Fish Catching by Adopting Chaos to Robotic Intelligence

見浪　護, 高　敬宇, 前　泰志, 吉田　俊章, ◯平尾　潤 (福井大学)
Mamoru Minami, Gao Jingyu, Yasushi Mae, Yoshida Toshiaki, Hirao Jun
Fukui, University of Fukui, {minami,gao,mae,yoshida,hirao}@rc.his.fukui-u.ac.jp

Abstract: We tackle a Fish-Catching task under a visual feedback hand-eye system with catching net. The fishes change escaping trajectory or speed up when being threatened as the net attached at hand approaches to them. Furthermore, as the time of tracking and catching process flows, the fish can somewhat get accustomed to the hand motion pattern and gradually find out new strategies on how to escape from the bothering net. For example, the fish can swim slowly along the pool edge where the net is forbidden to enter or keep a reasonable distance from the net as if it konws the visual servoing system bears steady state error by constant speed escaping. For the sake of such innate ability being widely existed in animal's behavior, the catching operation becomes tough and some effective intelligent method needs to be conceived to go beyond the fish's intelligence. The purpose of this research is to construct intelligent system to be able to exceed the fish's intelligence to survive. Then we embed chaotic motion into the hand motion of robot, and we have shown the chaotic net motion can overcome the fish escaping strategies.

Keywords: 1-Step GA, Gazing-GA, BVP model, Chaotic motion, IDI

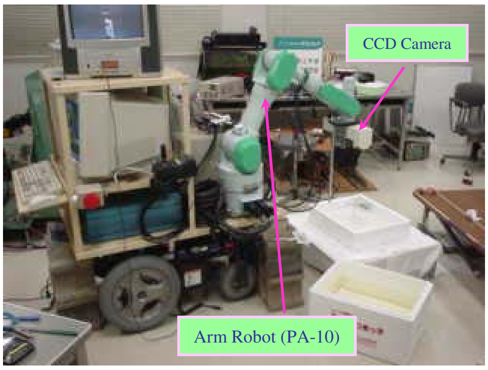


Figure 1: The fish catching system

1. Introduction

Visual servoing has been executed successful in our lab and applied to fish-catching experiment successfully[1]. The hardware composition for Fish-Catching mainly includes three parts: Host computer, CCD camera, and the 7-link manipulator shown in Fig.1. By adopting the visual system provided by CCD camera, fish recognition has been performed from the successive input video rates.

With the combination of proposed Gazing-GA[1] and 1-Step GA method, the real time recognition is performed and its process is shown in Fig.2. The CCD camera gets successive images every $33ms$ shown in Fig.2(a), one image corresponds to one time GA evolution (so-called 1-Step GA). Then the fish recognition is performed shown in Fig.2(b) and once the fish is spotted, the fitness value can become large enough for the hand-eye to switch to local recognition process (so-called Gazing-GA). Then based on the designated position from the top GA, the visual servoing will be performed and the pa-10 will move to track the target fish shown as Fig.2(c). The recognition result is shown in Fig.3, where we can see even there are some water plants in the pool, the place where fish exists also comes to the largest fitness value so the fish can be recognized successfully regardless of the existence of noise in real-time. By analysis of Fig.3, we can see the position with peak fitness value will move in real-time in coincidence with the position of the target fish swimming in the pool.

2. Purpose and Motivation

By adopting the fish-catching system shown in Fig.1 and based on the system control flow shown in Fig.4, we did the experiment described as below: 8 fishes (with length about 40[mm]) are released in the pool in advance, and once the fish got caught it would be released to the same pool at once. The result of this experiment is shown in Fig.5, in which vertical axis represents the number of caught fishes and horizontal axis represents the catching time. We had expected that the capturing operation would become smoother as time flew on consideration that the fishes may get tired and their swimming speed can slow down. But to our astonishment, the fish-catching number decreased gradually.

The reasons of decreased catching number may lie in the fish learning ability or emotional factor stated before. For example, the fish can learn how to run away around the net shown in Fig.6(a) by circular motion with about constant distance from the net. Also, the fish can keep swimming within the narrow strip area along the pool

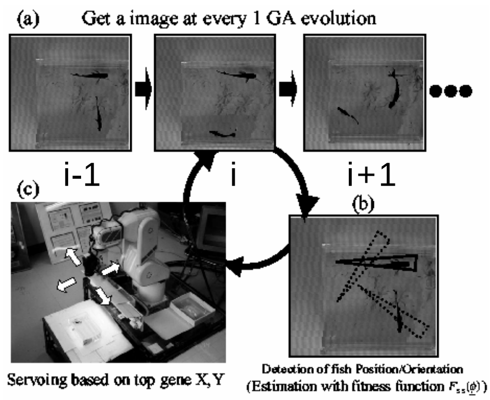


Figure 2: The process of recognition based on the updated images in real time

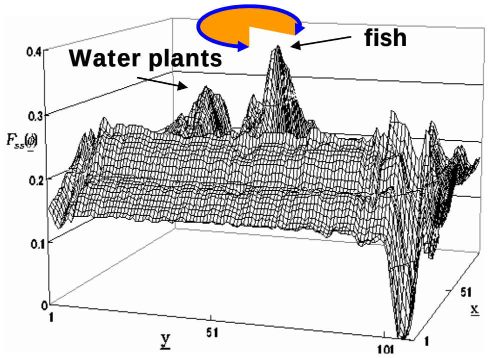


Figure 3: The recognition result

edge where it is prohibitated for the net to enter shown in Fig.6(b). In order to solve the problem that may happen as above, more intelligent system needs to be constructed to track and catch the fish effectively. So the purpose of this research is to find an effective way to resist the fish intelligence acted as escaping strategies stated above, in other words, we will dedicate ourselves to constructing one more intelligent system in order to exceed the fish escaping intelligence.

3. BVP chaos generator

3.1 Chaos and neuron

In our research, we will embed chaos into the net motion to overcome the fish ingelligence for escaping strategy. Here we would like to show the reasons why we adopt chaos for intelligence realization of robot. The chaotic regulation has close relationship with biology: Chaotic abnormal excitement had been apparently revealed in the experiment in 1982, where the vegetable cell and the nerve of mollusk had been periodically stimulated with electric current[2]; Furthermore in 1984, the periodical electric current had also been exerted to the gigantic axon of squid and apparent chaotic response had also been obtained [2]; In the later 1980s, some relationship existing between chaos and neural system has been

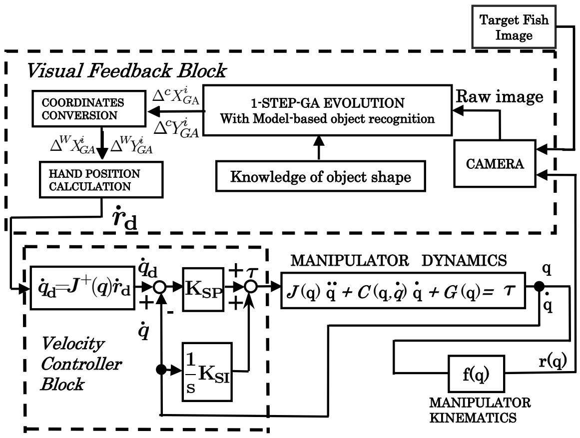


Figure 4: Block diagram of the controller

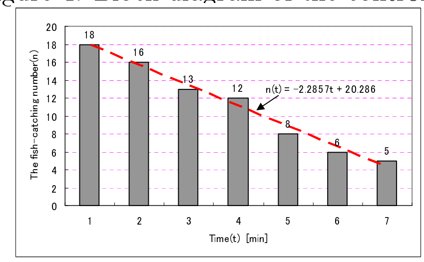
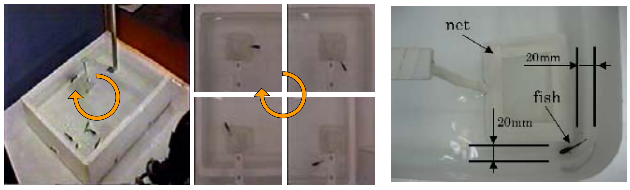


Figure 5: Result of catching number



(a) Motion (1) of a fish (b) Motion (2) of a fish

Figure 6: Fish motion pattern

proved, in order to investigate the exciting pattern of sea cucumber motion nerve, Mpitosos research group has shown that the frequency fluctuation of the continuous discharge that has relationship with the motion rhythm is subjected to the chaotic regulation [2].

3.2 BVP model

The BVP model is a simplification of the Hodgkin-Huxley model. Though the solution of the BVP model in not necessarily in complete coincidence with the real experiment result, the behavior of BVP equation can successfully regenerate the characteristic of the nerve membrane excitement in qualitative analysis, and it is a simplification of the Hodgkin-Huxley model because its differential equation becomes easier to solve in mathematics. BVP model has the satisfactory performance for representation of the nerve or neuron's excitement pattern. Based on the analysis above we make a trial to apply BVP model for mimicking the animal behavior in this research. FitsHugh proposed BVP model in order

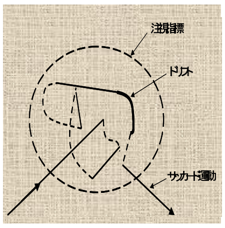


Figure 7: eye-motion

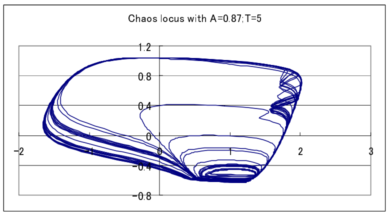


Figure 8: Chaos trajectory

to generate the chaotic motion in the potential plane[2]. The BVP equation can be deduced from the following differential equation.

$$\ddot{x} + c(x^2 - 1)\dot{x} + x = 0 (c > 0) \tag{1}$$

Through some transformations, the BVP simultaneous differential equation can be finally acquired as below:

$$\begin{aligned} \dot{x} &= c(x - \frac{x^3}{3} + y + z) \\ \dot{y} &= -\frac{x + by - a}{c} \end{aligned} \tag{2}$$

Here we make some biological explanation about x and y arisen from BVP differential equation. The item x denotes the value of reversal sign of membrane voltage in cell and y signifies the refractory nature. The item z represents pulse signal served as the outer stimulus signal. Based on the parameter setting shown in the paper [3], relatively ideal responsive result that is similar to the practical behavior of the nerve excitement can be regenerated by the BVP model, and the parameters a, b and c are confined as follow:

$$1 - \frac{2b}{3} < a < 1, \;\; 0 < b < 1, \;\; b < c^2 \tag{3}$$

4. Fish-catching experiments

4.1 1-Fish Catching experiments

By embedding the chaos signal solved by Eqn.2 (the trajectory is shown in Fig.8) into the net motion, following experiments were done in order to check the efficiency of chaos as one method for intelligence realization.

We took close observation into the fish tracking and catching experiment with chaotic motion embedded into the catching net. This experiment lasted for nearly 40s till the fish got caught successfully. During the first 9s, the net mounted at the 7-link manipulator tip sometimes moved round the pool regularly to search for the swimming fish and sometimes chased the fish once it appears in the camera vision area. After 9s, the fish began to swim slowly along the the pool edge where it is forbidden for the net to enter. In order to observe clearly how the chaotic motion would act effectively towards that kind of fish escaping strategy, we had taken a series of photoes

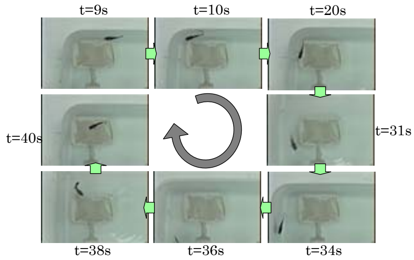


Figure 9: The fish-catching process by use of chaos

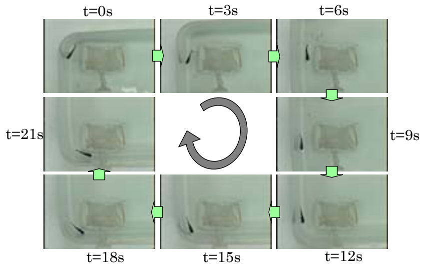


Figure 10: The fish-catching process without chaos used

during the remaining 31s shown in Fig.9. The picture with $t = 9s$ shows the fish began to swim slowly along the pool edge or stopped in the pool corner. After current condition that the fish was swimming slowly stick to the pool edge was confirmed, the net took chaotic motion during time interval from $t = 10s$ to $t = 31s$. The photoes from $t = 31s$ to $t = 36s$ show the process of the fish swimming out of corner and the visual servoing system lost the fish who exceeded the hand-eye view area when $t = 36s$. When the condition that the fish becomes out of the current camera vision area is satisfied, the net is designated to move towards the position that possibly be the next fish place after the fish got lost on the basis of N.N. prediction result, and the fish future position prediction with N.N. is being researched by a member in our lab. The target fish fell into the vision span again and the net reached the place in front of the fish from observation towards the photo with $t = 38s$. The fish was finally caught at $t = 40s$ once it fell into the net center. The camera vision frame is in accordance with the real input image. The net is preset in the origin of this camera frame and it will be pulled up rapidly when the fish swims into the rectangular area 80×60[mm] round the net center.

In order to show the optimal performance with chaos adoption into the experimental system, we also did the fish-catching experiment without chaos used and the target is the same fish with the one in Fig.9 that has the escaping experience. we also take a series of pictures every 3s when we do not use chaotic motion and the fish swims stick to the pool edge slowly. By observing the Fig.10 we can see the net only followed the fish outside the prohibited area. No matter how much time flows, the fish still stayed within the thin long strip area along the pool edge without daring to swim out, so the catching

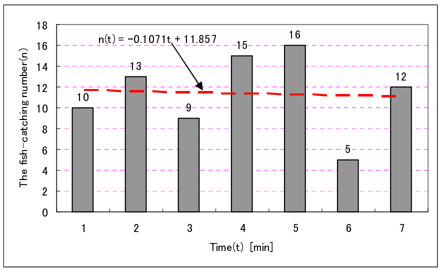


Figure 11: Fish-catching result

operation ended in failure this time.

4.2 plural-Fish Catching experiments

Under the same condition as the one in Fig.5, we also kept catching 8 fishes in pool continuously with chaos used. We recorded the catching number of fishes every 5 minutes. As analyzed before, the fish will generally get tired while being chased and caught continuously, in the meantime the fish will also get used to the net motion pattern. According to the result shown in Fig.5, the fish-catching number kept decreasing. But after we embedded the chaotic motion to net movement this time and the catching number of fish does not go down as shown in Fig.11.

Furthermore, we tried another experiment to examine whether the chaos adoption can prevent the decreasing trend of the Fish-Catching number by using one 8-fish group that is different from the fishes used in former experiments shown in Fig.5 and Fig.11. In this experiment we also released 8 fishes into the pool and keep tracking, catching and releasing operation continuously for 100 minutes: with mere visual servoing during the first 50 minutes and with visual servoing plus chaos in the remaining 50 minutes. The result is shown in Fig.12, where the horizontal axis represents time and vertical axis represents the Fish-Catching number recorded with a 5-minute time span. For convenience of observing the trend of Fish-Catching number, we adopt the linear Least-Squares approximation to fish-catching changing tendency analysis. We make separate analyses towards the two 50-minute periods and two linear functions can be generated. From the two approximated curves (denoted by n_1(t), n_2(t)) generated from Least-Squares method, we can see the Fish-catching number gradually decreases without chaotic motion used and after 50-minute catching operation it can generally keep above the level of 11 fishes after chaos adoption. Therefore, the effectivity of chaotic motion embedded into the catching-net's motion has been justified through the two experiments shown in Fig.11 and Fig.12 respectively from two different aspects.

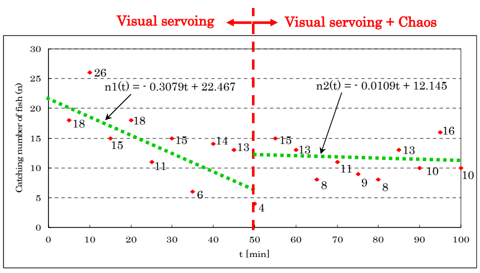


Figure 12: Data analysis of the Fish-Catching number

Up to now, as the numerical analysis towards the animal intelligence degree has not been performed, we want to make a trial to give a numerical definition for animal intelligence. The inclination of n_1 corresponding with the tendency of fish catching-number during the first 50 minutes is -0.3079, and the inclination of n_2 coinciding with the remaining 50 minutes is -0.0109. In order to give a material description about the intelligence competition between robot and animals, we define the inclination as the Intelligence Degree Indicator (IDI) for the fish group on the condition that the fishes swimming in pool are chased and caught continuously by the catching-net mounted at the robot hand. It is obvious that the smaller IDI value tends to be the higher intelligence level that the fish group can possess because the decrease in fish-catching number just shows that fishes have gradually become adaptive to the net. Furthermore, we consider the relationship between the robot and fishes can be figuratively described as the relationship between the predator and preys. The preys (fishes) can gradually generate adaptive ability (such as escaping strategies) to avoid the threatening predator (robot) for surviving because of the predator's continuous chasing and catching. From Fig.12, we can see the robot with chaotic motion used has effectively overcome the fish learning ability in the longtime intelligence competition process between them because the IDI has varied from -0.3079 to -0.0109. Therefore the chaotic modification can overcome the fish intelligence and is useful for the robotic intelligence realization.

5. Conclusion

We analyze the intelligent behaviors of fishes and make a trial of intelligence realizaiton by chaos. The optimal funciton of chaotic motion to exceed the fish's intelligence has been confirmed. We also make numerical analysis towards the fish intelligence degree and make a comparision on intelligence between robot and fishs.

References

[1] H. Suzuki, M. Minami, J. Agbanhan: "Fish Catching by Robot Using Gazing GA Visual Servoing", Transaction of the Japan Society of Mechanical Engineers, C-68-668, pp.1198-1206, 2002 (in Japanese)

[2] K. Aihara: "Chaos in Neural System", pp.126-151, 1993 (in Japanese).

[3] R. FitzHugh: "Impulses and physiological states in theoretical models of nerve membrane", Biophy.J.1, pp.445-466 (1961).