Life-Like Animation System of Virtual Firefly Based on Animacy Perception

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Abstract. In this paper, we propose a computational model to generate life-like motion for firefly-like creatures. By using a two-stage stochastic process and simple operational elements, we could generate various life-like motion patterns. Then, we incorporated these patterns in our animation system, where virtual fireflies move and emit light dynamically. We experimented and verified using surveys that the virtual fireflies look like living beings, and that different animations give rise to different impressions.

Keywords: Procedural Animation, Artificial Life, Firefly, Animacy Perception.

1 Introduction

The fireflies, with their typical glow and drifting movement, have been a popular summer tradition for a long time, and always had a relieving effect for the people watching them. With regard to the effects and principles of the fireflies' light emission, a number of studies have been conducted in areas such as engineering and physiology, e.g. there is a case that demonstrates their healing effect by using electroencephalogram data and surveys[1–3], also a virtual illumination system for welfare has been proposed[2].

In the art and entertainment areas, in order to produce contents such as games and movies, moving and glowing objects like fireflies (virtual fireflies) are widely used in the production of both real and virtual spaces[4–11]. To incorporate virtual fireflies it is necessary to generate fireflies' behavior automatically using computational models to allow for user interaction.

Reproduction technique by calculation model has been proposed for synchronization phenomena and emission pattern of firefly ever[2, 12–14]. On the other hand, in the field of cognitive science, the phenomenon of "animacy perception" is known as a research about the object to the behavior typical life[15–17]. The study of animacy perception, that appearance is an effect on the perception of life a sense of change in the speed or direction of motion change even a simple geometric shape is known. Therefore, it is conceivable in order to represent the quality of life of fireflies, making a model of how to move in consideration of the change in speed or direction change in motion is important. However, in past studies about firefly, it has not been taken up for the element of motion.

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In this paper, we propose a computational model for automatically generating and easy, the motion looks like like a creature light-emitting object, such as a firefly. Through the modeling of the movement of fireflies, it can be expected to become easily incorporate virtual creatures like fireflies to art and entertainment contents.

2 Generating Method of Life-Like Motion

In this chapter, we introduce a life-like motion generation method based on the concept of animacy perception.

Our method complies with rigid body dynamics. A firefly is treated as a single rigid body, and translations and rotations are performed according to the firefly velocity and angular velocity. In this paper, we assume a left-handed coordinate system, with the fireflies standard position facing the positive direction of the Z-axis.

2.1 Motion Modules and Two-Stage Stochastic Model

We define the motion of a firefly with two modules (we call "motion modules") that consist of "acceleration (including redirecting)" and "deceleration", that transition in a gradual manner. This method consists of a two-step probability selection processes, first it selects stochastically a model and then selects the stochastic parameters of the motion generated in the previous step. With this approach, even with a few parameters and models various realistic patterns can be obtained. This procedure is repeated at small time intervals, each time selecting a motion module, doing the relative computations and finally producing the data.

2.2 Selection Process of the Motion Module

In this stage, the next motion module is selected depends on current motion module. This can be expressed as a stochastic process (a simple Markov chain)(Fig.1) in a discrete time series, such as the following:

$$p(x_0, x_1, \ldots, x_r) = p(x_0)p(x_1|x_0)p(x_2|x_1)\ldots, p(x_r|x_{r-1}) \tag{1}$$

$$\text{State space: } \Omega = S_1, S_2$$

However, S_1 is the acceleration motion module and S_2 is the deceleration motion module. That is, the probability that a motion module is selected at the discrete time n depends only on which motion module has been selected at the discrete time $n-1$. Transition probabilities should be given as constant parameters in advance.

2.3 Selection Process of the Parameters

The second stochastic control stage is performed in the acceleration motion module.

Acceleration Motion Module. In the acceleration motion module, at first we generate a force vector $\boldsymbol{F}$ has a random component on the local spherical coordinate system with the origin at the center of the firefly, as shown in Fig.2. r is the magnitude of $\boldsymbol{F}$ and is a given constant parameter. Arguments θ and ϕ are determined by the following equation:

$$\theta = 90 + R(a_\theta), \quad \phi = 90 + R(a_\phi) \tag{2}$$

$R(a)$ is a function that returns a pseudo random number in the range $-a$ to a. When $R(a_\theta), R(a_\phi) = 0$, the firefly goes straight without rotation at all. a_θ and a_ϕ are given constant parameters. Then, we convert $\boldsymbol{F}$ from the local spherical coordinate system to a local Cartesian coordinate system (left-handed) as follows:

$$x = r \sin\theta \cos\phi, \quad y = r\cos\theta, \quad z = r\sin\theta\sin\phi \tag{3}$$

Next, we determine the acceleration $\boldsymbol{a}$ and the angular acceleration $\boldsymbol{\alpha}$ as follows:

$$\boldsymbol{a} = \frac{1}{m}\begin{pmatrix}0\\0\\z\end{pmatrix}, \quad \boldsymbol{\alpha} = \frac{1}{I}\begin{pmatrix}-y\\x\\0\end{pmatrix} = \frac{1}{mr^2}\begin{pmatrix}-y\\x\\0\end{pmatrix} \tag{4}$$

The mass m and the radius r are given constant parameters. I is the moment of inertia. Finally, we compute the velocity $\boldsymbol{v}$ and the angular velocity $\boldsymbol{\omega}$ by integrating $\boldsymbol{a}$ and $\boldsymbol{\alpha}$.

Deceleration Motion Module. In the deceleration motion module, we subtract the velocity $\boldsymbol{v}$ and angular velocity $\boldsymbol{\omega}$ as a drag that mimics the air resistance. The drag D exerted on the rigid body (firefly) in the fluid is proportional to the square of the speed, and is calculated by the equation $D = \frac{1}{2}C_D\rho u^2 S$. C_D is the drag coefficient, ρ is the density of the fluid, u is the speed of the firefly, and S is the representative area of the firefly. The values except u are given constant parameters.

3 Animation System of Virtual Firefly

In this chapter, we will build an animation system that incorporates the life-like motion generation method that was described in the previous chapter with virtual fireflies.

Fig.3 shows an example of the generated virtual fireflies. Virtual fireflies move in a virtual space and emit light at the same time. The configuration of the virtual fireflies

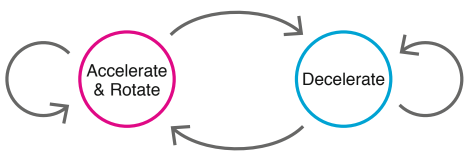

Fig. 1. Stochastic process to select motion module

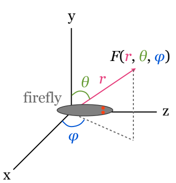

Fig. 2. Virtual firefly and force vector on spherical polar coordinates

contains two subsystems that stand side by side, the motion generation sub-system for generating motions and the emission control subsystem for controlling light emission (Fig.4). In order to focus on how virtual fireflies move, they do not possess a CG model representing their body. Their visible shape is generated as a circular particle, expressing pseudo glowing by changing size in conjunction with the light amount.

In the motion generation subsystem, we perform translations and rotations in the manner described in the previous chapter. However, in the acceleration motion module, because fireflies cannot assume a vertical orientation, the “attitude control biasing” works on the random component $R(a_\theta)$ that affects the pitch angle.

In the emission control subsystem, we control the glowing of the virtual firefly (i.e. changing size of the particle) in a simple way. This also uses a two-stage stochastic process as in the motion generation subsystem. The virtual firefly must select one state among “brightening”, “keeping”, and ”darkening”. The state continues to transition stochastically.

4 Evaluation Experiment

In this chapter, we experiment using surveys in order to verify if the virtual fireflies look like creatures and what impressions do they give. The subjects were 9 men, with an age ranging from 21 to 29. Seven of them had seen firefly with the naked eye. Two of them had never seen with the naked eye, but had seen moving fireflies in the video.

4.1 Equipment and Procedure

We present three animation sequences to subjects for 60 seconds each in random order, used the 21-inch LCD display. And then wait for them to fill out the questionnaire separately each time. At this time, we do not explain that we are mimicking the fireflies, nor the differences of each motion pattern. The difference of animations is as follows:

– The virtual fireflies does not move at all. (P1)
– The virtual fireflies perform linear motion with constant velocity. (P2)
– The virtual fireflies move according to our model. (P3)

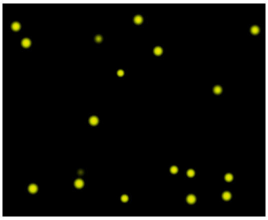

Fig. 3. Animating virtual fireflies (screenshot)

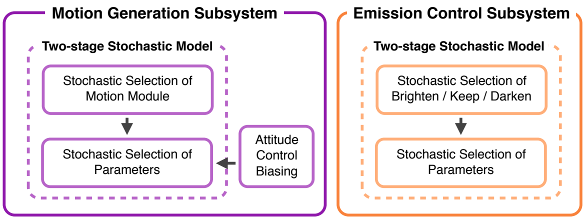

Fig. 4. Configuration of the animation system of the virtual fireflies

The portions that do not get involved in the motion generation, such as the emission control subsystem, are common to all patterns. A total of 15 virtual fireflies is generated in the virtual space with a random initial position. Parameters set in advance.

In the questionnaire, the subjects assign a score using a rating scale of 9 steps, from 1 to 5 points with 0.5 point intervals, regarding their impressions about the quality of the creatures currently displayed. There are 8 scoreing items: Not life-like/Life-like, Uninteresting/Interesting, Unfriendly/Friendly, Simple/Complex, Get bored easily/Get bored hardly, Not healed/Be healed, Unpleasant/Pleasant, Dislike/Like (1 point/5 points). In addition, if subjects have particular impressions or notice something while watching the scene, they are invited to write in the apposite blank space.

4.2 Results

Rating Impressions. The list of mean and standard deviation of the scores of the rating scale for each pattern is shown in Fig.5. The length of the bar indicate average score and the length of the error bars indicate standard deviations. Furthermore, as a result of the analysis of variance to analyze the effect on the impression of the differences in the pattern, a significant difference was observed in 4 of 8 items.

In "Life-like/Not life-like", there is significant main effect ($F(2, 26) = 25.436, p < .001$). The result of the multiple comparison using HSD method by Tukey has large significant difference between groups of P1–P3 and P2–P3 ($p < .01$). In "Interesting/Uninteresting", there is significant main effect ($F(2, 26) = 4.894, p < .05$). The result of the multiple comparison using HSD method by Tukey has significant difference between groups of P1–P3 and P2–P3 ($p < .05$). In "Complex/Simple", there is significant main effect ($F(2, 26) = 26.0183, p < .001$). The result of the multiple comparison using HSD method by Tukey has large significant difference between groups of P1–P3 and P2–P3 ($p < .01$). In "Pleasant/Unpleasant", there is significant main effect

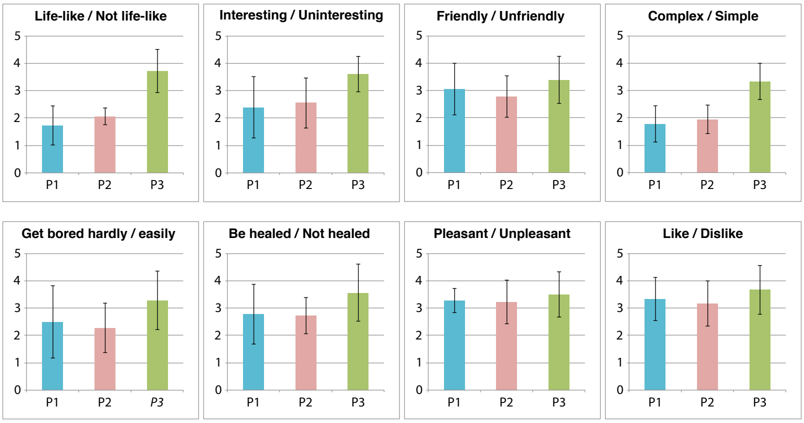

Fig. 5. Mean and standard deviation of the scores in each animation pattern

($F(2, 26) = 5.131, p < .05$). The result of the multiple comparison using HSD method by Tukey has significant difference between groups of P1–P3 and P2–P3 ($p < .05$).

Free Description. In the free description part of the questionnaire, there were many impressions on P1 about the light patterns being too simple, for example, “Felt like just sparkling lights” and “Looks like christmas lights”. Mechanical impressions such as “Feels like looking at the flow of traffic” and “The movement is monotonous” were raised in P2. Impression about the creature-likeness, such as “Moves randomly like a creature” and “Creature-like” came to be seen in P3. In addition, for P3 many wrote comments about the glowing and the movement such as “I think acceleration and deceleration are too strong” and “Flickering slowly while moving fast does not feel natural”.

5 Conclusion

In this paper, we proposed a computational model to generate life-like motion for firefly-like creatures. By using a two-stage stochastic process and simple operational elements, we generated various life-like motion patterns. By incorporating an object that mimics a virtual firefly, we built an animation system where virtual fireflies move and emit light dynamically. We experimented and verified using surveys that the virtual fireflies look like living beings, and made the subjects feel healing and fun.

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