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Study on a Projected Image of Light and Shadow on Floor and Wall
Case Study: A Cross of Church

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影，光，投影像，コンピューターシミュレーション，デザイン手法

1. Background and purpose

There are several buildings which are using light as the main theme of the concept that have been built in the world. Some architects have an intention of using light in the design, for examples Church of Light by Tadao Ando, he introduced light cross inside the main room for praying which occur from cross hole in the wall and only happen in some times in a year as seen in figure 1(a), and Fujisawa Akibadai Cultural Gym by Fumihiko Maki, he create circle inside the Gym from windows as half circle and reflection of light in the floor as another half circle as seen in figure 1(b). In Hoki Museum, Yamanashi Tomohiko used natural light and combined it with LED light to create harmonic interior environment inside the museum like in figure 1(c). Nishizawa Taira use light as living process in a house in Utsunomiya as seen in figure 1(d).

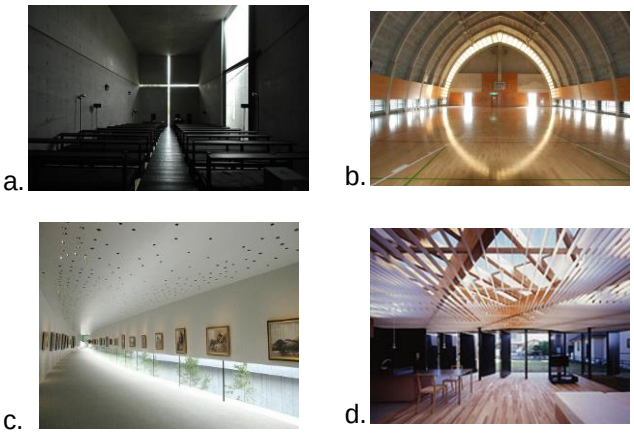


Figure 1. (a) Church of Light[1] (b) Fujisawa Akibadai Cultural Gym[2] (c) Hoki Museum[3] (d) House in Utsunomiya[4]

In the past, when architects designed a building using light and shadow, they were using scaled model and actual light to study the effect (table 1). This method was not efficient and time consuming. In the modern world, computer simulation have been used as one of the method to simulate the actual world. Although It`s not commonly used yet, this method have proof of accuracy and efficiency.

Table 1. Method of experimental design study

Architect	Building	Method
Tadao Ando	Church of Light	Making model
Taira Nishizawa	A house in Utsonomiya	Making model
Fuhimiko Maki	Fujisawa Akibadai Cultural Gym	Making model
Tomohiko Yamanashi	Hoki Museum	Computer simulation

The purpose of this study is to identify the characteristics of shadow (light) changing due to the sun position. Computer simulation becomes part of the design process, which will be a new design tool.

2. Method of simulation

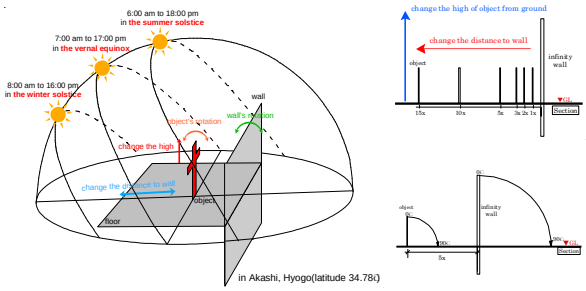


Figure 2. Setting up the simulation

In this study, we simulate a form of two-dimensional shadow that falls on the floor and wall and measure the distortion to disclose characteristics of the shadow in the vernal equinox, the summer solstice and the winter solstice using Ladybug and Honeybee simulation program from the Grasshopper in Rhino 3D software[5]. This software use the weather file as an input of location to determine the position of sun in the sun path diagram in the current study location.

2-1. Setting condition

We decide a time from 7:00 am to 17:00 pm in the vernal equinox, from 6:00 am to 18:00 pm in the summer solstice and from 8:00 am to 16:00 pm in the winter solstice that are decided from a time of sunrise and sun down in Akashi, Hyogo (latitude 34.78°) and analyzed using the simulation software. The basic position of the object was set on the ground and will move to the front and to the up position with height of X. The wall was place 5 X in front of the object in the north side as seen in figure 2.

We used a cross of church as a case study to simulate a shadow of two-dimensional form and projected to the floor and the wall. There are some variables that will be analyze in this study. Variation of distortion that happen on shadow which fall on ground and on wall. Also the effect of modification of the wall surface that will effect on the shadow position and distortion. The vertical length of shadow (light) of two-dimensional form will be "vertical distortion length" and the horizontal length of the shadow distortion as " horizontal distortion length". The angle from the Y axis to the shadow as "spread angle" and x that is used in this study define the height of two-dimensional form (cross). In addition, we call the length which is from lowest position of two-dimensional form to lowest position of shadow (light) with "spread length".

3. Study result and analysis

3-1. Shadow variation characteristic on floor

Figure 3 (a) shows hourly shadow variation diagram when the object is on floor. The vertical distortion length change with passage of time but horizontal distortion length don't occur. The vertical distortion length is change intensely in morning and evening every season. When the object move to the up direction, the also move away from the center object, but the length of the shadow remain the same. Figure 3 (b) shows a spread length of the object that have height (5x) from the ground. When the height position of the object from the ground change 1x, 2x, distortion length that changes the height from the ground is same as when the two-dimensional form is on the ground. This figure also shows the change of spread length of the shadow when the height of the object change from the ground. Growth of the spread length has become intensely in the morning and evening, spread length of 5x become five times as much as that spread length of 1x.

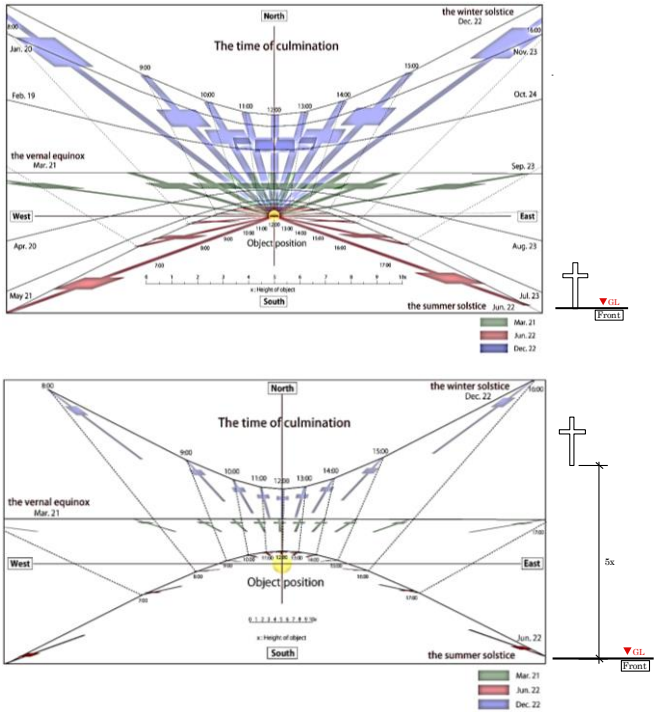


Figure 3. Shadow`s projection on floor

There are some variations of angle distortion which we call them “spread angle”. These variations are depend on the sun position which have different time availability in different season as seen in figure 4.

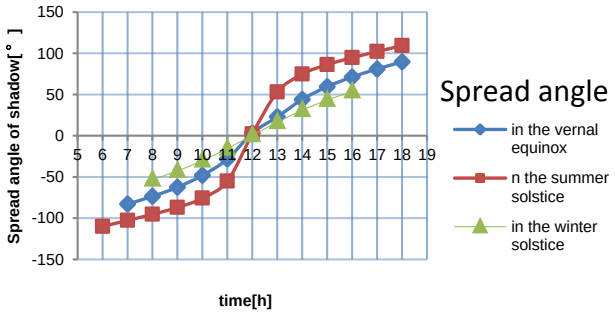


Figure 4. Shadow`s spread angle on floor

Figure 5 shows the angle of the shadow when the object is tilted from 0 degree to 90 degree on floor in summer. In 90 degree, it don't have shadow because it is consistent with floor. When tilting the object in the

floor, the spread angle is reduced and close to the shadow at culmination. The Angle change intensely in 0 degree and 60 degree, and the constant slope is closer to 45 degree.

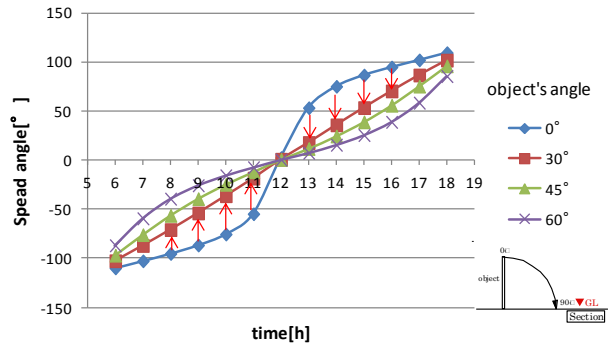


Figure 5. Shadow`s spread angle on floor

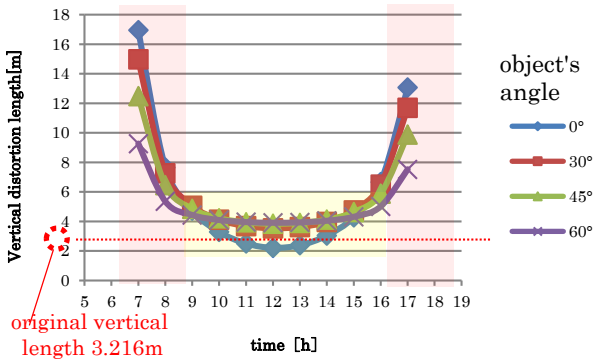


Figure 6. Shadow`s length distortion on floor

Figure 6 shows the distortion length in spring when we rotate the object to front. It was found that in morning and evening, the distortion rapidly decreases by changing angle at every month. It is because of the positional relationship of shadow and the object approaches in parallel. Moreover, we found that distortion length is almost same even with different rotation of the object at 9:00 to 15:00. When the angle of object is 0 ° in winter, although distortion length is large, there is no reduction of distortion by changing the angle in change of time.

3-2. Shadow variation characteristic on the wall

When shadow of the cross fall in to the straight wall, the height of the shadow and the height of the object remain the same. This is because the direction of sun rays are always the same angle as seen in figure 7 and it will start to have distortion of height when the object were rotate. If we want to have the shadow to fall on the wall, the position of the object must be above the ground line, especially when we want to have full shadow of the object.

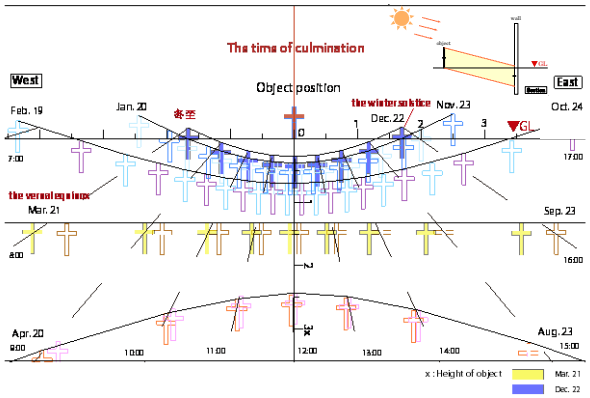
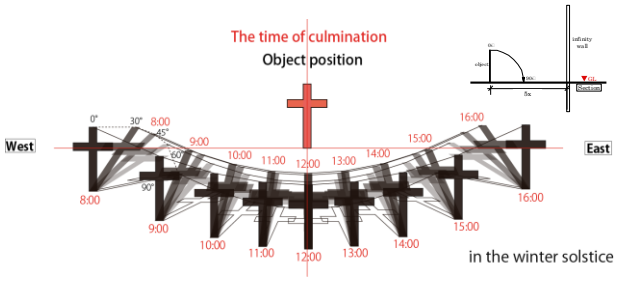
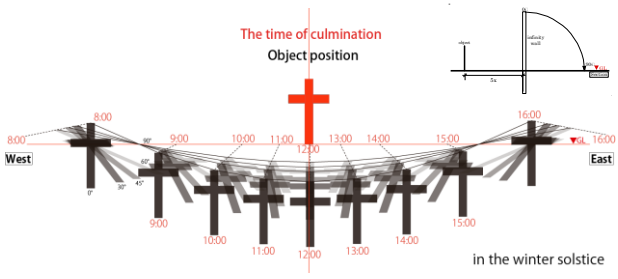


Figure 7. Shadow`s spread angle on Wall

The distortion of the shadow in the wall can be seen in figure 8(a) happen when we rotate the object from 0 degree until 90 degree to the front of the object. From this figure we can see that in the morning and in the afternoon, there are some distortion of the length of the shadow which are longer than the object. In figure 8(b) the variation of shadow on wall happen when we rotate the wall itself but the object still remain the same position. In this figure, the length of the shadow also have some distortion especially in the early morning and in the late afternoon.



a.



b.

Figure 8. Shadow`s effect on floor and wall with object or wall variation

3-3. Effect on curved surface

From the result so far, we found that the shadow (light) have distortions and the range which shadow fall is large. Then we analyze how much possible range that can be reduce to get the shadow on wall when using curved surface wall. Figure 9 shows the change of the distortion length by curved surface.

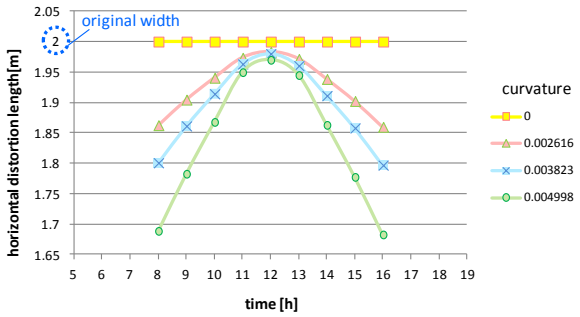


Figure 9. Shadow`s spread angle on floor

This example is in the winter solstice. Although the vertical distortion length doesn't occur like flat wall, the horizontal distortion length caused by increasing curvature. In particular distortion is large in the morning and evening, shadow approach the width of the original object length closer to the time of culmination. By using this method, we can reduce the area of the wall to capture the shadow in the same time between flat wall and the curve wall. The reduction of the wall area depend on the curvature of the wall as seen in figure 10. In other word, we can create specific shadow effect in our design by using this simulation.

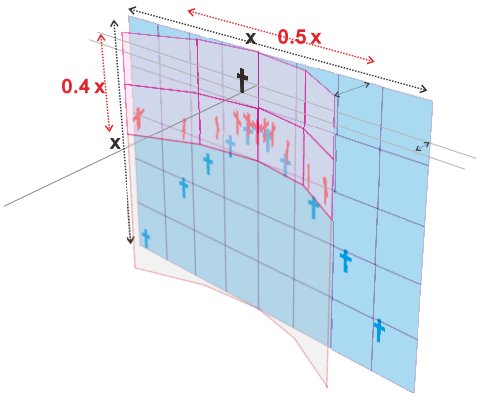


Figure 10. Shadow`s spread angle on floor

4. Conclusion

From the analysis of the shadow variation which projected on floor and wall, we can conclude that:

1. The study on shadow (natural light) in architectural design depends on the position of the site, every place have their own sun path diagram.
2. The use of computer simulation can be an alternative approach for an architect to study the effect of light and shadow in architectural design.
3. The distortion of shadows on the floor are in the angle and the length in different season.
4. The length of the shadow on wall have the same height with the original object in straight position, but will have distortion when the object or wall being rotate.
5. Curve surface have more efficient in capturing the shadow than flat surface in the same time range and have different effect.

5. Reference

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