Visual Illusions Expressed by Deep Neural Networks

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ABSTRACT

The predictive coding theory, which is one of mathematical models of the visual information processing of the brain, were incorporated to deep neural networks. We found that the deep neural networks represented the motion for illusion images that were not moving physically, much like human visual perception.

1 Introduction

It is said that the cerebrum cortex learns the world in unsupervised manner (or self-supervised manner), and predicts the spatiotemporal structure of objects to digest the constantly obtained visual information in real time. Furthermore recently, the visual researcher generally assumes that region in the brain responsible for sensory perception interpolates inevitable neural delay to adapted to the world. Predictive coding [1] is one of the most influential theory that can comprehensively explain the information-processing mechanism of the visual system of the cerebral cortex, and this theory assumes that such inner system predict the outside world and is updated to minimize error between prediction and obtained actual information. This system is constructed with the multi-layer and reciprocal pathways which feedback pathways connecting to higher-layer from lower-layer and feedforward pathways connecting to lower-layer from higher-layer. Feedforward signals propagate prediction signals calculated in each layer and feedback signals propagate differences between prediction signals and input signals as error signals. Our research group focused on the theory and pointed out noticeable relationship between human misperception on visual illusions and the predictive coding information processing of the visual cortex. [2] The visual illusion, which is

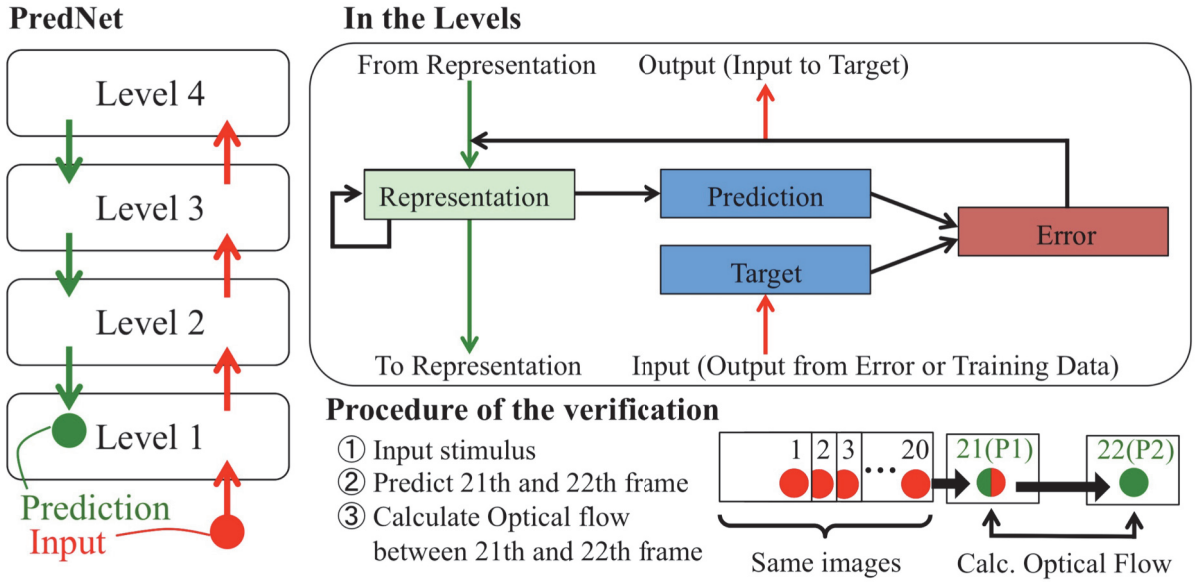

Fig. 1 Overview of PredNet and verification.
PredNet is constructed four layers and reciprocal connection, and each layer have four modules. Feedback pathways propagate prediction signal and feedforward pathways propagate error signal. Stimuli inputted at level 1 are subtracted with predictive image based on predictive learning with at error module, and propagate to higher level. Considering perceptual information is this predictive image, in this verification, optical flows are calculated between predictive image P1 and P2 which is predicted from P1.

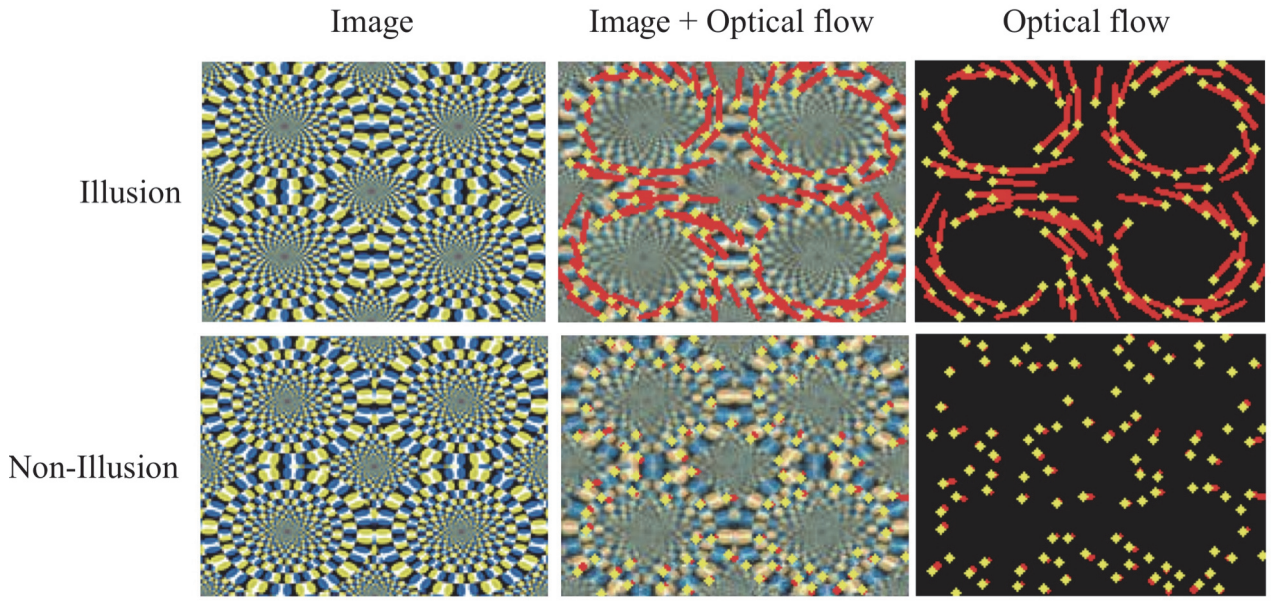

Fig. 2 Images and optical flows for Akiyoshi Kitaoka's rotating snake illusion and its negative control.

In rotating snake illusion (upper left figure), four rings induce the rotating motion perception in the direction of clockwise and counter-clockwise. The DNN model predicts the rotational motion (upper center and right figure) in direction as like human perception. On other hands in negative control against rotating snake illusion (lower left figure), all rings do not induce the motion.

utilized to analyze the mechanism of visual processing in ordinary brains and to study psychiatric disorders, may contribute to the study models of the brain.

PredNet [3], which is developed as deep neural network (DNN) for video prediction based on predictive coding theory, calculates the future frame for video sequence. These local predictions are made by backward information from higher-layer, and difference between prediction and obtained data is propagated from lower-layer for prediction in next time step as shown Fig. 1. Mathematical technic for DNN is broadly applied in the real world. Therefore understanding of mechanism for generation of visual illusion is also important in field of DNN application as risk management.

2 Method

Our research group ported PredNet written in Keras to Chainer for convenience, thus dataset was inputted to the DNN to learn the spatiotemporal structure of the world in the unsupervised-manner. The training dataset is about 530K still JPEG images (width of 160 × height of 120 pixels) made by natural scene videos (Sampling frequency is 30 fps) of the self-motion of the viewer. Note that taking difference of training component among videos into account, this trained DNN is considered to one predictive coding model.

When stimuli are inputted to the DNN model, 20 same images copied by stimuli are utilized as input data without update of inner system. The DNN model predicts 21st frame P0 subsequently to 1 to 20th images, and 22nd image is predicted by P0 as input data to calculate optical flow vector which is made between P0 and P1 by Lucas-Kanade method.

3 Result

3.1 Representation of motion illusion [4]

Fig.2 shows rotating snake illusion, which induce motion perception in spite of the static image, and optical flow vector of its prediction by the DNN model. In the optical flow image, yellow points indicate start point of optical flow vector and red lines indicate absolute and direction of motion. Four rotating directions of optical flow in the figure are difference, and each direction is corresponded to human perception. Furthermore negative control image, which doesn't induce motion perception, didn't detected motion perception by the DNN model. This result supports that predictive coding can explain human perception.

3.2 Finding exception

Detail verification of representation of the motion illusion was conducted for generality of reproducing illusory motion is confirmed and

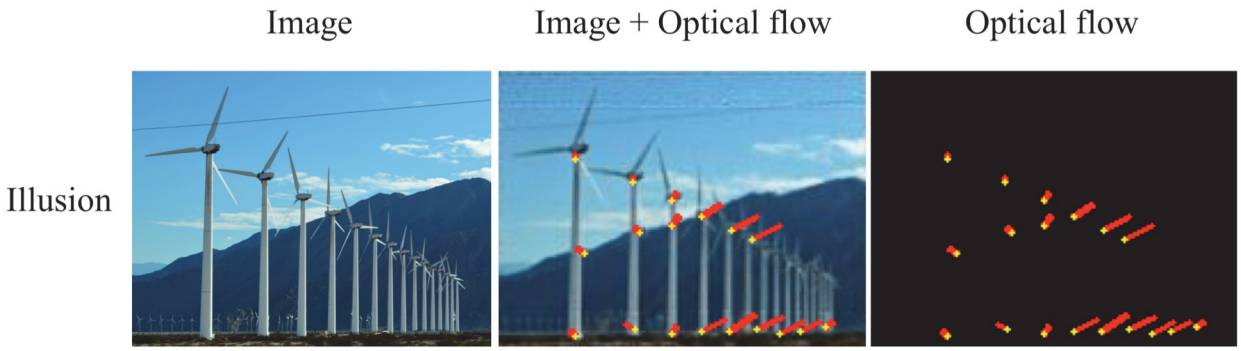

Fig. 3 Example of exceptional image and its optical flow.
Exceptional image (left figure) seems to be no illusionary motion by human perception. However the DNN model detects the motion as shown figure center and right.

finding exception of the prediction. In this verification, 300 visual illusions and 1500 general images composed of arts and photographs which seems to do not induce motion perception in human were prepared. In this result, in almost cases the DNN model could identify motion illusions from the stimulus, and represent illusionary motion. However, there are some irregular cases in general images which were detected motion perception by optical flow analysis as shown in Fig.3. Although this perception does not occur in human perception, human is able to detect the motion perception to make artificial image as shown Fig.4. These results present a border about same corresponding part and different part between actual human perception and mathematical model.

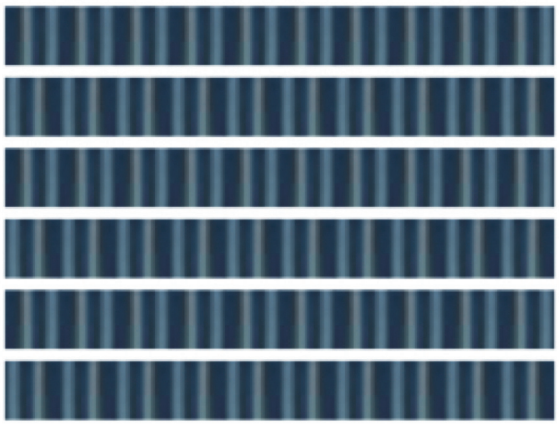

Fig. 4 Motion illusion made by the DNN model.
The motion illusion is made to align the trimmed image of Fig. 4. In trimmed region, especially large motion vector is detected by the DNN model. This figure induces motion perception in also human perception.

4 Discussion

The DNN model predicted the rotating illusion in manner similar to human perception. This result indicates that application based on predictive coding can be expected to use as simulator of brain information processing to understand brain function. To understand the mechanism of generation of motion illusion, research of what component in the training dataset is effect such reproducing and analysis of inner system is necessary. However, although this verification results were notable, they did not accurately reproduce the illusory motion perceived by humans. In addition to finding exception, even reproducing of motion perception for rotating snake illusion is strictly different to human perception, in which illusory rotation of a ring does not occur due to direct attention. Predictive coding is simple model without brain function such as attention, saccade, and central vision. This model has still potential to close to actual human perception by implementation of other brain function.

5 Acknowledgment

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Refference

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