

**LABORATORY OF NEUROPHYSIOLOGY**



Associate Professor  
**WATANABE, Eiji**

*Specially Appointed Assistant Professor:*

**KOBAYASHI, Taisuke**

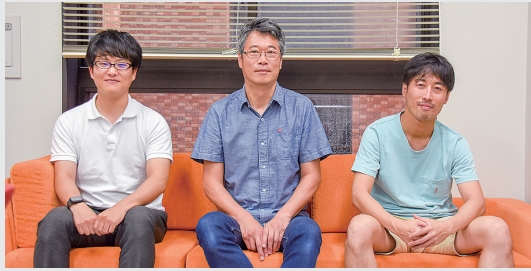
*JSPS Postdoctoral Fellow:* **NISHIUMI, Nozomi**

*Visiting Scientist:* **KOMATSU, Hidehiko**

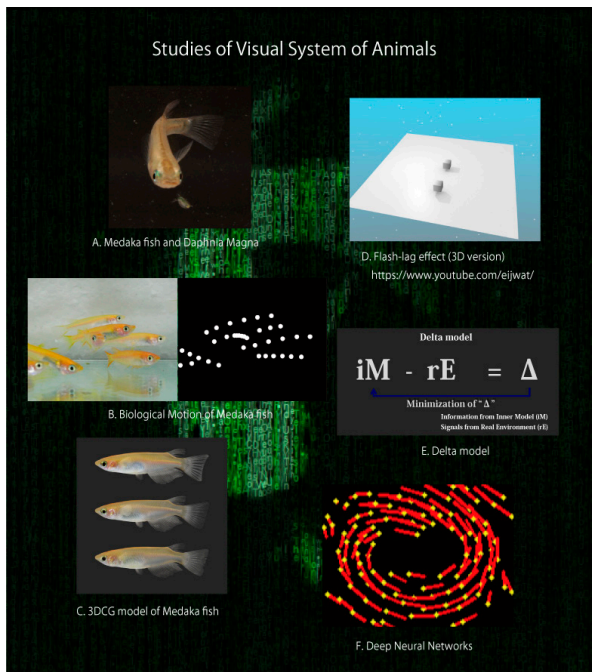
*Technical Assistant:* **WATABE, Mihoko**

**TSURUMARU, Mayumi**

**SUGINAGA, Tomomi**



We believe that the best way to understand mechanisms underlying a certain system is to reconstruct the system as it exists. By utilizing computer technologies, we are accordingly trying to build the systems based on psychophysical and ecological viewpoints in particular to understand systems of animal perception and behavior. This type of methodology based on computers will pave the way for biology in the future.



**I. Psychophysical study of medaka fish**

One of our major subjects is the psychophysical and computational study of medaka (*Oryzias latipes*, Matsunaga & Watanabe, 2010). We have made progress in studies of prey-predator interaction using both these organisms and zooplankton. Visual motion cues are one of the most important factors for eliciting animal behaviors, includ-

ing predator-prey interactions in aquatic environments. To understand the elements of motion that cause such selective predation behavior, we used a virtual plankton system where we analyzed the predation behavior in response to computer-generated plankton. As a result, we confirmed that medaka exhibited predation behavior against several characteristic movements of the virtual plankton, particularly against a swimming pattern that could be characterized as a pink noise motion (Matsunaga & Watanabe, 2012). As a side-story, we analyzed the swimming behaviors of adult water flea *Daphnia magna*, and found apparent sexual differences: laterally biased diffusion of males in contrast to the nondirectional diffusion of females (Toyota *et al.*, 2022).

Many fish species are known to live in groups, and visual cues have been shown to play a crucial role in the formation of shoals. By utilizing biological motion stimuli, which in this case was the depiction of a moving creature by using just a few isolated points, we examined whether physical motion information is involved in the induction of shoaling behavior. We consequently found that the presentation of virtual biological motion can clearly induce shoaling behavior, and have shown what aspects of this motion are critical in the induction of shoaling behavior. Motion and behavioral characteristics can be valuable in recognizing animal species, sex, and group members. Studies using biological motion stimuli will further enhance our understanding of how non-human animals extract and process information which is vital for their survival (Nakayasu & Watanabe, 2014).

Additionally, we have developed a novel method for behavior analysis using 3D computer graphics (Nakayasu *et al.*, 2017). The fine control of various features of living fish has been difficult to achieve in studies of their behavior. However, computer graphics allow us to systematically manipulate morphological and motion cues. Therefore, we have constructed 3D computer graphic animations based on tracking coordinate data and photo data obtained from actual medaka (Figure 1). These virtual 3D models will allow us to represent medaka more faithfully as well as undertake a more detailed analysis of the properties of the visual stimuli that are critical for the induction of various behaviors. This experimental system was applied to studies on dynamic seasonal changes in color perception in medaka (Shimmura *et al.*, 2017), and on underwater imaging technology (Abe *et al.*, 2019 and Yamamoto *et al.*, 2019).

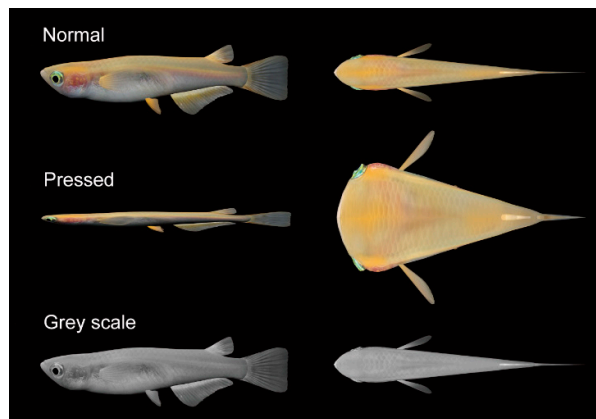


Figure 1. Virtual medaka fish.

## II. Psychophysical study of human & AI vision

Another of our major subjects is the psychophysical and theoretical studies of the visual illusions experienced by human and artificial intelligence (AI). One recent focus of this debate is the flash-lag effect, in which a moving object is perceived to head towards a flashed object when both objects are aligned in an actual physical space. We developed a simple conceptual model explaining the flash-lag effect (Watanabe *et al.*, 2010).

In recent years, we have made more developed novel visual illusions, such as the shelf-shadow illusion (3rd Award of the Illusion Contest), the Monstre Benham illusion (2nd Award), the Morning Monster Illusion (10<sup>th</sup> Award), and the Genkikan Illusion (Figure 2).



Figure 2. Okazaki Genkikan.

Watanabe (NIBB) and Sinapayen (Sony CSL) got 2nd place at the 13th Visual Illusion Contest, for the Okazaki Genkikan Illusion. It is one of the Poggendorff illusions. (<http://www.psy.ritsumei.ac.jp/~akitaoka/sakkon/sakkon2021.html>). It was found in Okazaki Genkikan Facility.

In 2018, we successfully generated deep neural networks (DNNs) that represent the perceived rotational motion for illusion images that were not physically moving, yet similar to what we experience in human visual perception. (Watanabe *et al.*, 2018). These DNN computer models will help to facilitate our future work on perception science. This experimental system was applied to studies on evolutionary illusion generator in collaborating with Dr. Lana Sinapayen (SONY CSL) (Evolutionary Generation of Visual Motion Illusions, <https://arxiv.org/abs/2112.13243>, Sinapayen and Watanabe, 2021). Currently, a variety of research is being conducted using these AI systems (<https://arxiv.org/abs/2106.12254>).

In 2022, we examined the properties of the network using a set of 1500 images, including ordinary static images of paintings and photographs and images of various types of motion illusions (Visual Illusions Dataset, <https://doi.org/10.6084/m9.figshare.9878663>). Results showed that the networks clearly classified a group of illusory images and others and reproduced illusory motions against various types of illusions similar to human perception. Notably, the networks occasionally detected anomalous motion vectors, even in ordinarily

static images where humans were unable to perceive any illusory motion. Additionally, illusion-like designs with repeating patterns were generated using areas where anomalous vectors were detected, and psychophysical experiments were conducted, in which illusory motion perception in the generated designs was detected (Figure 3). The observed inaccuracy of the networks will provide useful information for further understanding information processing associated with human vision (Kobayashi *et al.*, 2022)

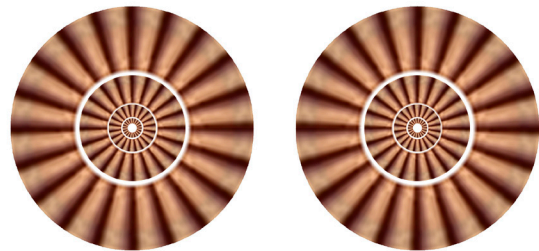


Figure 3. A visual illusions extracted by AI

## III. Ecological study of tactics in predators and prey.

We are interested in behavioral interactions between predators and prey concerning the ecological aspect. In the process of the co-evolution, predators and prey have developed various tactics to overcome each other. To elucidate the sophistication of these tactics, we have examined the mechanisms and efficacies of predatory and antipredator behaviors of several animals such as fish, dragonflies, bats and birds. In addition, we have developed experimental system for those studies, which present interactive virtual predators to prey animals based on animation (Figure 4) or robotics. This experimental system consists of three modules as a sensing, a command generating and a virtual animal module. According to the spatial scale, the system employs appropriate technologies in each module. For example, in a small aquarium scale, we use high speed cameras as a sensing module and virtual reality animation as a virtual animal module. On the other hand, in a large outdoor scale, we use real-time GPS as a sensing module and unmanned aerial vehicle as a virtual animal module. Therefore this system are able to cover wider range of animals and expected to strongly support the study of animal interactions.

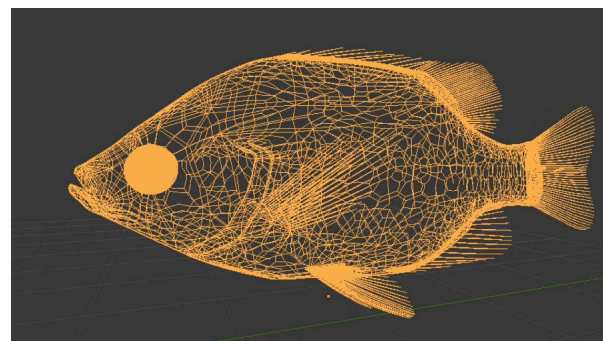


Figure 4. A computer animation of the virtual predatory fish.

**Publication List:**

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**[Original paper]**

- Kobayashi, T., Kitaoka, A., Kosaka, M., Tanaka, K., and Watanabe, E. (2022). Motion illusion-like patterns extracted from photo and art images using predictive deep neural networks. *Sci. Rep.* *12*, 3893. DOI: 10.1038/s41598-022-07438-3