# Cognitive Modeling of Artificial Fish Learning and Memory

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## Abstract

Artificial fish is a kind of artificial animal living in three-dimensional virtual environment, and a computer animation created by using the method of artificial life. In nature, behaviors of fish are not only driven by its instinct. They also try to adapt to new environment by their learning and memory, and then to turn what they have learned and their memory into the experience knowledge. The more abundant the experience knowledge of fish is, the stronger ability the individual has in adapting to the environment. To enrich the natural life characteristic of the artificial fish, the relation cognitive modeling of learning and memory of artificial fish is established in this paper, based on the ecological theory and their learning and memory mechanism of fish in nature. This is to control the behavior of the artificial fish, so that they will play a more independent and intelligent role.

## 1、Introduction

By taking advantage of animal forms, habits and behaviors, X. Tu [1] has successfully created artificial fish, called “Xiaoyuan Fish”, which realized the common basic characteristics of artificial animals through computer animation: bio-mechanics, movement, sense and behavior. Every artificial fish is a self-animating autonomous agent. “Xiaoyuan’s Fish” starts a new way for computer animation---artificial life method;

Grzeszczuk[2] and Terzopoulos[3] developed a learning technology, which can automatically synthesize the vivid movement based on physical animal modeling. This technology is especially suitable for the movement synthesizing of the animals with highly soft body, such as fish, dolphin and snake. It can automatically learn effective methods in movement control and abstract proper parameter format out of them. They also development dolphin modeling in visual environment, which can perform kinds of “ocean acrobatics”;

John Funge[4] put forward the idea of controlling the behaviors of animals in the game through cognitive modeling and expressing the uncertainty in cognition by adopting method based on interval mathematics and situation calculus, which has realized the animation character and behavior with cognitive ability;

Learning and memory are two cognitive processes

At present, the study in the cognitive method of learning and memory of artificial fish is still not systematic and more effective methods are called for. The study in the animal cognition involves a wide range, and the research mainly starts from psychology, ethology and biology with different emphasis and methods. Manning, an ethologist, thinks that the behavior of an animal “includes all those processes by which the animal senses the external world and the internal state of its body and responds to changes which it perceives.” And cognition just studies how to respond. Shettleworth[5] put forward some important opinions about animal cognition and studied the cognitive process of animal communication, predator learning, attention modeling, space cognition, social learning, etc.

Learning and memory are two cognitive processes closely related to each other, important means to realize cognition and basic intelligent characteristics of human and animals. Learning is the neural process when human and animal acquire environmental knowledge while memory is the process of storing and reading the acquired knowledge, which is the necessary condition for learning. The importance of learning and memory lies in that they can guarantee that human and animal can adapt to the changing environment and seek existence and production. How could the brain learn and memorize, i.e., how to acquire and store information, has become one of the most heated scientific topics at present. Biologists have pointed out that ocean creatures such as dolphin and fish have very strong learning and memory ability. They seem to be simple and common, but in fact they are extraordinarily acute and flexible in some aspects. Therefore, the study of cognitive modeling of artificial fish based on learning and memory and the realization of the advanced cognitive functions of animation characters of artificial fish is a charming and challenging topic.

## 2. System structure of artificial fish

In the real-time dynamic complex virtual ocean environment, every artificial fish is an autonomous Agent with independent perception, decision and behavior. The ocean world composed of multiple artificial fish is a multi-Agent system, in which there exist the interaction among artificial fish and the interaction between artificial fish and environments. Firstly, we provide the cognition-based architecture for artificial fish Agent.

It adopts the features of hybrid Agent to construct the whole structure model of cognition-based artificial fish. (as shown in Figure 1). Artificial fish includes three sub-systems: perception, cognition and behavior. These

sub-systems are connected by information flows and control flows. Among them, the content in the dashed box is the perception system. The sensors in the perception system can pass the perceived external environment information to the cognition system for processing, and then the behavior decision will control the behavior system to let the actuator generate detailed actions, which take effects on the external environment. Sometimes, when artificial fish perceives some information, they will be driven by instinct directly, without the stimulation of cognition processing response action, e.g., collision avoidance. During making decision, intuition actions have the highest priority, and should be handled as interrupts in the program.

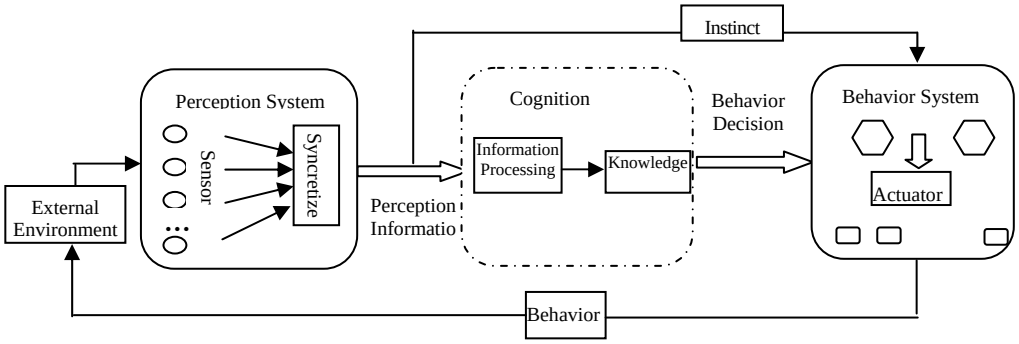


**Figure 1：Collectivity Structure Modeling of Artificial Fish**

The structures and functionalities of three sub-systems of artificial fish are as follows:

1. Perception system: information acquisition system, including a set of sensors and information aggregation module. The artificial fish has various kinds of sensors, e.g., visual sensor, audial sensor, olfactory sensor. At the same time, different sensors can get different environment information. We need to synthesize such information to facilitate the later information processing and behavior decision. Perception is the prerequisite of cognition and behavior planning.

2. Cognition system: information processing system, which takes the output of perception system as the input. For perceived information, the agent utilizes stored experiences and continuous learning to perform induction, deduction and decision to transform the information into the knowledge of its own. The agent then makes the behavior decision, which is transferred to the behavior system for execution.

3. Behavior system: execution system for behavior planning, which directly takes effects on the environment. It includes a set of behavior programs and a set of actuators. The behavior programs are the high-level actions, and the actuators execute the detailed actions. Every behavior program can be divided into a series of low-level actions, which are executed by actuators.

## 3. Relation between learning and memory of artificial fish

Animals acquire skills and knowledge from other animals, and fishes are no exception. There is now strong experimental evidence that many species of fish exhibit social learning and traditional behaviors[6].

Social learning refers to any incidence in which individuals acquire new behavior or information about their environment via observation of, or interaction with, other animals or their products[7].

Social learning is sometimes assumed to be more common in, of a more sophisticated form in, or even restricted to, 'intelligent' or 'large-brained' taxa. However, research over the last 50 years has demonstrated that social learning is common amongst fish, birds and mammals, and should now be regarded as a regular feature of vertebrate life [7][8].

In the study of memorizing ability of animals, many ichthyologists have, through experiments, shown that many species of fish have the ability to seek food by using visual space information, i.e., they have a certain capacity of working memory and reference memory. Thus they can adopt food- clue association and guide their behaviors in seeking food with the help of memorized information. Couzin[9], etc. put forward self-organizing modeling of three-dimensional group lineup to study the spatial dynamic characteristics of animal groups, such as fish and bird, to show that the minor change in individual interaction may result in transference of group behavior mode and that similar animal groups have group memory. Ransom Winder[10] etc. studied the issue of group memory. The experiment of improving self-organizing behavior by giving distributed limited memory to each individual in groups and achieving the goal in the environmental with obstacles showed that those with memorizing ability can achieve goals more rapidly than those without memorizing ability.

According the characteristics of fish in learning and memory, we design the relation modeling of artificial fish learning and memory. In its environment, artificial fish processes the perception information: after it has received information through audial sensor, visual sensor, tactual sensor, olfactory sensor, etc., it will compare the information with the past experience knowledge. If it is

similar to the past experience, it can solve problems by using existing experience knowledge; if it is new information, it will take advantage of social learning process, receive useful solutions, change it into knowledge and store it in the memory, which will become the experience knowledge in the brain of fish.

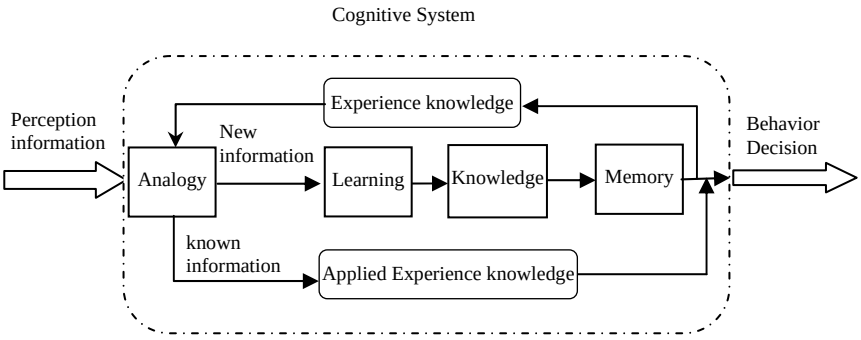


**Figure 2：Relation modeling of artificial fish learning and memory**

## 4. Learning cognitive modeling of artificial fish

Documented cases of social learning in fish are now commonplace. there are evidence show that social learning plays a role in fish : antipredator behavior; migration and orientation; foraging; mate choice. In these processes, young and inexperienced individuals often learn from others' behavior and acquire proper responses or abstract these responses. Then they can make correct responses and the response speed is becoming faster and faster. According to the fish situation, we put forward the cognitive modeling of artificial fish learning by using a reinforcement learning algorithm based on BP neural network. as shown in Figure 3 .

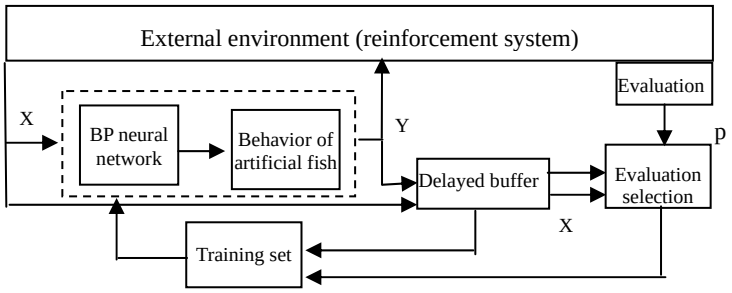


**Figure 3：Learning modeling of artificial fish**

BP Neural Network[11]: system input (status) X, output Y.;

Evaluation: Based on the output Y, the environment generates the evaluation signal p;

Delayed buffer: Due to the delay of evaluation during reinforcement learning, so delay np steps to synchronize Y ,X and evaluation.

When training cases reach certain number, training set is putted in network learning . the rule of producing training set is " better than average".

System put evaluation to neural network for adjusting weight by delay.

The input and output of traditional BP neural network are produced by increment. The knowledge that studied ago is forgotten. But reinforcement learning based on neural network may make function mapping to input according to ancient experiment knowledge by improving traditional BP.

Artificial fish acquires useful experience knowledge through the rewarding and punishing mechanism of environment and cultivates good behavior control ability through behavior system. There are two possible results of artificial fish behavior: 1.satisfactory effect; 2. dissatisfactory effect. If it is satisfactory, the process of solving problems is the process of reinforcement learning. If it is dissatisfactory, it will change and update the existing experience knowledge by adjusting the solution according to the environment.

## 5. Conclusion

This paper takes artificial fish as the research topic. According to the ecology principles of fish in the nature and the features of fish learning and memory, we build the architecture of artificial fish and propose the learning and cognitive model of artificial fish. As the social learning of fish is a gradual learning process, which is the result of long-term interactions with the environment and is also the learning in the environment, we propose reinforcement learning based on BP network to enable

artificial fish to perform learning during the interaction with environments. These models enrich the original cognitive model of artificial fish, and let it with more features of natural beings.

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