Science & Engineering

Studying visual illusion and vision through mathematical approach

Hitoshi Arai
Professor
The University of Tokyo

【Background】

In recent years, research on the vision has been rapidly developing hand-in-hand with the development of brain science. But many questions about vision remain. For instance, it is being clarified that certain functions of vision are closely related to certain areas of the brain. But little is known about how visual information is mathematically processed in these areas of the brain. I believe that advanced mathematics can effectively be applied to resolving this question. Almost no systematic research on the vision making the best use of advanced mathematics has been conducted.

【Results】

In my research method, a mathematical model of visual information processing in the brain is first constructed. I then test whether the model is appropriate for human vision. The test is carried out by using visual illusions. If my model is appropriate, a computer run on it will generate a visual illusion. On the other hand, an unknown mechanism of visual information processing may be speculated by finding a model on which a computer generates illusions.

To build a mathematical model, I initially used a mathematical tool called a wavelet frame. In a unified method, I successfully made a computer create a certain type of visual illusion thought to be generated in the primary visual cortex of the brain (V1). I later developed with my research partner Shinobu Arai improved wavelet frames to make them more suitable for the neuroscience of vision. With these wavelet frames, we mathematically analyzed fractal spiral illusions that we discovered. We not only identified the factor of these illusions but also eliminated the illusions by removing the factor (Fig. 1). We believe that our wavelet frames are closely linked to neurons in visual area V4 of the brain.

【Outlook】

We believe that the wavelet frames developed this time can be applied to building a mathematical model of visual area V4. They may also be applied to image processing and other applications. We are sure that our study and other mathematical research on the vision and visual illusion will lead to the discovery of new mathematics.

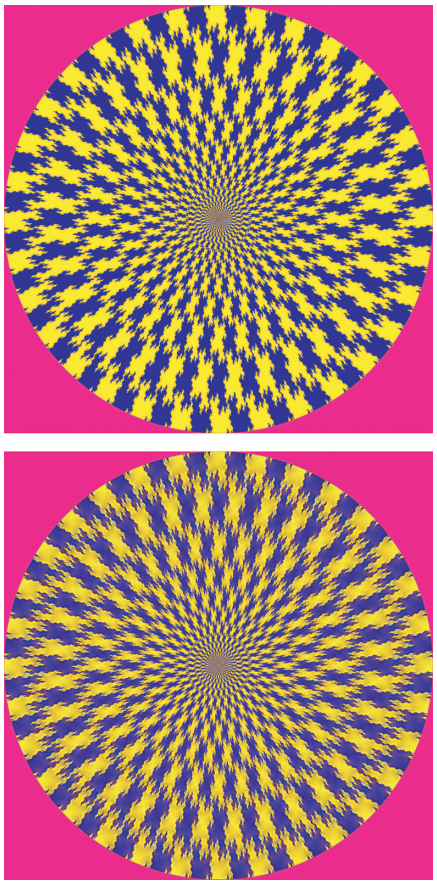

Fig. 1
Upper picture: Fractal spiral illusion; the concentric circularly arrayed fractal islands look like they are whirling.
Bottom picture: Removing the factor of visual illusion through wavelet frame analysis

Related Grants-in-Aid for Scientific Research:

FY2004-2005 Grant-in-Aid for Exploratory Research: "Research on visual information processing and visual illusion with wavelet"
FY2004-2006 Grant-in-Aid for Scientific Research (B): "Multi-wavelet frame and its application to harmonic analysis"
FY2007-2009 Grant-in-Aid for Scientific Research (B): "Study on harmonic analysis and its application to multidimensional signal processing"