Discussion and Application of 3D and 2D Aperture Problems

Guang-Dah Chen, National Yunlin University of Science and Technology, Taiwan
Yi-Yin Wang, National Yunlin University of Science and Technology, Taiwan

The Seventh Asian Conference on Arts & Humanities 2016
Official Conference Proceedings

Abstract
In Kinetic art, most visual effects are related to visual psychology. By the mean of literature review, this current study analyzed the dynamics optical illusion between the 3D aperture problems caused by rotating the form with spiral pattern and the 2D aperture problems caused by dynamic flat line from the angle of visual psychology. Based on the results to sum up the similarity and difference of the perception of movement displayed from two different visual forms. Moreover, this study analyzed the structure and discussed about the studies which were related to aperture problems to integrate the thinking and application from different design. The researcher in this study wish to make contribute to some basic theories in kinetic art by making interdisciplinary research on kinetic art and visual psychology.

Keywords: Kinetic art, Dynamics optical illusion, Perception of movement, Aperture Problem

Introduction

Kinetic art is a performing form which combined with the element of time, and this make the form become 4D and produce a great diversity of visual effects. Movement has close relationship with time, the movement always followed by the flow of time (S. Y., Lin, 1975), therefore, the mutual perception between movement and time is a very important condition in the dynamic effects which was produced by the works in kinetic art. However, it not only concern about the change of the form, when the kinetic art combined with visual psychology, it makes us be able to do a deeper research about the relationship between the dynamics optical illusion which caused by kinetic art and human visual perception. The combination of kinetic art and mechanism makes the movement's form of kinetic art have multiple development, and these multiple research about different fields makes the forms have more different dynamic effects.

Recently, the works of kinetic art attempted to make some try and innovation, but most of them focused on the display of the works; by comparison, the basic theory of kinetic art is not completely established. The combination of technology and art become the trend of future creation, it shows the importance of the basic theory of kinetic art, as a result, strengthen this basic theory is quite important.

In the works of kinetic art nowadays, motors play an important role, because they have the characteristic of stable, regularity, and easy to manipulate; therefore, many creator will use motors as the power source of the works of kinetic art. When the spiral line on the surface of the form making the movement of rotating by the motor, it makes the visual have the movement perceptions like: apparent motion, movement after-image, and induced movement…, etc. these perceptions of movement doesn't do the real movement but an illusion (Y. M., Liu, 1987).When the spiral lines rotating quickly, the forms between different shapes will have different effects of dynamics optical illusion.

When the threshold of the speed reach the standard, the spiral lines will move to where there are more grating terminator rather than doing the rotating which we thought they were, and this kind of situation is induced movement. The situation that the lines moving to where there are more grating terminators is similar to the illusion which was caused by 2D aperture problems, but the moving forms are different. From the angle of visual psychology, this is because human's visual perception system deal with local and global visual differently, the dynamic effect of the spiral line form could be sorted into 3D aperture problems.

From the research about aperture problems, most of the research tend to add various interfere figure behind the grating to explain how the visual perception system solved the problem of vague illusion. As for the research about the form of spiral lines in 3D aperture problems, the research will focus on the relationship among changing the thickness of the lines, the interval of the lines and the threshold of the speed. To be brief of the above points, this current research discussed and analyzed the studies which related to 2D's and 3D's perception of Dynamics optical illusion, and take the studies as references to make an extension research on the display of dynamic form.
Purpose of this research:

1. Collect related studies about kinetic art, visual psychology from domestic and international to analysis theory and organize.
2. Summarize the principles and related theories about 2D's and 3D's forms of dynamics optical illusion.
3. discuss about the future development of 2D's and 3D's perception of dynamics optical illusion.

Dynamic illusion's perception of movement

When we are looking at something, we used not only our eyes but our brain. Perception means when we are using our brain to look at things. When we see something wrong, we called it illusion. P. C., Lin (2005) pointed out in his research that there are three main reasons that will caused human's illusion:

(1) Psychological illusion which was caused by central perception: when we met something which can't be correctly judged by our eyes about its form or structures, our perception will organize the clues which we have and the past experience to explain the situation, rationalize the objects, and generalize those has less interval; in order to make the effect fit human's physiological, psychological, and cognitive, then people have the illusion.
(2) The illusion caused by eyes: in order to adapt to the living environment, human's physical structure can handle the relationship between environment and body sensitively in order to keep the balance.
(3) The illusion caused by external stimulations: caused by the interference which comes from the forms or the comparison of the colors.

The illusion which produced by dynamic art was mainly caused by the mental illusion of the central perception, and the figures, shapes, colors, speed of rotation, or the direction of rotating will produce different Dynamics optical illusion's perception of movement. The objects' moving speed in the space is the basic condition of producing perception of movement (Darley, Glucksberg, & Kinchla, 1991), when the speed is too fast or too slow, it can't produce the perception of movement. According to Takahashi Masahito (1992) indicated that when our visual sensed the object is moving, and the object's moving speed threshold is between 600 mm/s to 0.6 mm, there will be perception of movement (G. D., Chen, Z. W., Lin , X. W., Fan, 2015).

We can divided the perception of movement based on their effect of illusion into apparent motion, induced movement and movement after-image, these three kinds of dynamic perception of illusion.

Aperture Problem

In human's visual perceive, and it's hard to explain some dynamic figures precisely, when we watch a moving object from the aperture, the information that we got is ambiguous. If we observe the moving grating behind the aperture (see figure 1), we can find out that no matter it moves up-and-down and right-and-left, their moving direction behind the aperture is the same (Y. P., Chen, 2011). That is to say, there are many moving possibilities of diagonal stripes' moving direction that we observed from the aperture (Wallach, 1935; Marr & Ullman, 1981; Adelson & Movshon, 1982), this situation was called aperture problem.

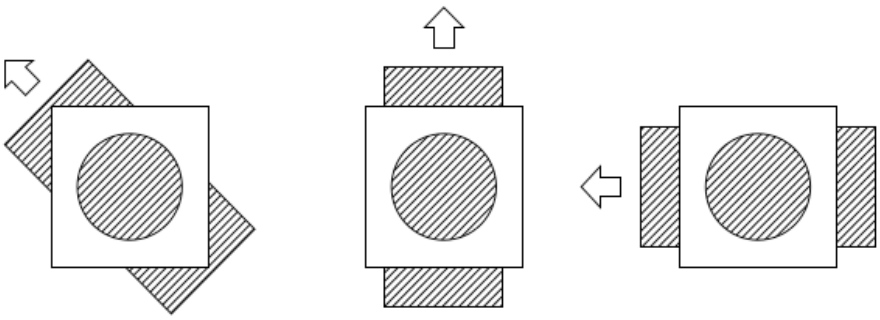

Figure 1: The aperture problems of 2D. (McGraw Hill, 2006)

Pleikart Stumpfs proposed the concept of aperture problems in 1911, he indicated that the motion sensitive neurons in the primary visual cortex (V1) will react to the lines which keep crossing the receptive field, despite the real strength and direction of the movement; as long as its direction is same as the direction of best sensitive direction, it will show the moving effect of the direction. In Human's visual perception, there are differences in local and global visual processing, including biology and artificial vision system, the analysis of movement started from local measuring. Each cell will react to the lines with specific angle, and this kind of situation is called local computation. We can only observe local moving effect rather than the certain moving condition. Hence, we need the global computation to integrate the local signals. When the visual signals transfer to higher level cells, for example: V5, they can integrate the signals from multiple apertures, and to determine the moving direction and vector of the entirety when we feel the whole subject is moving. The perception of movement is a global problem, we can only calculate in parts, we are not able to return to the moving way of the entirety.

We can't make precise judgment about the moving because the aperture problem is like the motion neurons in V5 zone watch the outside world by using the aperture which is rather small.

Relative research about 2D aperture problems

2D aperture problems were caused by dragging and pulling the grating behind the aperture, the motion stimulus need to be enclosed within the area of aperture. In 1935, Wallach had pointed out that the shape of the aperture will affect the direction of the perception of movement (see figure 2).

More specifically, vertical rectangle aperture tends to have the perception of movement along direction of long side, this kind of result was explained that is because the terminator of the line lengthened and increased the signal of the movement along the rim inside the aperture, and the terminators provide specific moving information and have a vertical upward moving effect. If we make the rectangle aperture into horizontal direction, the moving direction will turn into horizontal; if the aperture shape if round or square, it's hard to provide us the right information of moving cause they have equal length of rims. In this kind of situation, the perception of movement will normally be perpendicular to the direction of the lines (diagonal).

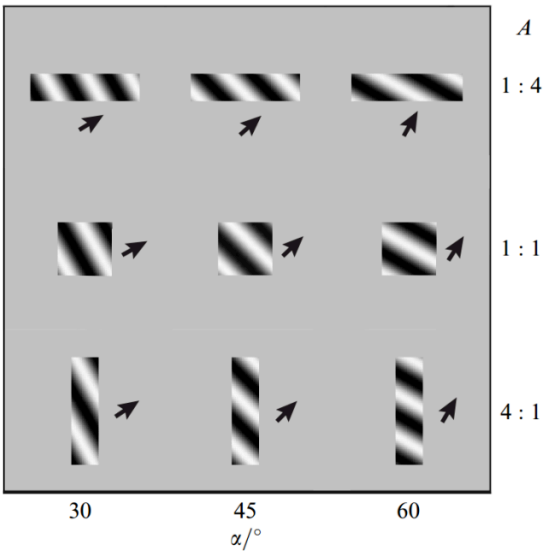

Figure 2: The perception direction of the terminator (Nick Fisher, & Johannes M Zanker., 2001, 1324)

Besides dragging and pulling the grating, breathing square is another example which was classified similar to 2D plane aperture (see figure 3). This kind of illusion appears when we look at a square which rotating in constant speed from a cross aperture, we will found that the square will make a periodical expansion and contraction breathing, and this is so called breathing square. The illusion of expansion and contraction is because the moving signal mainly follows the line of the aperture when the range of the aperture is very narrow. The local information will cause the square to do expansion and contraction obviously due to the lack of entirety's limit condition of shapes. The illusion will display in out visual, and try to affect the shape of moving surface by integrating the information from the area of big graph.

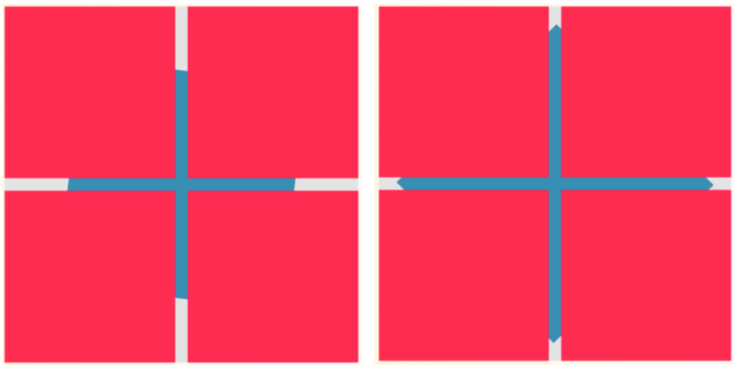
Figure 3: Breathing square（Drawn by the research.）

Represent of perception of movement in 2D aperture problems

If we dragging and puling the grating behind the aperture, when the lines moving entirely to where there are more grating terminators, this perception of movement is induced movement. When reach the induced movement, if we speed up until the induced movement's perception meets threshold of being disappear, there will be virtual shapes appear around the lines, this kind of illusion is movement after-image, after the appearance of movement of after-image, there will be endless virtual shapes,

and the virtual shapes won't have the threshold of disappear, so if we speed up, it will make the perception of after-image become more obvious.

Related research about 3D aperture problems

3D aperture problems put its emphasis on drawing many horizontal spiral patterns on the surface of the form, and make the spiral form rotating horizontally to produce the effect of illusion, it's an interaction between shapes and movement. The most representative example is the Barber-pole illusion (BPI) which was claimed by Wallach in 1935 (see figure 4), that is the dynamic effect which was produced by the rotating column sign of barber shop in early stage; the column revolves on its own axis and make the spiral lines on the surface of the column form have the effects of the illusion that it is moving upward vertically rather than rotating.

BPI is the column with rotating spiral form in 3D aperture problems. So far now, "barber-pole illusion" had been studied as a similar form of aperture problems. When the rotating speed of column reach the certain speed threshold, the moving perception of the lines will move to vertical direction, this is because the effect of illusion was limited by the form of the column. Wallach pointed out that the shape of aperture will affect the direction of the perception of movement could clearly prove that the visual system need to use the clear grating terminators to explain the line with vague movement. When measured through a spatially limited receptor, each of these features produces a motion measurement having a different degree of ambiguity. In 2D space, the translation point's movement could be measured explicitly, but the translation homogeneous lines could be only roughly measured. The grating terminators of the lines is an interesting features of figures, the visual system is able to allot different weights to the grating terminators, and make the grating terminators of moving perception system produce different moving signals under different conditions.

Figure 4: barber-pole illusion (Suwarnaadi, 2015)

Represent of the perception of movement in 3D aperture problems

There are three kinds of represent of the perception of movements which we've discussion before: apparent motion, movement after-image, and induced movement. What this current research wanted to discuss is movement after-image and induced movement in aperture problems, they produced the perception of movement by the changing of rotating speed; when the speed reach certain threshold, the lines in the spiral form will make an illusion that they are moving to the direction where there are more grating terminators rather than the actual horizontal rotating direction, this kind of movement was induced movement. If we keep speed up until the threshold of induced movement, there will be virtual shapes appear around the lines of spiral form. the faster the speed is, the obvious the virtual shapes are, and this kind of movement was called movement after-image.

G. D., Chen did a perception of movement research about the thickness, angles of the lines on column with spiral pattern in 2008, and found out that when the column with spiral pattern moving by the movement of rotating; the lines on the column with spiral patter will change because of the thickness, angles, interval, distance of visual, the rotating speed and other reasons, and these will affect the perception of movement's production. After analyzed results of experiment which pointed out that when the thickness of the line is 10 mm and it's a continuous line, the line's effect of differentiation will be the strongest, and the speed threshold of the dynamic effects will be the biggest, but if the thickness of the line is smaller or bigger than 10mm, it will has the phenomenon of interfere and glitter. When the angle of the line is 15 degree, it will has best effect, if the angle increased, the dynamic optical illusion's perception of movement will getting worse. When the visual distance is 4m, it will most obvious dynamic illusion's perception of movement.

After the research mentioned above, G. D., Chen and Z. W., Lin (2015) did a further research about different forms' perception of movement, and found out that in the induced movement, the form with more rims could sense the perception of induced movement, it could last in a long time and has better effect; column is the best cylinder which performs best in induced movement, its' lower absolute threshold is 44.65rpm, its' upper absolute threshold is 290.85rpm, and the range of speed threshold is 246.2rpm.

As for cone, it's the best centrum which perform best in induced movement, its' lower absolute threshold is 53.3rpm, its' upper absolute threshold is 266.1rpm, and the range of speed threshold is 212.8rpm. about the performance of perception after image, the form with fewer rims will make people perceive about the movement after-image earlier, hence, the triangular prism is the centrum which perform best in the movement after-image, its' lower absolute threshold is 191.95rpm. the cones is the best perform form in movement after-image, its' lower absolute threshold is 174.7rpm. Once the perception of movement after-image appears, there won't be threshold of disappear, therefore, we don't need to discuss about the movement after-image's upper absolute threshold and speed threshold.

The integrated discussion of 2D's and 3D's dynamics optical illusion

There are few works about 2D's and 3D's application in dynamic optical illusion so far now. Takamichi Ito presented his works in 1985 and 1989 (see figure 5 and figure 6), which is bending the stainless steel pipe into spiral and combine with motor to rotate; this could make the form display induced movement's perception of movement, observers will have the illusion that it's climbing up when looking at this work; and this is a design work of Dynamics optical illusion which is expend from 3D aperture problems.

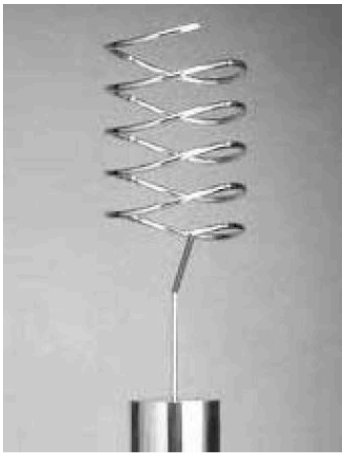

Figure 5: Takamichi Ito，1985
(Takamichi Ito，1999， 30)

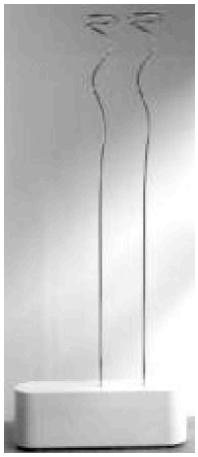

Figure 6: Takamichi Ito，1989
(Takamichi Ito，1995， 28)

Based on literature review, we could generalized the related research course of 2D's and 3D's perception of movement in dynamics optical illusion (see figure 7), and found out that from 1911 to 2000, researcher mainly focused on how did visual perception system solve the aperture problems which caused by 3D and 2D illusion phenomenon while they are doing the study about aperture problems. There are more research about physiology and visual psychology. But recently, researcher started to put their emphasis on the built of basic design theory of 3D's perception of movement in dynamics optical illusion, and trying to experience the effects of different lines to the perception of movement in dynamics optical illusion, and the change of the relationship between different form and perception of movement in dynamics optical illusion. No matter what is the direction of the research, 3D's and 2D's perception of movement in dynamics optical illusion is a research issue which combined with many field.

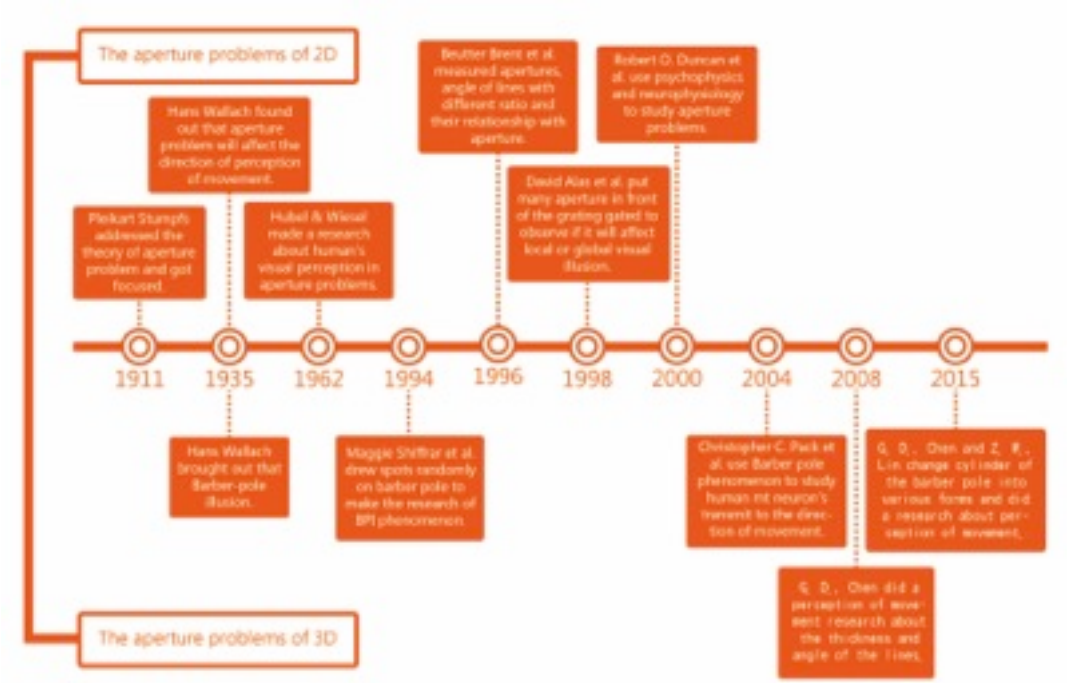

Figure 7: The related Research Course of 2D's and 3D's dynamics optical illusion. (Drawn by the research.)

Conclusion

The combination of technology and art is very common in the development of modern art. In addition to combine with technical art, 3D and 2D also conclude visual psychology, physiology, mechanism and many different aspects. The form and the appearance are the main design condition which constitute 3D and 2D dynamics optical illusion works. Hence, understanding the relationship between different dynamics optical illusion from different visual psychology is also an important part. According to the point of view from literature review, we can sum up following conclusions:

(1) Both 3D and 2D's aperture problem will react to the direction where there are more grating terminator, and will moving to that direction.
(2) 3D's aperture problem belongs to 4D's moving type, and 2D's aperture problem belongs to 2D's moving type.
(3) There are few works about 3D's and 2D's dynamics optical illusion, hence the basic theory establish of dynamics phenomenon relationship's changing which will be a reference for future development of design.
(4) 3D's and 2D's dynamics optical illusion's visual effects are strong, therefore, this could be applied to many visual create area.

This current research analyzed related theory and studies of 3D's and 2D's perception of movement dynamics optical illusion, and we'll make a further research in the near future to observe the effect of various perception of movement between 3D and 2D to increase the completion of the basic theory and expend more developed possibilities of 3D's and 2D's perception of movement in dynamics optical illusion, furthermore to create brand-new visual enjoyment.

References

Adelson, E. H., & Movshon, J. A. (1982). Phenomenal coherence of moving visual patterns. Nature, 300(5892), 523-525.

Darley, J. M., Glucksberg, S. and Kinchla, R. A. (1994)，*psychology* (Y. Y., Yang., trans.). Taipei: Gui guan.

Guang Da, Chen., Chih Wei, Lin., Hsi Wen, Fan. (2015). A Study of Motion Perception on Column of Rotational Dynamic Illusion in Kinect Art. *Journal of Design, 20(3)*, 1-19.

Marr, D., & Ullman, S. (1981). Directional selectivity and its use in early visual processing. Proceedings of the Royal Society of London B: Biological Sciences, 211(1183), 151-180.

McGraw Hill BEUTTER, B. R., MULLIGAN, J. B., & STONE, L. S. (1996). The barberplaid illusion: plaid motion is biased by elongated apertures. Vision research, 36(19), 3061-3075.

Nick Fisher, & Johannes M Zanker. (2001)The directional tuning of the barber-pole illusion. Perception, 30, 1321-1336

Pin Chang, Lin. (2005). *Principle shape*. Taipei: Chuan Hwa Science and Technology Books.

Shu Yao, Lin. (1975). *visual art*. Taipei: Weixin shuju.

Wallach, H. (1935). Uber visuell wahrgenommene Bewegungsrichtung. *Psychologische Forschung*, 20(1), 325-380.

Ying Mao, Liu. (1987). *Basic psychological process*. Taipei: Da Yang.

Yi Ping, Chen. (2011). *Visual psychology*. Taipei: Yeh Yeh Book Gallery

Contact email: wangyiin511@gmail.com