Hybrid Synthetic Approach to Animal Interaction

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Introduction

Not only studying and analyzing real lives on earth but also creating life as it could be on computer simulations can be our strong method to understand what life is (Langton, 1989). It becomes the main philosophy in artificial life community and various types of simulations have been developed in different levels of life such as artificial chemistry, evolutionary robotics, multi-agent social system, etc. The synthetic approaches have been applied not only to computer simulations but also to chemistry and robots in our real world. Regardless of the virtual or real world as experimental grounds, when we can reconstruct life there, we could understand the essential mechanisms that make an entity capable of being life.

Those experiments have been performed in either real or virtual world separately. As rather new direction, in this paper, we investigate a hybrid synthetic approach that combines the real and virtual experiments. In biology, there is a close idea for our hybrid synthetic approach called playback experiments where real animals interact with the virtual individuals, which can be robots or computer graphics displayed on a monitor. For example, Nakayasu et al. examined how much real medaka (small fish, *Oryzias latipes*) can be attracted by the computer graphics animation or the biological motions, which has been made from the actual behaviors of medaka (Nakayasu and Watanabe, 2014). They showed that the color, shape, and movements of the virtual individuals affect the real medaka's movements and change attractiveness.

However, the playback experiments cannot be our hybrid approach in a sense that real individuals just react to virtual one and there is no mutual interaction. In the real interactions, the behaviors that individuals have performed in the past affect the future behaviors of the others mutually. It is known that the mutuality is important for the interaction in the human and animal interactions. In this paper, we establish a hybrid experiment where the real and virtual individuals interact with each other and investigate if there is a difference between mutual and playback interactions. We used medaka for test animals for the sake of the simplicity of establishing an experiment environment.

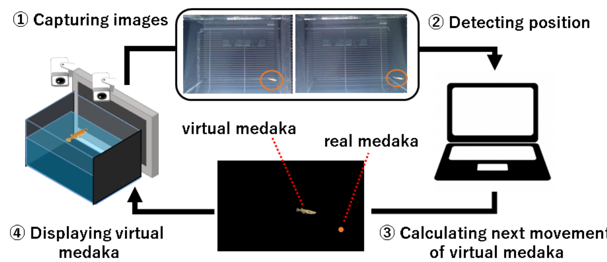

Figure 1: Experimental environment.

Experiment

Our experimental environment consisted of an aquarium tank, OLED display attached on the side of the tank, and two web cameras to detect the real medaka positions (Fig. 1). The glass walls at the bottom and both sides of the tank were covered with black plastic sheets to shut out the other visual stimulus. The three dimensional positions of the real medaka were detected by two cameras.

The movement of the virtual medaka was controlled by the Boids rules (Reynolds, 1987). Because the movements of the virtual medaka are restricted on the 2-D plane of the monitor, the positions of the real medaka is projected onto the 2-D plane of the monitor and the virtual medaka moves on the plane while following the Boids rules. The position and velocity vectors of the virtual medaka v_v, p_v were updated according to the Boids rules as follows,

$$\boldsymbol{a}_v^t = \alpha(\bar{\boldsymbol{p}} - \boldsymbol{p}_v) + \beta \sum_i \frac{(\boldsymbol{p}_i - \boldsymbol{p}_v)}{\|\boldsymbol{p}_i - \boldsymbol{p}_v\|} + \gamma(\bar{\boldsymbol{v}} - \boldsymbol{v}_v) \qquad (1)$$

where α, β, and γ are coefficients that describing the influence of cohesion, separation, and alignment, respectively. The bars show the averages of other individuals including real and virtual ones. In our current experiment, there are only one each for the real and virtual medaka, which means that the average position and velocity are equal to the position and velocity vectors of the real medaka. The virtual medaka has the view range R, and moves as described above when the distance to the real medaka is smaller than R. Otherwise, it moves simply go straight and turn when reach the edge of the 2-D space. The motions of the virtual medaka was created by exchanging the medaka images, which were prepared using female 3D medaka model shared in figshare (Watanabe, 2017)

The experiment consisted of three different conditions, i.e., reactive (mutual), non-reactive (playback) and blank. No stimulus was presented to the medaka in the blank condition. Under the reactive condition, the virtual medaka moved in accordance with the Boids rules, which reflected the current real medaka motions. During this condition, the whole movements of the virtual medaka were recorded. The recorded video was replayed under the non-reactive condition. It means that the visual stimuli to the real medaka of the reactive and non-reactive period were identical. The difference is that the movements of the virtual medaka in the reactive period were generated in an online manner as a result of ongoing interaction while it was just playback in the non-reactive period. The experiment was performed in the order of blank (blank1), reactive, blank (blank2), non-reactive conditions for all medaka participants ($N = 10$). Each condition lasted three minutes.

Results

We recorded the three dimensional positions of the real medaka during the experiments. Figure 2 shows the examples of the spatial distributions of the real medaka during reactive and non-reactive conditions. The colors of the plots indicate the passage of the time. The medaka was attracted to the display for longer time when the virtual medaka moved in a reactive way. On the other hand, when the non-reactive stimulus was presented, the medaka was hardly attracted to the display.

In order to confirm the effect of mutuality, we measured the total time when the medaka staying near the display (within 3cm from the display) during each stimulus period. Figure 3 shows the average staying time of all 10 medakas during the period of each condition. The medaka was most attracted to the display when the reactive stimulus was presented (red line, about 78 sec over 3 min in total). Soon after the reactive period, the real medaka tended to stay close to the monitor as the hysteresis effect but gradually it went away from the monitor. The staying time in the playback period (blue line, about 46 seconds in total) was longer than the blank1 period (black line, about 21 sec in total). These results show that the mutuality contributed to attract the medaka.

Discussion

In our current study, the virtual medaka was controlled by the Boids rules which can generate realistic swarm behaviors. The hybrid approach shows that there is a difference

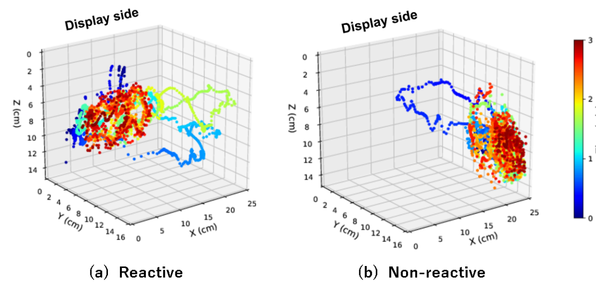

Figure 2: Examples of spatial distribution of real medaka during (a) reactive and (b) non-reactive periods.

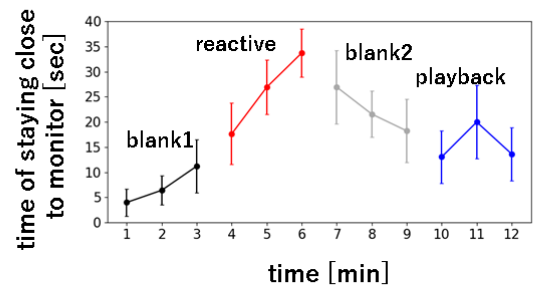

Figure 3: Averaging time when the distance between the real medaka and the monitor is less than 3 cm. It is obtained every minute. The bars show the standard errors.

in the medaka reactions between reactive and non-reactive experiments. It shows that the Boids interaction rules have an ability to establish an interaction with the real medaka. It seems that these abilities of generating realistic swarm behaviors among multiple agents and establishing an interaction with real individuals are different but our results suggest that they might be related. On the hand, it is not clear if the Boids algorithm is the best for our experiment. The reason why we chose it is because there is no choice in the other simple algorithms. To find the better algorithms becomes an interesting challenge but it would not be simple. This could be achieved by having ALIFE challenges as a competition.

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