Automatic Behavior Generation of Artificial Fish Using Elasticity Momentum

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Summary

The objects real time rendered in the 3D cyber space can interact with each others according to the events which are happened when satisfying some conditions. But, to representing the behaviors with these interactions, too many event conditions are considered because each behavior pattern and event must be corresponded in a one-to-one ratio. It leads to problems which increase the system complexity. So, in this paper, we try to physical method based on elasticity force for representing more realistic behaviors of AI fish and present a new method can create the various behavior patterns responding to one evasion event.

Key words:
Virtual Space, Artificial Fish, Elasticity, Sensory System

1. Introduction

Digital Creatures are characters like real animals, plants or virtual livings which are restored using digital technology, and they are used widely as digital library in contents like a picture, game, etc... In virtual world, realistic behavior of digital creature gives an esthetic satisfaction to user. So, it is an essential element to satisfy the users, as well as the high graphical quality.

Artificial Fish is a kind of digital creature which is changed to automatic agent in the interactive media like a computer animation, computer game. It is controlled with according to the data that is generated by qualified logical rules, and formed dynamical communication methods and algorithms by these rules. The complexity of autonomous behavior of artificial fish is restricted to the mutual relationship between the initial variables of artificial fish and the variables of ocean environment.

For expression the oceanic life, many researches have been studied about the modeling based on physics and the behavior pattern. The Original artificial fish were created by Terzopoulos and Tu[1]. It contains a dynamic biomechanical muscular movement model, photo–realistic texture mapping, accurate sensory abilities, a model of desires, and a decision tree based on action selection mechanism. [2]

Tu[1] made the behaviors of Artificial Fish by means of combination of motion mechanism which is decided by its intentions ; Fear, Hunger, Libido. If each intention is decided, artificial fish products the suitable behaviors according to its situation by using muscular system for realistic motion. But above mentioned method don’t consider the factors that can be affected the fish’s behaviors, such as fish’s weight, access velocity, mutual relationship among the other fish, and so on. So artificial fish’s behavior is not diverse because of the same event always generates the same behavior. It is neither realistic nor natural.

In this paper we suggest that the method of behavior generation based on physics considered environmental variables for more realistic behavior expression. This method brings about the various behaviors of the artificial fish in spite of the same input and attribute provided. For an implementation of this method, we consider the fish’s inertia force and direction, and apply the kinematical force as environmental variables. We determine an evasion direction by calculating the combination of direction vectors between predator and prey, and then determine the evasion velocity and an access distance between the two objects by using the inertia force.

The rest of the paper is organized as follows. In section two, we survey the related researches, and then we present the new method that decides the evasion direction and initial evasion velocity considered the connection of each force in section three. In section four, we show the result and discuss about it. Finally we explain about conclusion and future works.

2. Related Work

Generally, there are variable factors for the control of an artificial fish’s behavior in a 3D virtual ocean; a modeling technique for control of fish’s unit-motion, a sensor system for mutual perception, a behavior routine algorithm leading to reaction after perception.

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2.1 Artificial Fish Modeling

Tu[1] designed the initial artificial fish which is base on Spring-Mass model with elasticity. This fish consist of 23 point masses and 91 springs which were named "Muscles." This fish generates the behavior by changing the rest length of spring. Fig1 is the dynamic fish model that Tu suggested.

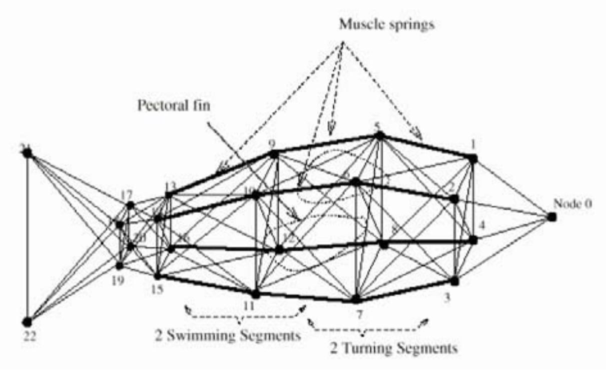

Fig. 1 Dynamic Fish Model.

2.2 Sensory System

A fish has many sensory abilities from which the most common three are, mechanoreception (hearing), vision, and chemoreception (smell and taste) [3]. Similarly an artificial fish need a sensory system to percept the dynamic objects or static objects in a virtual ocean. A sensory system is one of the algorithms that perceives the object within a constant distance and then gives a pertinent event to an artificial fish according to a target. Among three sensory abilities, Tu proposes the sensory system that has a vision of 300 degree by using its vision ability. Fig 2 is a vision sensory model presented by Tu.

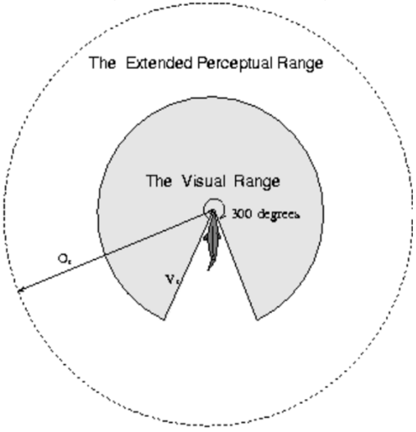

Fig. 2 Vision Sensor.

V_v is a radius of view volume, and O_v is a radius of expanded perception sensor. V_v and O_v influence the size parameter S_i^p in each fish's animation. It means that S_i^p is relative to V_v .

2.3 Fish Motion and Behavior

Gray [4] produced a mathematical function that gives the ratio of a fish's velocity to the perpendicular velocity of the fish's tail to the main axis. This expression is given in equation 1. Therefore by multiplying this value by the perpendicular velocity of the fish the resulting value should be equal to the speed attained.[5]

$$(V_{fish} / V_{tail}) = (2\pi a^2 / \lambda^2)[1/((1+[4\pi a^2 / \lambda^2])] \quad (1)$$

where :
- a is the amplitude of the wave
- λ is the wavelength of the wave
- V_{fish} is the velocity that the fish is traveling at
- V_{tail} is the velocity that the tail is propagating at.

Artificial Fishes are classified into 3 types; predator, prey, pacifist. A predator hunts for food, a prey avoids predator, and pacifist is not included. Predators and preys act according to reactions of sensor. If there is no one input in a sensor, artificial fishes wander (just swimming without an aim such as searching for food) in the virtual ocean. Generally, because radius of sensor is proportional to the Fish's size, Predator can perceive widely than prey

3. Behavior of Artificial Fish Applied of Elasticity Momentum

In a virtual ocean, artificial fishes are influenced by variable forces; propulsive force, buoyancy, gravity, friction by viscosity of water. In this paper, we generate the elasticity momentum on the basis of these basic forces. The elasticity momentum is generated by a virtual spring between predator and prey. While the spring is contracted, if it is over the critical point, it will make a repulsive power because of inertia by a propulsive force. This method gives a different elasticity force to fish in proportion to its speed, and produces a variable velocity by its size and weight. Therefore, an artificial fish can have realistic behaviors by means of controlling the modulus of elasticity.

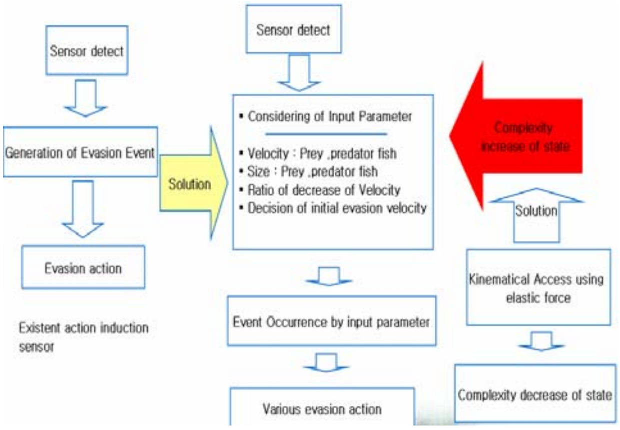

Fig.3 Weak point of existent research

In existent research, for action induction, Sensor produced event by two about if is whether is going to evade object after perception.

This time, evasion event generates always same action independently with the access speed or dimension of fish, direction etc…

This was restriction on natural and various action expressions. So, we designed method to consider various Input parameter to solve this problem.

But, this method is shortcoming that increases complexity of state because input parameter is too many.

We attempted physical accesses that use elastic force to solve this.

3.1 Decision of Evasion Direction

When the sensory system perceives the predator, a prey flees with the evasion velocity ($V_{evasion}$), and an evasion direction ($D_{evasion}$) is decided by considering of predator and obstacle nearby itself.

If there is nothing in a perceive range, the prey has the same direction with the predator. If there is something in the perceive range, an evasion direction is decided by the following rules. In advance to describe the rules, we define the notations used in equation.

$P_{predator}$ is the position of first predator

$P_{Obstacle}$ is the position of second predator (or obstacle)

P_{prey} is the position of prey

And then we can write the position of three items like below equations below.

$$P_{predator} = (x_{predator}, y_{predator}, z_{predator})$$
$$P_{obstacle} = (x_{obstacle}, y_{obstacle}, z_{obstacle}) \qquad (2)$$

$$P_{prey} = (x_{prey}, y_{prey}, z_{prey})$$

If we know the position of the prey, we can decide the relative direction of the predator ($\vec{O}_{predator}$) and an obstacle ($\vec{O}_{obstacle}$) to that of the prey as follows.

$$\vec{O}_{predator} = (x_{predator} - x_{prey}, y_{predator} - y_{prey}, z_{predator} - z_{prey})$$
$$\vec{O}_{obstacle} = (x_{obstacle} - x_{prey}, y_{obstacle} - y_{prey}, z_{obstacle} - z_{prey}) \quad (3)$$

At that time, the opposite direction of sum of two direction vectors becomes the evasion direction ($\vec{D}_{evasion}$) of the prey as follows. Here, we did not consider the scalar volume, except the direction

$$\vec{D}_{evasion} = -((x_{predator} + x_{obstacle} - 2x_{prey}), (y_{predator} + y_{obstacle} - 2y_{prey}), (z_{predator} + z_{obstacle} - 2z_{prey})) \qquad (4)$$

Fig. 4 represents the evasion direction of prey.

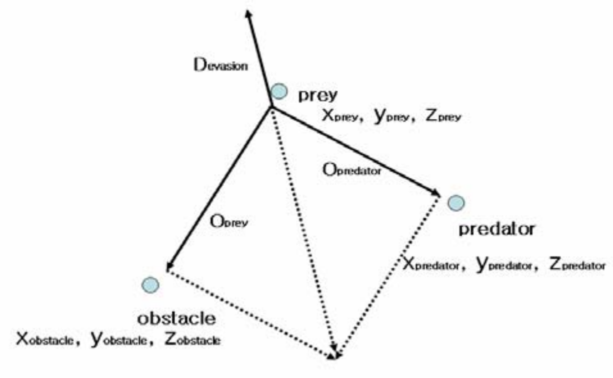

Fig. 4 Evasion direction vector

3.2 Generation of the Virtual Spring for Elasticity Momentum

In our system, if the prey finds a predator, it creates the event that generates the elasticity spring, not generates the evasion event directly. Once it moves a certain distance (x) for balancing between the propulsive force and the evasion force. If x has a maximum value, it generates an evasion event only. At this time, all elasticity force is converted to the kinetic energy and influenced in its velocity. Fig. 5 shows the virtual spring.

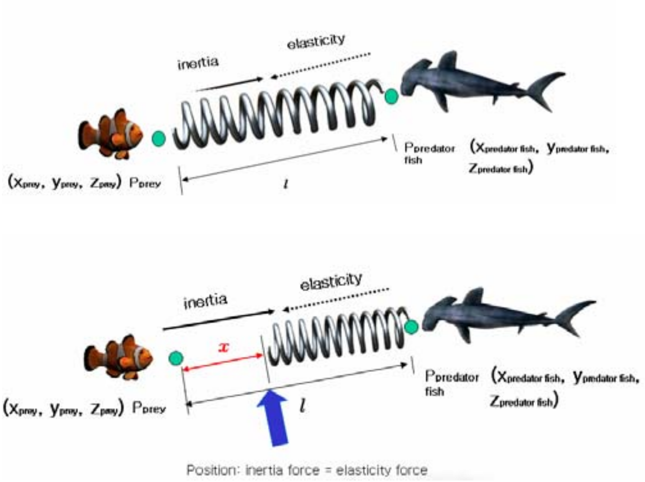

Fig. 5 Virtual Spring

Now, let us explain about the use of this virtual spring. Distance (l) between $(P_{predator})$ and (P_{prey}) is defined as follows.

$$l=\sqrt{(x_{predator}-x_{prey})^2+(y_{predator}-y_{prey})^2+(z_{predator}-z_{prey})^2} \quad (5)$$

If the perception status of both sensors becomes true, our system generates the virtual spring that has a length of l, and a modulus of elasticity (k). Then, the Potential energy (V_e) of this spring is defined as equation. 6

$$V_e=\int_0^x Fdx=\int_0^x kxdx \qquad (6)$$

where : • F is propulsive force of artificial fish
• k is the modulus of elasticity
• x is strain ratio of spring

If the predator size is infinite compare to the prey size, then the predator can not influence the compression of a spring and only change the spring position. So we don't need to consider the relative propulsive force of the predator. The propulsive force of prey is defined as follow.

$$F_{prey}=m_{prey}a_{prey} \qquad (7)$$

Through this force, if the spring is constricted as x, fish's works to spring (W_{prey}) can be expressed like equation 8.

$$W_{prey}=F_{prey}x \qquad (8)$$

So, the W_{prey} can be changed the elasticity potential energy like equation 9.

$$(m_{prey}a_{pery})\times x=\frac{1}{2}kx^2 \qquad (9)$$

Maximum value of strain ratio $(x_{\max})$ becomes $\frac{(m_{prey}a_{prey})}{k}$. and, when x reaches to the maximum value, an evasion event is created. The initial evasion velocity is decided by energy that is converted to kinetic from elasticity. Initial evasion velocity is defined as follow.

$$v_{evasion}=\frac{\sqrt{m_{prey}k}\,(a_{prey})}{k} \qquad (10)$$

4. Results

In this paper, we limited the relationship of fishes only to predator and prey. Also, only two behaviors are considered respectively. Predators' pursuit and wander, and preys flee and wander. These behaviors are created and disappeared by interactions of them.

For the implementation of artificial fish's behavior, we constructed the 3D fish modeling; a porgy is selected for prey and a hammerhead shark for predator. And then, we manufactured the unit motions like swimming, rapid swimming, turning for realistic and suitable movement

Table.1 Response type and event according to the state of sensor
(O : perception, X : not perception)

predator	prey	response	Event
X	X	Predator : wander Prey : wander	- Random move
O	X	Predator : pursuit Prey : wander	- Change the orientation of predator
O	O	Predator : pursuit Prey : Flee	- Create the virtual spring. - Decision of evasion direction

Fig.6 (a) and Fig.6 (b) show the perception sensor of porgy and hammerhead shark, we designed perception sensor that is spherical shape and proportional to size of object.

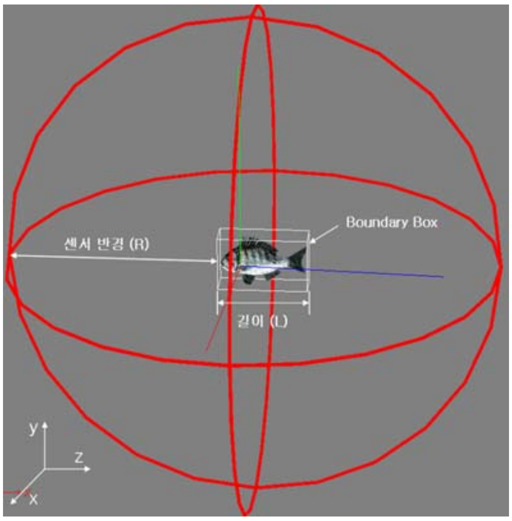

Figure 6(a). Perception sensor of prey

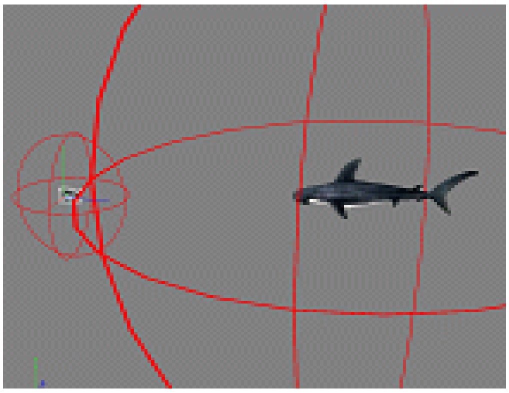

Figure 6(b). Perception sensor of Predator

Fig. 7 presents the behavior that perceives the other object and decides the evasion direction.

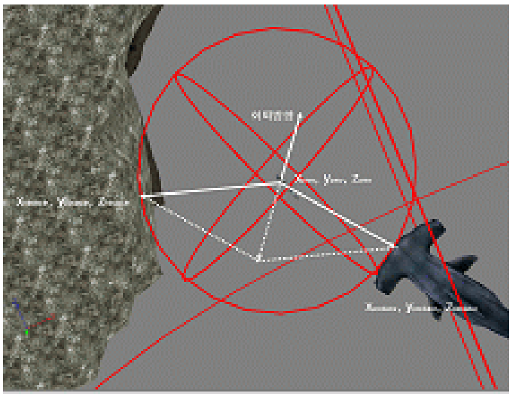

Fig.7 Evasion direction of prey

Fig 8 shows the changing of velocity of prey as time (t). After the prey perceives the predator, its velocity was decreased by elasticity and when it approaches the distance of $l - x$, the velocity had a minimum value and the elasticity force had a maximum value. For expression of realistic behavior, capability constant number C_{prey} was added on the initial evasion velocity like equation.11.

$$v_{evasion} = \frac{\sqrt{m_{prey}k}\,(a_{prey})}{k} + C_{prey} \qquad (11)$$

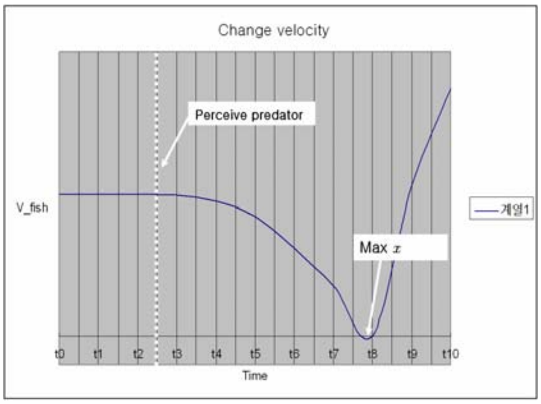

Fig.8 Velocity change of prey

4. Conclusion

In this paper, we proposed the physical method based on elasticity force for representing more realistic behaviors of an AI fish, and this method can create the various behavior patterns responding to one evasion event.

For this, we devised the elasticity spring that gives a different elasticity force to fish in proportion to the its speed, and produces variable velocity by its size and weight. This process is calculated in real time. By using this method, we could achieve the effective animation, movement, and behavior for fish. In concrete terms, they are decisions of evasion direction and velocity, calculation of approaching distance between predator and prey.

Mostly, realistic behaviors of artificial fishes rely on the sensitive motion control that considered various environment variables. But in this paper, only fixed environment variables are applied to the motion control.

So, for the more realistic expression of behavior, we have to consider the more various environment variables like temperature of water, speed of fluid as well as more advanced Artificial Intelligent like learning techniques.

Acknowledgments

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