], a set of comprehensive software tools, the data in Grasshopper could be transferred into Arduino board [6] which bridges the digital and physical environments. In this way the digital servo motors can respond to computer (Fig. 2).

B. *Algorithm*

The computational approach demonstrated in this paper uses simple geometrical calculation in Grasshopper. Each mirror (X*Y mirrors) can be regarded as one pixel. The first task is to find the corresponding points on the information. To achieve it the form that needs to be reflected is first divided by X lines. Next step, X*Y points will be averagely found on the image that is composed by the information. The vectors, from the center points of each mirror to the corresponding points on the reflected images are reflected light vector. Based on the incidence light vector (sunlight vector) and reflected light vector, the normal vector of each mirror will be calculated. Then the position of each mirror will be computed. Furthermore the rotation angles of the mirrors from the first position will be calculated. After it, the rotation angle will be digitally sent to the motors in real time (Fig. 3).

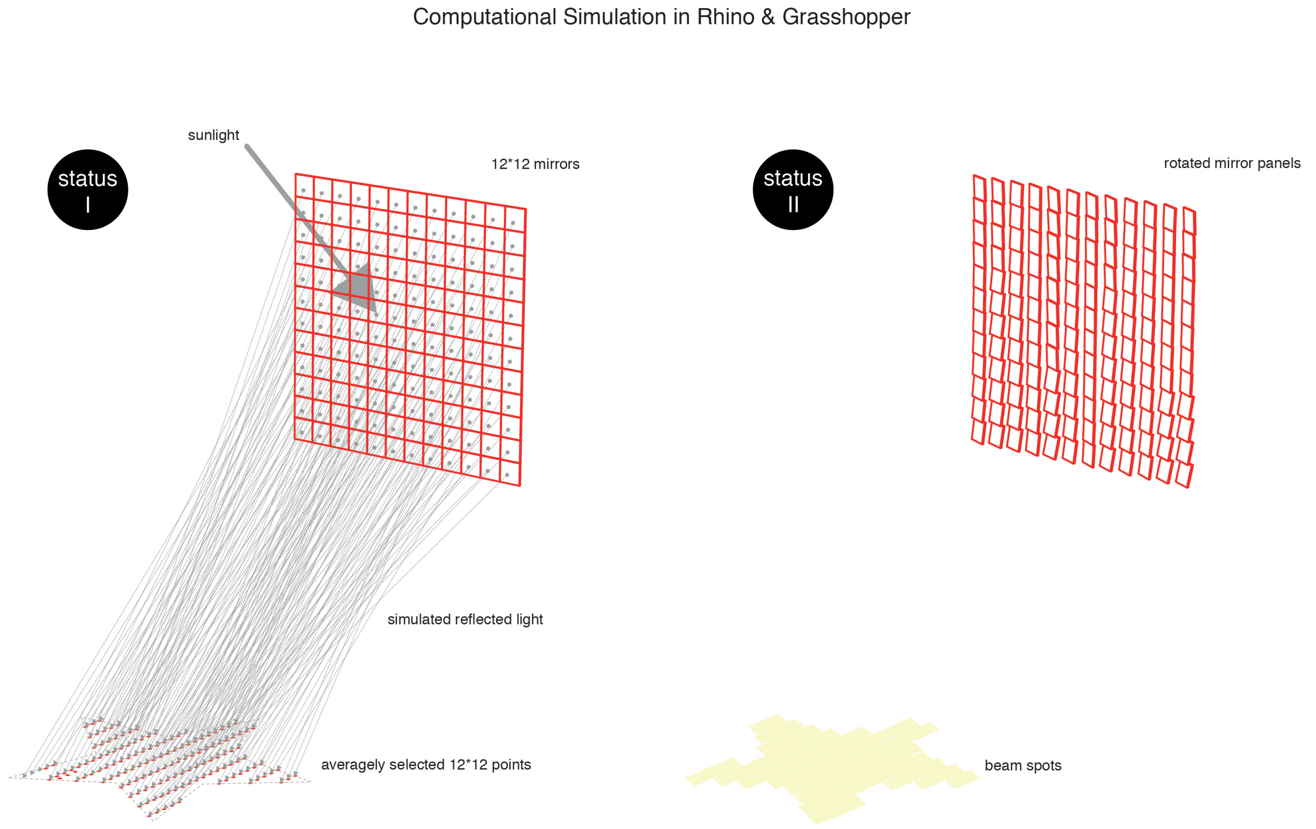

Figure 3. Simulation

C. *Visual Model Test*

In order to test the possibility and effect of the approach, visual models are simulated. To test the applicability different kinds of form are experimented. e.g. polygon, bézier curve; trimmed form, untrimmed form. In the test, 12*12 panels are used and therefore 144 corresponding points are equally chosen on the image that will be reflected. The simulated results show that the reflected image has a relative low resolution, the boundary is not even and there is sometimes interspace. In one word, the form is lack of some information. This problem can be partly solved by manipulating more panels. But from the perspective of cognition, the form could be recognized correctly when the resolution reach certain degree (Fig. 4).

The Gestalt theory proves human's ability of grouping figures. According to the vicinity law, the eye will group the figures together if the distance between them is small enough. Therefore even if there is small interspace between the spots, they could be grouped together into one image. Furthermore, past experience plays an important roll in shape perception [7]. It will also help people to recognize the form.

But in any case it breaks the conventional reading habit, the new way evokes the imagination and the reconstruction in the mind. The human could get a different and abstract experience.

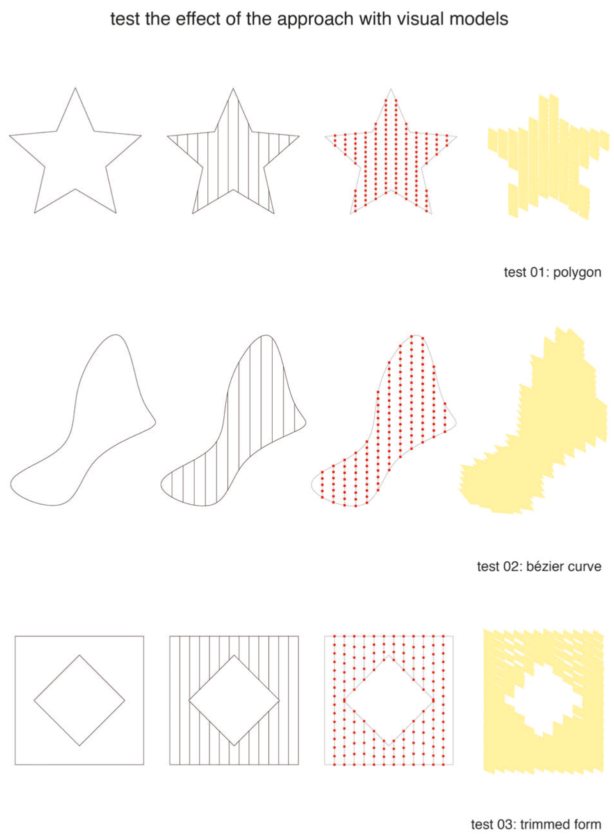

Figure 4. Visual models

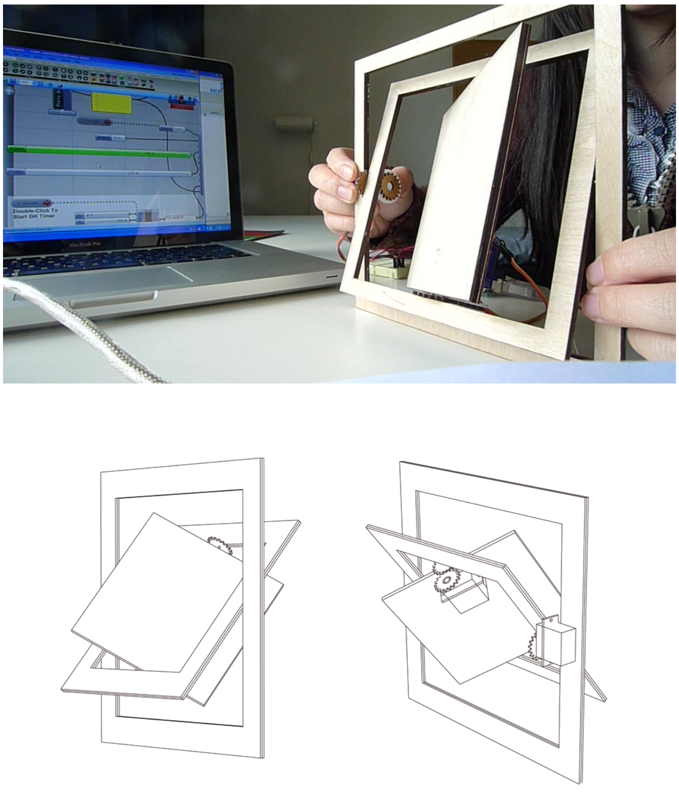

Figure 5. Structure 1

Figure 6. Structure 2

D. Structures

To achieve the digital simulation in physical world that all of mirrors can rotate individually, the structure is a big topic in the project.

In order to fix the mirrors and force them rotate differently in real time, two kinds of mechanical structures are experimented.

1) Structure 01

The first structure composed of a panel that can rotate through the vertical axis and two frames in the structures. The outer frame is static and the inner one can rotate through the horizontal axis. In this way, the rotation in two axes can be achieved. The structure is using gears to transfer the rotation of the servo motors to the panels and the kinetic frame. One servo motor is placed on the backside of the panel and the other one onto the static frame (Fig. 5).

The structure is simple and compact, but it is restricted by some conditions in the next step. One of the key problems is that the reflected form of the mirror may be partly hidden by the kinetic frame. Another consideration is on the energy waste. Since the servo motor that is fixed on the panel has its weight, it is heavier for it to get the panel and itself rotate. Aimed to optimize the structure, a second structure is born.

2) Structure 02

In the second structure, the mechanical part is divided from the mirror part and hidden behind the static façade. To connect the two parts, metal wires are used. As soon as the servo motors rotate, the movement will be transferred to the front mirror (Fig. 6). Comparing to the first prototype, the division of the mechanical enhances the stabilization of the whole structure. It is easier for testing and regulating. And from the aesthetical perspective, the front only composed by amount of the mirrors gives a neat appearance.

E. Interaction between Human and Architecture

As the project is inspired from the children's trick with mirror, the project attempts to open the chance for visitors to participate a play with the building façade. The visitor can draw or write what they want and the computer will calculate it and direct the façade to move. In the way, the people can manipulate the appearance of the static building and enjoy the process.

F. Appendix

The physical kinetic model is built with 3*3 panels. The nine panels composed a module that can be further used in a big scale. From the backside, all the mechanical structures are integrated and all the servo motors are connected with the pins on the Arduino. Once the mirrors rotate, different images will be reflected (Fig. 7-12).

Figure 7. Physical model

Figure 8. Physical model (position I)

Figure 9. Physical model (position II)

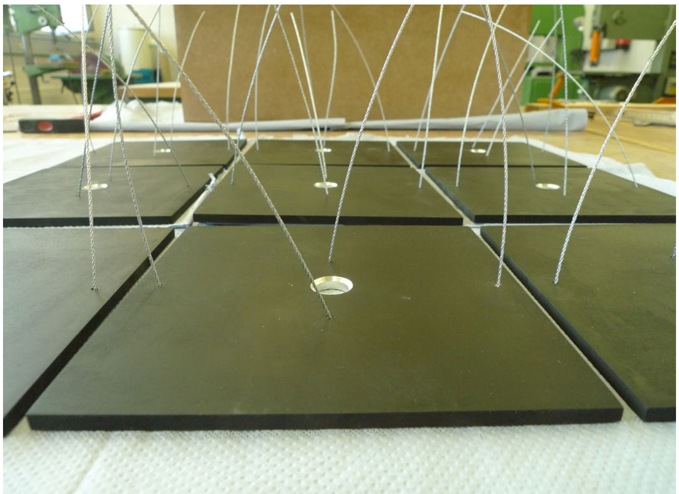

Figure 10. Physical model (mirror part)

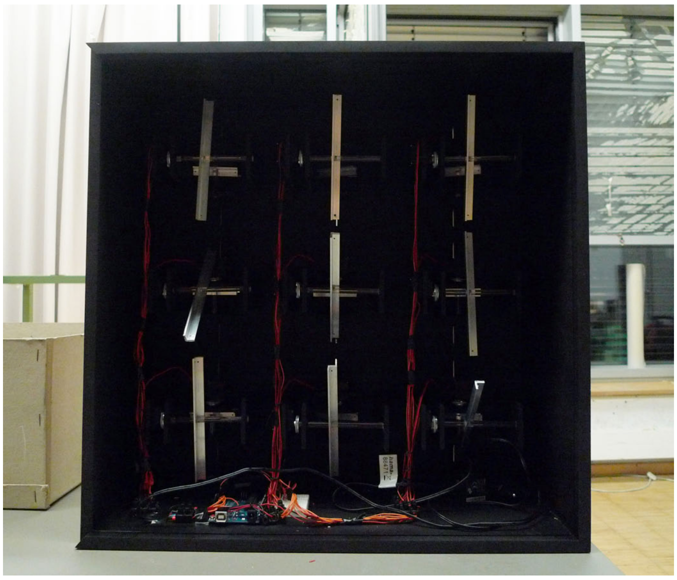

Figure 11. Physical model (mechanical part)

Figure 12. Physical model (structural detail)

IV. Conclusion and Further Thoughts

Starting from an idea of creating a performing, kinetic façade to reflect sunlight for conveying messages, the paper was built upon a series of experiments, which attempts to find a simple solution for both algorithm and mechanical structure.

For testing the feasibility of the algorithm, the reflections of 3 different kinds of form are simulated. In order to enhance the robustness of the physical structure and reach a higher aesthetical level, two mechanical structures are tested. The project is still in an early stage. There are still a lot of possibilities to improve it.

First, the algorithm still needs a lot of proffs by testing other forms.

Second, the physical structure used in this installation is a simple and inexpensive solution. It could also be replaced by robotic arm for a higher precision.

Third, the technology that is applied in the research for measuring the solar angle is calculation in the computational environment. Otherwise, one specific sensor could be placed on the top of the building in the further experiment, e.g. E910.86 integrated solar angle sensor of the German company Elmos [8], which can sensor the angle of light incidence in both XZ- and YZ-planes. (The Z-axis is perpendicular to the device surface/ façade surface.) Through the SPI-compatible communication interface the angle information could be received by e.g. Arduino. In this way the solar angle in real time can be measured, even under the unpredictable weather condition.

But the project introduces a new status of the traditional façade. The mirrors installed on the façade vary the appearance of the future architecture. Visible from a long way off, it opens a future for the interaction between architecture and human being.

V. Acknowledgements

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VI. References

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