IMPLEMENTING ARTIFICIAL CATCHING-PREY BEHAVIOR USING FUZZY LOGIC ON FISH ROBOT

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Abstract

Fish robot has been interesting topic in Instrumentation and Control Research Group, Institut Teknologi Bandung. Some researches have been done to observe any possibility to make fish robot as real as the natural fish. In animal robot, realistic or natural behavior can be provided by its mechanical, electronics and software algorithm. By observing natural behavior of natural fish when pursuing a prey, trajectory could be obtained. And subsequently, patterns of speed caused by undulation of tail could also be derived. Furthermore, those patterns were approximated by manipulating fuzzy logic parameters. In the research, prey moved slowly compared with thrust speed of fish robot. The result shows that for some experimental range, fish robot could imitate natural-pattern of fish when pursuing a prey. The average speed to catch and trajectory have been chosen to become successful criteria.

Keywords- Fish Robot, Fuzzy logic, and behavior

1. Introduction

There are many research about locomotion of robot fish like was done by Hirata [3] in 1999. Dynamic motion of fish became the most interested topic for many years. Robot fish actually used fin to propulsive or turning. In animal robot, making robot as real as the natural animal was the main goal. Some behaviors of fish have been observed. One interesting behavior of fish being observed was the behavior to find its prey. Prey used to be small fish or other sea animal which has ability to escape when fish intended to catch them. Handoko, et.al. [3] has been studying the behavior of tail fish when pursuing a prey. The thrust speed as indicator to swim forward and C-turn speed as 180 degree turning speed indicator the agility to move a head of prey.

Based on fish swimming gait, ordinary fish could be classified into two categories: swimming with body and/or caudal fin (BCF) and swimming with Median body and/or Pectoral Fin (MPF). Every category represent the agility of its swimming and the power. The synergy of every fins and body could make hydrodynamic profile to overcome the water resistant and to break through wave pressure from forward. The undulation of body and tail (caudal) fin is shown on Figure 1 [4]. Some types of fish, like tuna, use its body and caudal fin to get acceleration when pursuing the prey or when they escape from predator. However, the other swimming gait like oscillatory swim used its pectoral fin to swim forward and maintaining stability (hovering) for example sun fish.

There are a lot of natural behavior according to appropriate agent which stimulate the behavior, for example the behavior of seeking food, mating and afraid. Almost all behaviors have special and same repetitive pattern for same species. Or it can be said that variety of behavior in the same species is very small. Unique pattern sometimes can be used to determine its species at least to determine the gender for mating behavior.

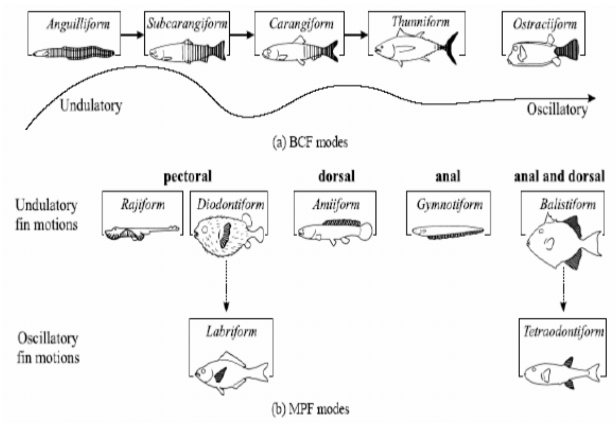

Figure 1. Swimming gait type and moving mechanism of fish: (a) Body and/or Caudal Fin (b) Median Body and /or Pectoral Fin [4]

2. Representing The Behavior Of Catching Prey

2.1. Natural Behavior of Fish

In this research, fish robot was designed by imitating the morphology of *Oreochromis niloticus*, local called Nila fish *Oreochromis niloticus* currently swimming in upper surface of water with no big current of wave come to its body. It usually has form like shown in Figure 2. Fish can make three motions: thrust (straight), yaw and

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turning. Rolling motion is not considered as normal motion although some fish like dolphin can do it easily. To move straight, fish uses its tail fin and tail peduncle, and to turn fish uses its body and tail fin. The undulation of its tail fin determines its speed. Other fin contributes in stabilizing the body and hovering.

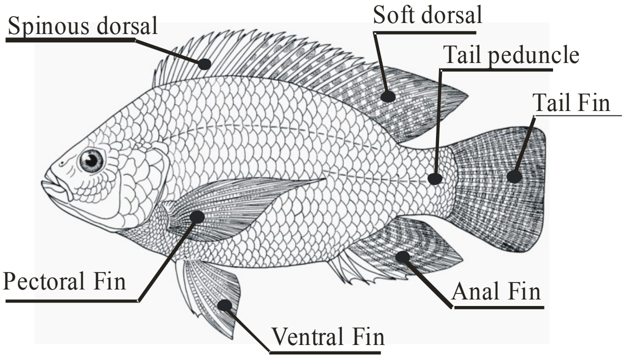


Figure 2. Fin morphology *Oreochromis niloticus (Drawing* by S. Laurie-Bourque) [9]

2.2. Design of Behavior Mode

As mention before, they are three primary behaviors of fish: a) finding food b) catching a prey and c) afraid (or escape). These primary behaviors sometimes call as basic animal instinct. To solve catching-prey behavior, usually fish accomplishes it by fast thrust and sometimes by fast turning. However, fast turning to catch prey was rarely done in some fish only the big predator as shark, barracuda and whale seem to do that style. Some of fishes have catching style by firstly they are lurking and meanwhile prey passes in front of them, they ambush and catch with fast action. The other catching style is fish continuously chasing prey before they catch. This catching style needs high acceleration. So, the catching-prey styles can be divided into two styles. First, catching with high initial speed and the other styles is catching with high acceleration. All styles need fast swimming supported by the body and tail fin. The orientation of body and tail fin determine the speed and direction of its swimming. From experiment and observation was done by Hirata [3] and Handoko, et.al. [1, 2], found that the speed of thrust and turning mostly done by its tail fin. The undulation frequency of tail fin and the orientation of its tail has been chooses as important parameter. The research of them applied three mode of tail fin.

Mode A

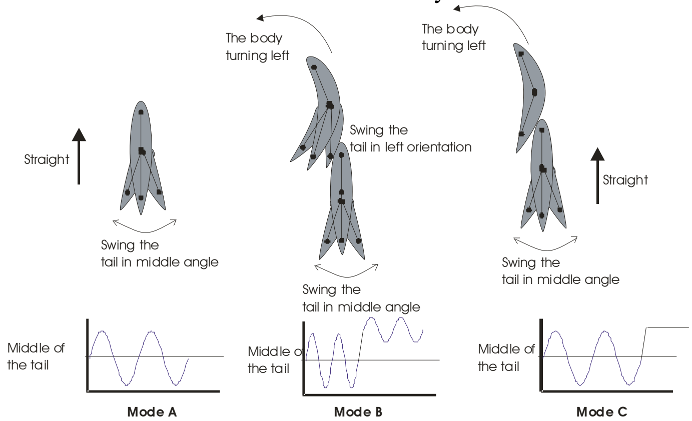
Figure 3.(a) shows the case of Mode A. The fish robot made some undulation swing on its tail around the center line of body. Mode A is dedicated to thrust mode for straight swimming and escape behavior. There is some range of high frequency of tail swing which can achieve fast thrust that represents escape behavior. In this mode, the body makes some little turning angle with different direction to the turning angle of the tail. Head of fish robot are equivalent to a rudder; the body and the tail fin are equivalent to a screw propeller of the ship.

Mode B

Figure 3.(b) shows the case of Mode B. Firstly the fish robot attempts to do Mode A than followed by the angle of body turned for some little turning angle. The tail fin accelerates the turning mode by making undulation with one side orientation. One side orientation is undulation in half side on the left or right from center line of tail with angle tendency not in middle angle. The last swimming gait is done until the fish turning into 180 degrees. This mode simulated the catching action when fish pursuing prey and the prey escape by turning action. It is also simulated the escape behavior when fish try to loss from predator coming from in front direction.

Mode C

In this mode as shown in Figure 3.(c), the tail makes Mode A first for a while then the tail stop at some angle. The body makes some angle at the time of tail being stop. This mode simulated condition when fish has captured the prey and fish let its tail at some angle. By kinetic energy the fish could turn without move its body or tail fin.



(a) (b) (c)

Figure 3. The three behavior of catching and escape mode

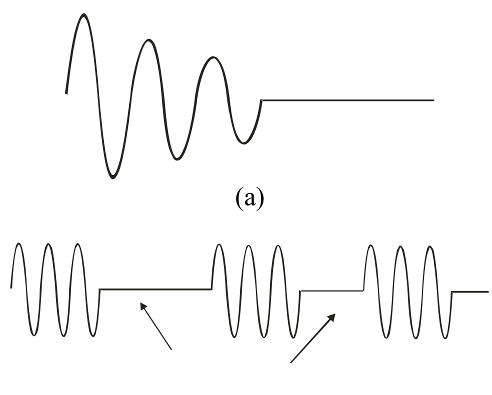


Figure 4. (a) High Initial Speed (HIS) styles; (b) High Acceleration (HA) Styles

Based only on mode A, the catching-prey behavior is made. For High Initial Speed (HIS) Styles the tail fin is made to do some series of mode A with firstly with high amplitude and followed by long delay as shows on Figure 4 (a) and for High Acceleration (HA) styles was made by series of mode A with constant amplitude and separated with gradually decreasing the time delay.

The Fish robot used in this research has one DC motor, one controller with two joints. The HIS style is easy to made because the normally DC motor when attached with hydrodynamic pressure will gradually lose its energy. HA-style is made by implementing a different time delay for every segments of mode A which drive by fuzzy logic. Proximity sensor attached on the body will be the single transducer used in this experiment. The orientation of tail fin is forced to remain in the center using rubber rope.

2.3. Design of Prey

The prey is the small wood-object controlled manually by hand to locate at desired location. The made-man prey is not designed to fully sink in the water.

2.4 Fuzzy Logic Algorithm as Behavior Imitator

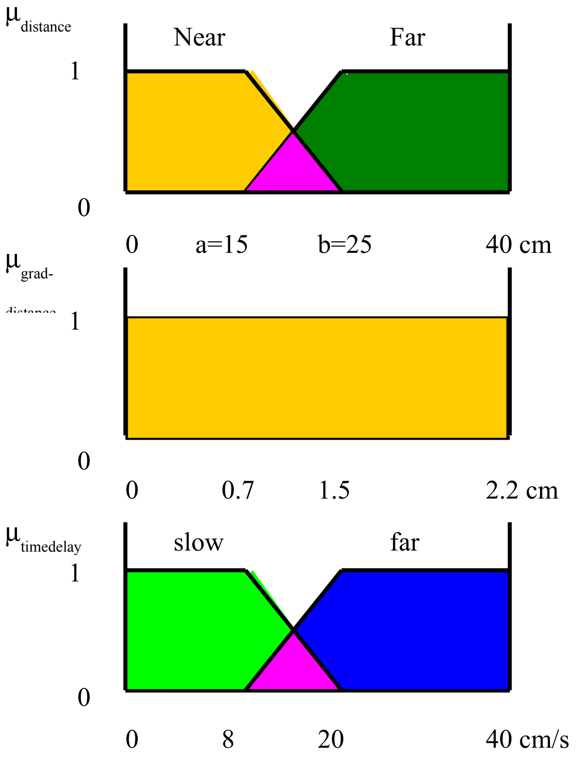


Figure 5 Fuzzy Membership Function for distance, gradient of distance and time delay

In the microcontroller AT89C52 with 4 Kbytes Flash PEROM, the complexity of fuzzy logic should be reduced to adequate size with minimal error. Two parameters is chosen to be inserted to fuzzy logic system; they were distance and gradient of distance to time. The output of the system was the value of time delay which is calculated with Tsukamoto-defuzzification algorithm, with Fuzzy rule as follows:

[R1] IF DISTANCE IS NEAR
AND GRADIENT-OF-DISTANCE AT RANGE
THEN TIME DELAY IS SLOW
[R2] IF DISTANCE IS FAR
AND GRADIENT-OF-DISTANCE AT RANGE
THEN TIME DELAY IS FAST

3. Experimental Result

From every successful captured which mean for every experiment that robot fish could strike the made-man prey, the speed was calculated by dividing the total distance with the time. The simplicity was made by making the Fuzzy Membership Function (FMF) of second input (gradient distance) was always be one. So the effort done only on first input, by maintained the shape of FMF and made various parameter of a and b. Some experiment could obtain some successful criteria, stroke (mean caught) prey and good trajectory follower for some little-moving-distance prey.

Although good trajectory follower not directly measured however it could be represented by the time and successfully stroke. Experiment for HIS-style shown at Table 1. This table shows every values of a and b as shown at Figure 5

Table 1. Experiment for HIS-Style with fix distance of prey (15 cm)

Parameter of experiment		**Total time to catch (second)**	**Average Speed (cm/s)**
a	**B**		
10	15	3.11	4.82
10	20	2.58	5.81
10	25	2.38	6.30
10	35	2.76	5.43
15	25	2.93	5.12

The smaller value of total time to catch is the best condition of this experiment. It means fish robot can ambush and catch prey in fastest mode. Chasing term is shown at Table 2. For fix distance, experiment will try to find optimum condition to follow and catch prey.

Table 2. Experiment for HA-Style with fix distance of prey (35 cm)

Parameter of experiment		Total time to catch (second)	Average Speed (cm/s)
A	b		
10	15	12.11	2.89
10	20	14.58	2.40
10	25	15.38	2.28
10	35	12.76	2.74
15	25	12.93	2.71

To analyze value of acceleration in every trajectory, experimental is done with variant distance. Table 3 shows at some different distance fish robot can catch prey with different acceleration. The most acceleration is achieved at 15 cm. At other distance the average acceleration nearly the same. Average acceleration at Table 3 is obtained from optimal value at Table 2.

Table 3. Experiment for HA-Style with variable distance of prey (35 cm)

Distance (cm)	Total time to catch (second)	Average acceleration (cm/s^2)
15	4.82	3.11
20	8.74	2.29
30	12.63	2.38
40	15.46	2.59

Sometimes the error could be caused by nonlinearity measurement of transducer. So firstly, it should be made some test to observer linearity of transducer. From experiment, linearity of transducer to distance is not actually linear, although for range 15 until 40 cm it can be assumed to be linear (Figure 6). Nonlinearity could be caused by quantization process in Analog to Digital Converter.

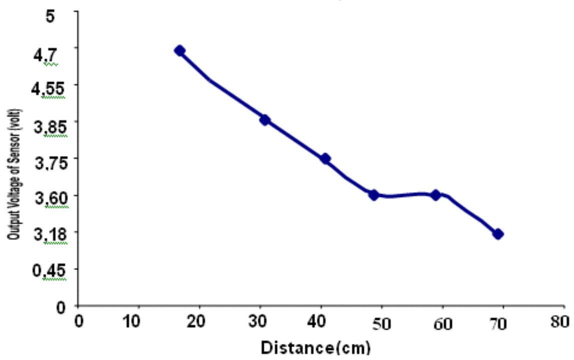


Figure 6. Linearity improvement of sensor

4. Conclusion

In this experimental investigation, it was found that a designed fish robot could catch prey with minimal average speed to HIS style and HA style respectively in 4.82 and 2.28 cm/s. Variation of time delay at HA-style could overcome water resistant and made the designed fish robot swim faster to catch prey.

In next research will be concentrated to observe more comprehensive on comparison of the profiles of fish robot to natural fish trajectory. In addition Also the trajectory to catch prey could be used to identify an object as prey or not

5. References

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