Automatic Generation of Moving Crowd using Chaos Model

Naoki Saiwaki Toshiaki Komatsu Tetsuya Yoshida Shogo Nishida

Department of Systems and Human Science
Graduate School of Engineering Science
Osaka University
1-3, Machikaneyama, Toyonaka, Osaka 560 JAPAN
E-mail: saiwaki@nishilab.sys.es.osaka-u.ac.jp

Abstract

In recent years, it is desired that computer can support to make computer graphics for reduction of user's labor. One of such functions is automatic generation of moving crowd. Though a considerable number of studies have been done in the field of generating the moving flock of animals, there are a few studies focused on the crowd of human.

In this paper, we are concerned with modeling and generation of the moving crowd in a three dimensional virtual city to increase reality. The virtual city often has few habitants. Even in case some habitants are there, they are controlled by the users or only repeat same behavior based on some strict rules. To actualize more natural atmosphere, many data and rules are needed. The purpose of this paper is to advance a method to simplify the operation for generating the moving crowd.

A general view of the moving crowd reveals significant characteristics. Though the behavior of each figure is independent, the crowd, as a huge mass of it, has a pattern as a whole. Chaos is very convenient to represent such features. It is controlled by a few parameters. For instance, since chaos is influenced quite sensitively by initial value, it can produce various non mutual values that decide the next actions of the figures. Moreover, these values form themselves into an attractor. As the attractor is transformed by changing a parameter, we can easily control the shape of the crowd. Although random numbers are often applied to such purposes, it is difficult to create and control such patterns.

Utilizing these characteristics of chaos, we constructed the models of the crowd in the street and the folk dance. The prototype system was developed for evaluation and it was confirmed that users felt easy to generate and control the crowd.

1 Introduction

Recent development of VR (Virtual Reality) technology enables the real-time interaction in the 3D virtual space on computers, which can be used as the quasi-experience of the real world.
The construction of virtual cities is one of the typical examples of the utilization of VR technology. However, in previous research the number of people who move around in the VR space tends to be relatively small. Moreover, the behavior of people is often directly controlled by the user or is programmed beforehand only to produce typical responses. Thus, there are few approaches to reproduce the realistic motion of crowds in cities (1). One of the reasons for making the behavior of people in the VR space unrealistic is that the load required for the realistic motion is too huge for the designer

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and/or user of the system [2][3]. For instance, to enable the "natural" appearance of the direction and speed of the motion of crowds, it is necessary to program the behavior of each person appropriately as well as to provide enormous data.

We focus on the motion of crowds which is observed in cities at the macro level, not on that of each person at the micro level as in the other approaches. Our approach aim to construct the behavior model of crowds which appears to have a pattern as a whole while each person moves around independently. We propose several basic methods for the construction of systems which easily produce the characteristic behavior of crowds in the VR space. In our approach the behavior of crowds is represented at the macro level, and the chaos equation is used to describe both the behavior of crowds as a whole and the relationship between persons. Thus, it is possible to represent the global behavior of crowd without specifying the behavior of each person nor the relationships between them. It also enables to create various behavioral patterns of crowd through simple parameter tuning. Various experiments with the computer simulation were carried out to examine the effectiveness of our method. Our method is expected to contribute to reducing the load in the creation of CG (Computer Graphics) when it is used as the module to produce the CG data.

2 Modeling of Behavior with Chaos

2.1 Behavior of Crowds

The issue of describing the behavior of flocks as a whole has been pursued since the beginning of the research in ALife (Artificial Life). Several methods have been developed to represent the behavior of flocks with as little data as possible by furnishing each individual with autonomy [4][5]. For instance, there are three basic rules for each member of a flock to create the behavioral pattern for the flock of birds and/or fish, as follows:

1) maintain a minimum distance from other ones in the environment, including other members
2) match velocities with others in its neighborhood
3) move toward the perceived center of mass of others in its neighborhood

The flock with these rules moves around by itself simply being provided with the initial configuration of each member and the initial speed. With the right setting for the parameters, a collection of birds will collect into a dynamic flock, which flies around obstacles in a fluid and natural manner, occasionally breaking up into sub-flocks to avoid obstacles. However, there are few researches which try to control the general behavior of crowds in human cases with small number of parameters, in contrast to the ones which deal with the collective behavior of animals.

There are several reasons for the lack of research on human cases. First, it is difficult to find out remarkable behavioral patterns, in contrast to the case in animals. Second, even if such patters are found, it is necessary to provide complex descriptions to produce the realistic behavior. In some cases it is necessary to provide so many data, the amount of which is almost the same to that of data required to specify the individual behavior in crowds. These reasons suggest the importance of the selection of behavioral patterns and their representation to deal with the crowd in human cases.

This paper considers the case in which people flows realistically along the street and the one in which people dances as a group by combining the circular motion which can be observed in folk dances. We propose to utilize the characteristics of chaos to represent the above cases. For instance, it is possible to exploit the fact that small disturbance in the initial condition greatly affects the subsequent trajectory in chaos. It is also possible to utilize the fact that chaos constitutes the pattern such as a strange attractor at the macro level even if it appears to move randomly at first. These features enable to represent the behavior of crowds with small number of description models, their initial conditions, and parameters.

2.2 Application of Chaos

There are three characteristics in chaos, each of which can be utilized to model the behavior of crowds. First, it has non-regularity, which can be used to represent the fuzziness in the behavior of people. Second, it is sensitive to the initial condition, which enables the completely different behavior as time goes by when the initial condition for each person differs. Third, the parameter value in chaos equations greatly affects the possible range and characteristic of the trajectory, which is useful to change the feature of the behavior of crowds as a whole by simple tuning of parameters.

Suppose that we try to model the case in which people walk along a straight street. It is possible to represent the random walk with probability (e.g., random number), however, it is impossible to control the behavior of crowds as a whole. In contrast, with chaos it is possible for the crowd to divide spontaneously into the sub-crowd which gets away swiftly and the one which wonders about. It is also possible to control the circular motion and the direction of dance when chaos is used to represent a dance. Furthermore, it is possible to locally modify the behavior of crowds as a whole by supplementing the above ones with electric charges. The details of these methods are explained in the following sections.

3. Modeling and Creation of Crowds with Linear Motion

3.1 Characteristics in Linear Motion

People primary notice the crowd which moves toward the place with lots of coming and going, even at the location where many people with various objectives move around freely. In this case it is almost impossible to walk straightly toward the destination due to the random influence from the surrounding people, and they tend to walk in the wandering manner to avoid the touching and colliding with others. As described in the previous section, although it is difficult to describe the wandering behavior of each person directly, it is possible to represent it with chaos easily.

3.2 Chaos and Wandering

Chaos can be considered as the non-regular vibration which s controlled by relatively simple rules (6). The typical rule for chaos is the logistic function:

$$X[n+1] = R\,X[n]\,(\,1 - X[n]\,)\ ;\ R_{\infty} < R \leqq 4 \qquad (1)$$

It is known that this function creates the chaotic progression with the initial value ($0 < X[0] < 1$) as long as the coefficient R is .

The value of R also affects the trajectory of progression (see figure 1 and 2 with X[0] = 0.3).

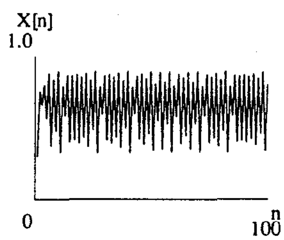


Fig. 1 X[n] (R=3.6)

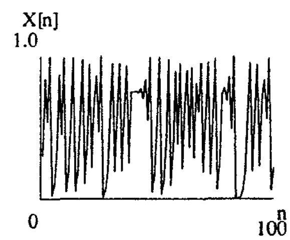


Fig. 2 X[n] (R=4.0)

Each member of a crowd is provided with the motion vector at each time to move the crowd as a whole. Utilizing the non-regular behavior in chaos to calculate the motion vector realizes the behavior of crowds, in which each member appears to wander at random but the global pattern is still observed.

3.3 Calculation of Motion Vector

The motion vector is expressed as in figure 3 and is calculated with the following expressions:

$$\vec{v} = r\vec{b} \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \qquad (2)$$

$$\begin{cases} r = 1.0 + X[n] - Avx \\ \theta = Y[n] - Avy \end{cases} \tag{3}$$

$$\begin{cases} X[n+1] = Rx\, X[n](1 - X[n]) \\ Y[n+1] = Ry\, Y[n](1 - Y[n]) \\ R_{\infty} < Rx \le 4.0,\ R_{\infty} < Ry \le 4.0 \end{cases} \tag{4}$$

In the above expressions b is the basic motion vector with magnitude 1 and is given as the initial condition. r and theta are the parameters to represent the wandering behavior and are determined as in expression (3) with the logistic function X[n] and Y[n]. Note that Avx and Avy are the constants which are determined by Rx and Ry. The initial value X[0] and Y[0] in the logistic functions are given at random. Our modeling make it possible to represent the behavior of crowds with two parameters Rx and Ry.

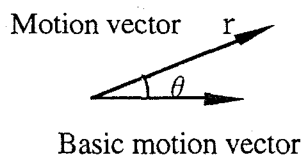


Fig. 3 Motion Vector

3.3 Control of Behavior through Parameter

Figure 4 and 5 show the trajectory of people in our model with the motion vector in expression (2). Figure 4 shows the case in which only Ry is changed to model the behavior of single person. It can be observed that the amount of wandering grows as Ry gets larger.

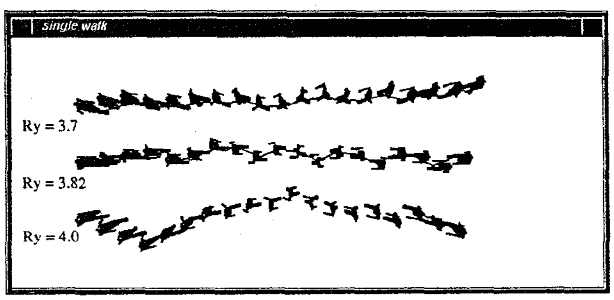
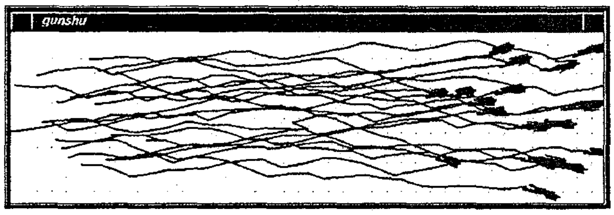
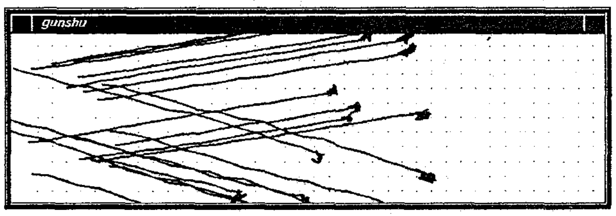


Fig. 4 Locus of wandering (Ry = 3.7, 3.82, 4.0)

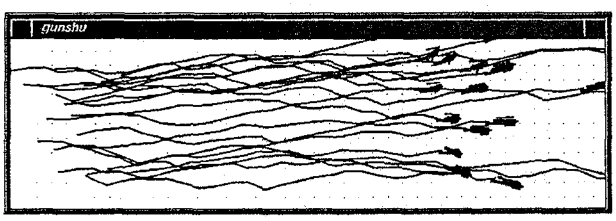
Figure 5 shows the example behavior of crowds with various settings for Rx and Ry by extending the above model to the multiple person case. In figure 5(a) the crowd flows smoothly along the street. In figure 5(b) the crowd is getting to be divided laterally into two groups. In figure 5(c) the crowd is divided into the group with quick steps and that with slow ones. In figure 5(d) all the members seem to walk in the wandering manner.



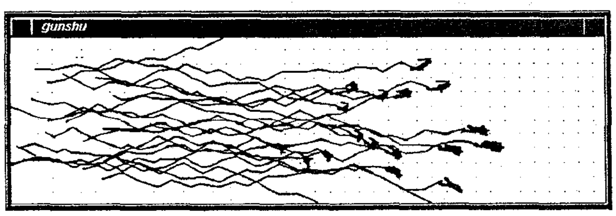
(a) behavior of crowds (Rx=3.7, Ry=3.7)



(b) behavior of crowds (Rx=3.6, Ry=3.7)



(c) behavior of crowds (Rx=3.7, Ry=3.6)



(b) behavior of crowds (Rx=4.0, Ry=4.0)

Fig. 5 Examples of behavior of crowds

By analyzing the relationship between the behavioral pattern and parameter, the two dimensional space defined by the parameter Rx and Ry can be classified into several regions with the characteristic behavioral pattern, as shown in Figure 6.

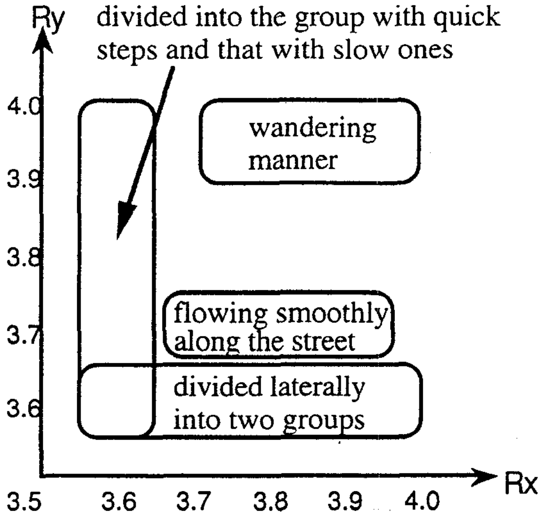


Fig. 6 Relation between the parameters and the characteristic behavioral patterns

The simulation has confirmed that one of the advantages of our modeling method with chaos is to allow the handy creation of complex behavior of crowds by tuning only small number of parameters.

4. Modeling and Creation of Crowds with Circular Motion

4.1 Attractor

We discuss the modeling of the behavior of crowds with the attractor in chaos by focusing on the circular motion, which is often observed in folk dances. Some trajectories with the chaos equation keep the complex and non-regular behavior confined within some region, and these are called attractors. The equations (6) are example equations for creating the attractor, whose trajectory is shown in Figure 7. The 4th order Lunge-Kutta method is used to solve the first order differential equations with high accuracy.

$$\begin{cases} \dfrac{dx}{dt} = (K_0(y - x) - g(x)) / K_1 \\ \dfrac{dy}{dt} = K_0(x - y) + z \\ \dfrac{dz}{dt} = -K_2 y \end{cases} \tag{6}$$

$$g(x) = K_3 x + \frac{1}{2}(K_4 - K_3)|x + K_5| + \frac{1}{2}(K_3 - K_4)|x - K_5|$$

(K_0=0.68, K_1=9.0, K_2=7.0, K_3=-0.5, K_4=-0.8, K_5=1.0)

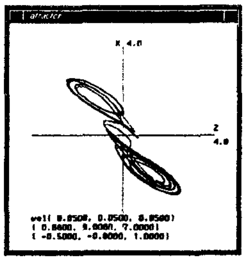


Fig. 7 Example of Attractor

4.2 Representation of Circular Motion

It is possible to reproduce the circular motion along the trajectory of attractor by disposing people on that trajectory. This modeling also scales up to the multiple person case as in the modeling of linear motion in section 3. The small difference at the initial condition amounts to produce a different trajectory and motion vector for each person, which can be used to represent a subtle difference in each behavior while showing the similarity as a whole. It is also possible to modify the shape of attractor by tuning parameters. For instance, it is possible to control the magnitude of the radius at will and to make the trajectory similar to the shape of number 8.Figure 8 shows the trace of the trajectories by modifying the parameter K0 to 0.68, 0.67, and 0.65. It is possible to observe from these figures how trajectories vary with different parameter values.

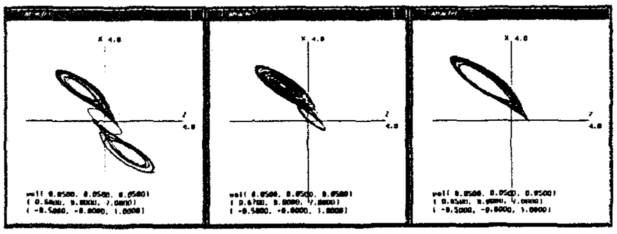


Fig. 8 Trace of the trajectories

Suppose the case in which the pairs of two persons perform the folk dance or social dance. The motion can be modeled and represented as the combination of one large attractor trajectory and multiple small attractor ones. The former determines the global behavior and the latter determines the motion of the pairs, as shown in Figure 9.

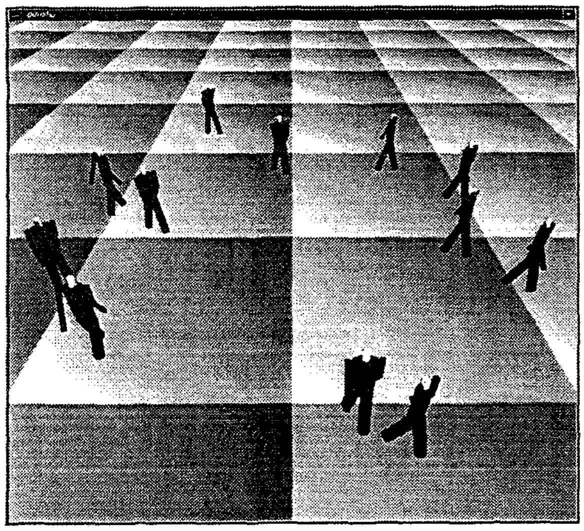


Fig. 9 Folk dance

5. Creation of Local Events based on Electric Charges

Besides the global pattern of motion described in the previous sections, the change of flow can occur as local events in the real behavior of crowds. For instance, some portion of a crowd can be attracted by a street performance. After a while those who have seen it go away from the performance bit by bit and new audience come to see the performance. When the performance ends, such a local accumulation of crowds disappears and the global behavior comes to dominate the motion. Not only this kind of behavior is often observed in reality, but also it can be considered as a crucial element to represent the realistic appearance of crowds. We extend the model of linear motion in section 3 by utilizing the electric attractive and repulsive forces. Each member of crowds receives the former one by attractive events and the latter by obstacles.

Suppose there are persons who play a street performance. Negative electric charges are given to them periodically while small positive ones are given to the surrounding people for a short period of time. This modeling enables to represent the people around the performance. It is also possible to represent the passengers who avoid the crowd with the repulsive force by the positive charges on people, as shown in figure 10. This kind of behavior is realized by calculating the electric field and adding up the force from it into the motion vector explained in section 3.

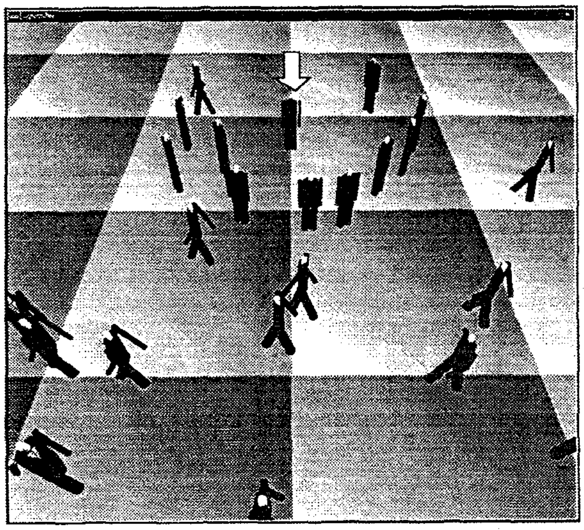


Fig. 10 Street performer and spectators

6. Conclusion

We have shown that the characteristics of chaos can be utilized to reproduce the behavior of crowds and have presented the creation of the behavior of crowds as computer animation in the case of linear and circular motion. We also have shown that the local accumulation of crowds and the avoidance of collision can be realized by adding electric charges. The user who used our prototype system commented that the system presented the interesting and realistic behavior of crowds. Especially, it was highly evaluated on the aspect of controlling the global behavior with a few parameters and that of the accumulation of people with electric charges.

We have used only small portion of the characteristics of chaos to model the behavior of crowds. Thus, it is possible to extend our method by utilizing other ones. It is necessary to investigate which characteristics of chaos are easy and/or hard to use when they are introduced into our system. Furthermore, at present the evaluation of the system relies on the subjective judgment by the user. We plan to define the evaluation criteria based on the analysis of real behavior of crowds and its quantitative evaluation so that the system can produce more realistic behavior in terms of the criteria. We also plan to extend the method with electric charges so that it can be applied to avoid the collision with obstacles such as buildings and cars. We hope that the behavior of crowds in our system can be made more realistic by combining the approach in Artificial Life (7).

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