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A Study on Some Optical Illusions Based upon the Theory of Inducing Field

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Abstract: **The study of optical illusion is an important method to elucidate the mechanism of visual perception. However, many details about the cause of optical illusions are still unclear. In this research, based on the characteristic of the physiological structure of the retina, we proposed an on-center receptive field model of the retina. Using this model, we simulated the distributions of the inducing field of some visual stimulus. Comparing to the past studies' results, the validity of the proposed model was proofed. Furthermore, we simulated the distributions of the inducing field of some typical illusions. The simulation results can explain these illusion phenomenon rationally. Therefore, it suggested that some of illusions are probably engendered by the distributions of the inducing field in the retina which generated by the illusions stimuli. The practicality of the proposed model was also verified.**

I. Introduction

Optical illusion is one particular visual character of the human vision. For example, there is a triangle drawn using black lines shown in Fig. 1. It is not only the line can be perceived from the white background but also the white area inside the outline seems be whiter than the background and appearing farther to the front.

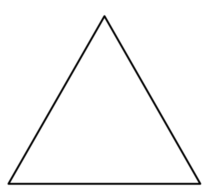


Fig.1. A triangle seems whiter than background and farther to the front.

Lots of researchers had interpreted this phenomenon using the various techniques from different viewpoints. The inducing field, as one technique to measure the influence of the figure on background, was used to investigate the mechanism of human vision (or optical illusion) in the past studies. Various measuring techniques have been developed for use in this field.

Yokosei [1] measured the stimulation threshold around the figure and inferred that the interaction of the forces in psychophysics field cause such a phenomenon (Fig. 2). They found that the threshold decreased with the distance from the contour of the figure to its surrounding field, and this decrease occurred in accordance with a lawful principle.

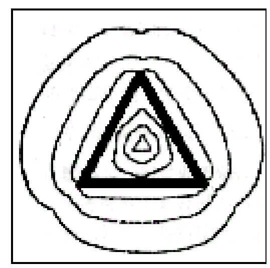


Fig.2 The equivalence lines for a trainle. (Copy from Yokose's paper [1]).

Ohkawa[2] used the method of c.f.f (critical fusion frequency) to measure the inducing field around stimuli figures. He got the equi-fusional lines around the figure similar to Yokosei's result. The value of c.f.f decreased as the distance from the figure increased. Sayanagi [3] studied the inducing field from the view point of the psychophysics experiment and measured the critical interval between two stimuli. Hongawa [4] put electrodes around the participant's eyes and measured the potential induced by the stimulation figures. He drew a retina inducing field from the view of pure physiology. However, in the above-mentioned research, a theoretical formula of the inducing field was not proposed. Yokose [5] tried to explain the phenomenon of the inducing effect using the theory of distribution of the potential, but a physiological basis wasn't found out. Although the measurement methods and techniques for the above-mentioned research were different, some principal conclusions can be summarized as follows.

a). The strength of the inducing field is an inverse proportion function of the distance from the contour of figure.

b). The brighter the stimulus figure is, the stronger the strength of the inducing field.

c). The distribution of the inducing field is affected by the shape (structure) of the stimulus figure.

The purpose of this research was to deduce a theoretical formula to describe the inducing field based on the physiological characteristic of the retina.

Ⅱ. PROPOSAL of MODEL

The retina of both human eyes has 125,000,000 rods and about 5,500,000 cones. However, there are only 900,000 optic nerves stretching from the retina to the brain. Therefore, it means that about 140 rods and 6 cones are converged into one optic nerve. Rots and cones are stimulated by the light signal and excited. Then, photochemical materials are secreted and make receptor potential occur. The synapses of rots and cones combine closely with the dendrite of the bipolar cell and the horizontal cell. The receptor potential which occurs with the excitement of rots and cones can be transmitted to the bipolar cell and the horizontal cell directly. The signals are weighted in both the bipolar cell and the horizontal cell.

In the past research [6], it was reported that the receptive field of the visual cell is a small disk. Also, some researchers studied the weighting function of the receptive field. However, it seems that there is no physiological report on the weighting function of the receptive field of the human retina yet.

The receptive field is presumed to be fabricated by excitatory and inhibitory responses [7]. Wilson [8] used the DOG function (Difference of Gaussian) to approximate the excitatory and inhibitory responses, and used the DOG function as the weighting function of the receptive field of human retina.

In our study, we adopted the DOG function as the weighting function of the receptive field, and proposed a theoretical formula to describe the inducing field as follows.

$$S = K \iint_{\Delta s} d(\xi,\eta) L(x+\xi, y+\eta) d\xi d\eta \qquad (1)$$

$$d(\xi,\eta) = \exp\left(-\frac{\xi^2+\eta^2}{2\omega_{on}^2}\right) - Q * \exp\left(-\frac{\xi^2+\eta^2}{2\omega_{off}^2}\right)$$

Where, S is the strength of the inducing field. K is the proportion coefficient (here, we set it as 1). $d(\xi,\eta)$ is the weighting function of the receptive field (DOG function). $L(\xi,\eta)$ is the brightness value of the figure (since in our study only the monochrome figures were used, the value is 1 or 0). Q is a proportion coefficient of inhibitory region and excitatory region. Δs is the scope of receptive field. Based on the characteristic of the physiological structure of the retina, and the mathematics relation between the inhibition region and the excitatory region, the coefficient of DOG function can be decided.

Ⅲ. SIMULATION RESULT

Using the proposed formula (1), we simulated the distributions of the inducing field for a typical figure (Fig.3.)

Observing the simulation results of the distributions of the inducing field, it is found that there is no distinct difference between the conclusions of past studies and ours.

Base on the distributions of the inducing field, we found that some phenomenon of optical illusions could be explained with the simulation result.

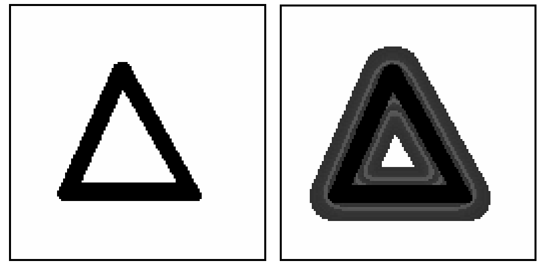


Fig.3. A triangle (a) and the simulation result of the inducing field (b).

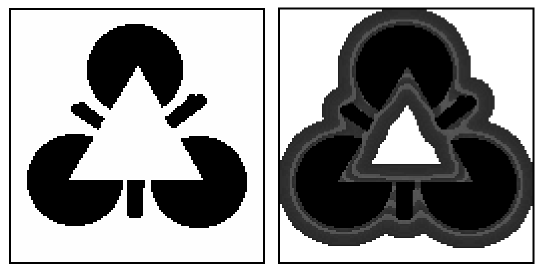


Fig.4. A typical subjective contour (a) and the simulation result of the inducing field (b).

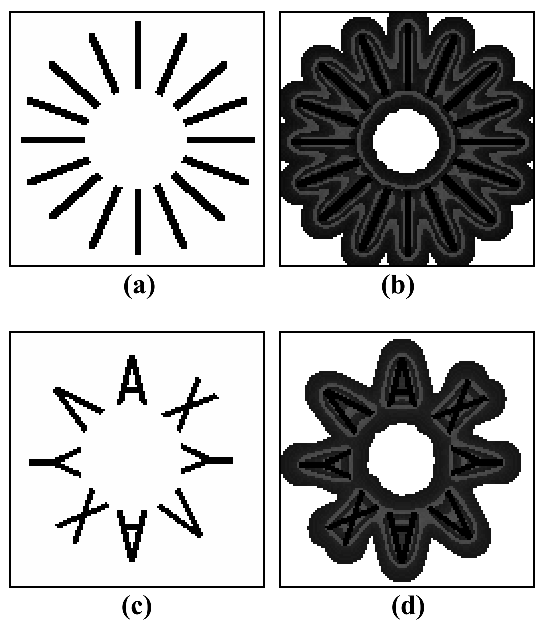


Fig.5. A white disk can be perceived in the center of figure (a), (c), and the simulation result of inducing fields (b), (d), respectively.

For example, there is an example of subjective contour (illusion contour) shown in Fig.4.(a). (For the sake of printing, we reversed the color of all the figures in this paper.)

The mechanism is still not clear that what gives rise to such a phenomenon generate. We tried to explain the phenomenon of subjective contour from the viewpoint of the inducing field. The simulation result of Fig.4.(a) is shown in Fig. 4.(b). It was found that the center part of the inducing field induced by the inducing elements which are shown in Fig.4. (a) is similar to the inducing field around the triangle which is shown in Fig.3.(b). Therefore, it is possible to make us perceive subjectively that a white triangle exists at the center of Fig.4.(a). We consider that the similar distribution of the inducing field tends to cause the similar perception.

The simulation results of the inducing fields which correspond to the other subjective contours, Ehrenstein illusion figures, are shown in Fig.5. Based on the stimulation results of Fig.5.(b) and (d), it confirmed that the distributions of the inducing field can explain the phenomenon of subject contour rationally.

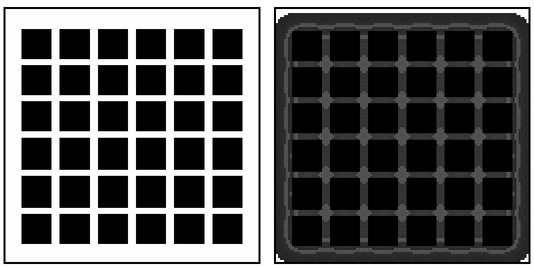
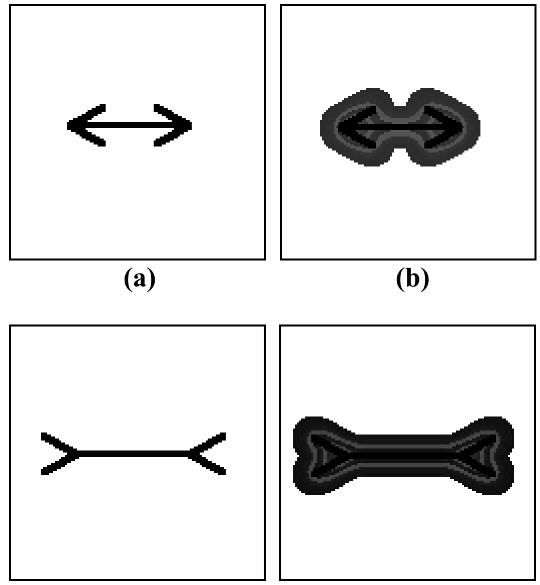


Fig.6. A typical grid figure (a) and the simulation result of the inducing field (b).

A typical Grid figure is shown in Fig.6.(a). It seems that the spot where squares intersect with each others is blacker than the background. Observing the simulation result (Fig.6.(b)), it is found that the strength of the inducing field of the intersection spot is different from the surrounding clearly. It confirmed that the distributions of the inducing field can explain the phenomenon of Grid figure rationally.

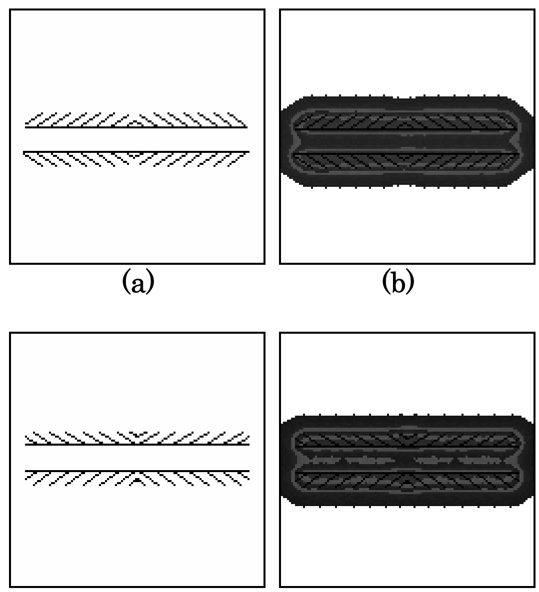
Yokose [5], Honngawa [4] investigated the Müller – Lyer figures with psychophysics and electrophysiology methods, respectively. They thought that the distribution of the psychological potential field / retina potential field is the generation factor of Müller–Lyer. We simulated the distributions of the inducing field of the Müller–Lyer figures, too. The results are shown in Fig.7.(b) and (d). The straight line of Fig.7.(c) seems longer than (a). We think that the inducing field of the straight line interfered by the inducing field of the “arrow-tail" which are on both sides of the straight line. We considered that this interference causes the emergence of the Müller–Lyer illusion.

Also, the results of the simulation can interpret the phenomenon of the Hering figures (Fig.8) very well. Based on the distributions of Fig.8.(b) and (d), it is clear that contour lines of the inducing fields around the center of the parallel lines are more narrower / wider than their terminals, respectively. Therefore, it makes observer feel that the center of the parallel lines is more narrower / wider than the terminals, respectively. It confirmed that the distributions of the inducing field can explain the phenomenon of Hering figures rationally.



(a) (b) (c) (d)

Fig.7. The Müller –Lyer figures (a), (c), and the simulation results of inducing fields (b), (d), respectively.



(a) (b) (c) (d)

Fig.8. The Hering figures (a), (c), and the simulation results of inducing fields (b), (d), respectively.

IV. Conclusion

Based on the stimulation results, the simulation results can explain some illusion phenomenon rationally. Therefore, it suggested that these illusions are probably engendered by the distributions of the inducing field in the retina which generated by the illusions stimuli. Furthermore, the practicality of the proposed model was also verified.

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