Research on Coordination Ability of Special Actions of Track and Field Jumping Events Based on Signal Autocorrelation

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Abstract. In order to express jumping scene in the real life, consisting of jumping site, large-scale jumping athletes and sports, this paper proposes expression of action coordination ability of track and field jumping events within signal autocorrelation. First of all, design the hierarchical logic model of track and field jumping field, conduct logic modeling and describe the complex jumping field from different levels, such as geometry and topology. Secondly, the existing research on special action coordination ability of track and field jumping events, using the micro method based on individuals, has low calculation efficiency for jumping events, and the small-scale method based on the flow cannot express complex jumping phenomenon. Therefore, put forward a new set of small-scale flow equation to describe the movement of jumping athletes in the track and field jumping site, to make small-scale flow model able to combine with the behavior model of jumping athletes, to vividly describe the complex jumping phenomenon. Experimental results show that, the proposed method is based on the realization of the high detail simulation of the movement of jumping athletes within the signal autocorrelation and its computational efficiency has the same order of magnitude with the small-scale flow model. Based on the virtual reality modeling of real jumping field in the practical application, analyze the special action coordination ability of track and field jumping events to further verify the effectiveness of the method.

Introduction

Jumping is one of track and field items, and is an important part of human society. To realistically display the real world in the computer generated space, construct the jumping site in the virtual environment, and express jumping athletes and jumping movement on the field, which is an essential part of the construction of the virtual world.

Jumping items of track and field in real life have the following prominent features. First, the jumping site has the complex structure, various crossings and various intersection lines arranged in the crisscross and perplexing pattern. Second, there is a large scale of jumping athletes. Therefore, how to achieve a realistic simulation of jumping movement within the signal autocorrelation, is an important problem in the field of virtual reality, but also the effective techniques for the design, analysis and competition for emergency evacuation plan, and city jumping planning. The significance and prospect of application can be summarized as follows. Firstly, achieve the rehearsable jumping simulation, to strengthen the ability to deal with special circumstances and emergency. Secondly, guide the design of competition of track and field jumping events. And the large-scale and detailed expression results, can avoid the unreasonable jumping plan, to for efficient co-ordination of the overall track and field jumping situation. Thirdly, enhance the user experience in the virtual scene. Integrate the realistic simulation of track and field jumping to further deepen the immersive feeling of the user.

In view of above problems, this paper presents a method to analyze the coordination ability of the special action of track and field jumping events within the signal autocorrelation. First of all, based on jumping site data and modeling, propose the hierarchical logic model of jumping site, conduct topology generation and hierarchical logic organization on the of input geometry data of lane lines, and describe the perplexing jump site from different levels. Second, based on the analysis and calculation on coordination ability of the special action of jumping events, put forward a set of new small-scale flow equation to describe the movement of jumping athletes of track and field, to make small-scale flow model able to combine with the behavior model of jumping athletes, and get the motion state of athletes through optimization solution.

Analysis logic model and calculation of coordination ability of the special action of track and field jumping events

Most of existing track and field jumping simulation software, use the micro model based on individuals to express the movement behavior of jumping athletes. There exists the bottleneck in terms of the computational efficiency of this kind of model, which is difficult to be applied in the analysis on the coordination ability of the special action of track and field jumping events. The small-scale method based on continuous flow simulates the whole movement trend of the jumping flow from the overall athletes, very suitable for coordination ability analysis of large-scale jumping events. However, the existing small-scale flow model used coarse grains to simulate movement behavior of athletes, which oversimplifies motion details of jumping athletes, especially ignores the jumping behaviors and process, and cannot realistically show various complex jumping phenomenon. This paper, make the improvement based on the classic small-scale flow model- cooperation game grid flow model [5], puts forward a set of new small-scale flow equation, to make the convenient connection and solution with jumping behaviors of athletes.

Small-scale flow model

During movement of jumping athletes, athletes can not only get the information about the density and speed of competitors in the front on the current lane, but also obtain the density and speed information of lanes on the left and right side. Based on this, this paper constructs an interactive cooperation grid flow model.

$$\begin{cases} \partial_t \rho + \nabla(\rho v) = 0 \\ \rho_{i,j}(t+\Delta t) v_{i,j}(t+\Delta t) = \\ \rho_0 \sum_{m=0}^{2} \left[f_{2-m}\left(H_{i,j}(t)\right) V\left(\rho_{i+1,j-1+m}(t), \ldots, \rho_{i+N,j-1+m}(t), \rho_j^*\right) \right] \end{cases}$$

The difference between the above equations and the classic cooperation grid flow model equation is the addition of the interaction term.

$$\sum_{m=0}^{2} \left[f_{2-m}\left(H_{i,j}(t)\right) V\left(\rho_{i+1,j-1+m}(t), \ldots \rho_{i+N,j-1+m}(t), \rho_j^*\right) \right]$$

This is to describe the impact of jumping athletes in the front on the current lane, or adjacent lanes on the jumping athlete on the current position. (I, J) represents the corresponding crystal grid (I, J) along the lane and perpendicular to the lane.

Wherein, $f_0(*) = \left\lfloor \frac{*+1}{2} \right\rfloor$, $f_1(*) = \left| |*| - 1 \right|$, $f_2(*) = \left\lfloor \frac{|*-1|}{2} \right\rfloor$.

ρ_j^* presents the athlete density at the current lane after the position (I, J) in the equilibrium state. $H_{i,j}(t)$ indicates the direction of the athlete, and when athletes flow into the lane on the left side, $H_{i,j}(t) = -1$; when on the right side, $H_{i,j}(t) = 1$; in other circumstances, $H_{i,j}(t) = 0$.

Use the finite difference method, make full discretion and numerical stability analysis on the above differential-difference equations, and get that if $H_{i,j}(t)$ is only determined, the equation has the only stable solution. With the help of jumping behavior model, it is possible to determine whether the lane change is feasible, so as to determine $H_{i,j}(t)$, and achieve the solution of jumping athletes in the movement state.

2.2 Model solution

In order to maintain the computational efficiency, starting from the jumping field, divide the jumping field into two parts, uniform and non-uniform sections [3]. For uniform sections, $H_{i,j}(t)=0$, that is, there will not be the jumping behavior. And sections, in which it is likely to have the jumping behavior, are defined as non-uniform sections, and use the jumping behavior model to solve $H_{i,j}(t)=0$.

In general, athletes will not frequently change lanes, and there are two kinds of conditions for jumping behaviors, one is due to the path change, such as the need to turn to another road from the road, this situation usually occurs on the lane relatively close to the intersection and ramps. In another case, there is a certain difference between the density and speed of adjacent lanes, such as one lane is blocked due to the accident.

Therefore, for any grid (I, J) in the track and field jumping site, if the grid meets any of the following conditions, the location is non-uniform.

(1) the density of the athlete at (I, J)is much higher than that on adjacent lanes of the current position;

(2) the speed of the athlete at (I, J) is much lower than the speed of athletes in the front on adjacent lanes;

(3) the lane of (I, J) will be closed ahead (due to converging or jumping faults);

The scope of the non-uniform sections is not fixed, but changing dynamically, and if there is an accident or jumping restriction, the scope of the non-uniform sections will be expanded accordingly. For the non-uniform sections, determine whether the individual at the position has the demand for changing the lane, and whether he can obtain trajectory of the lane changing which meets the constraint condition. If both are compatible, according to the direction of lane change, determine $H_{i,j}(t)=1$ or $H_{i,j}(t)=-1$, otherwise, $H_{i,j}(t)=0$.

Through the mesh subdivision on jumping lanes in the Frenet frame [28], after giving the initial value conditions, may combine athletes jumping behavior model with small-scale flow model for solution, get the speed and density of any athlete at any time and at any grid position. The solving process is shown in Figure 3, in which, the boundary data includes two parts. One is the motion state of the athletes on the lane at the initial time (including position and speed), the other is the motion state of athletes flowing into lanes in the middle time. The boundary data is defined and input by the user according to needs.

The analysis experiment of coordination ability of the special action of track and field jumping events

We give the efficiency and effectiveness test results of real-time expression calculation of jumping events by using the method presented in this paper. For the computational efficiency, if the jumping site scale is given, the computational efficiency of the system is almost independent of the number of athletes (Figure 1), and has the same order of magnitudes with the classic small-scale flow model (one-dimensional cooperation game flow model), indicating that the proposed method can be used for the analysis on coordination ability of the special action of jumping athletes. On the above-configured machine, this method can in real time express the movement of jumping athletes in the jumping site with the total mileage of 800m. In this experiment, the jumping site scale is as follows, the total mileage of the lane is about 800m, the non-uniform sections account for about 20% of the total site. Red line refers to the simulation results of the classic cooperation game grid flow model.

The measured data shows that 12 jumping behaviors in this section. Here, the first time is that a car enters into the adjacent lane from a lane through the lateral movement (perpendicular to the lane direction). In the measured data, starting moment for lane change is the time for athletes begin to laterally shift to the target lane, the end time is the time for athletes to reach the target lane and parallel to the direction of the lane, and the lane change duration is the difference between the end time and start time.

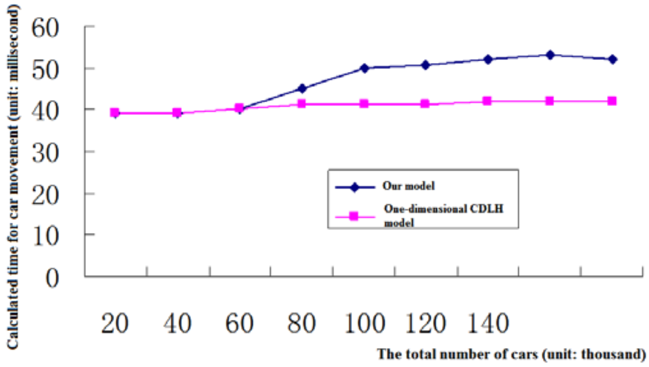

Fig. 1. The relationship between the number of jumping athletes and calculated time

Conclusions

With the development of virtual reality technology, the research on virtual city has been greatly developed. The integration of high-detail and high-fidelity simulation technology of jumping movement into the city simulation plays an important role in improving the credibility of simulation and enhancing the visual experience and jumping design and planning. Existing simulation methods not only have high requirements on the input data about the jumping site, and also can simulate city-level jumping events of track and field. Small-scale flow model can only describe the trend of the jump flow, but cannot simulate the individual interaction behavior of jumping athletes on lanes, which reduces the reality and reliability of simulation results. This paper presents a analysis method of coordination ability of the special action of jumping events within the signal autocorrelation, and demonstrates the technique detail of this method from jumping site logic modeling, analysis and calculation on coordination ability of the special action of jumping events. The experimental results and application cases show that the method has the following advantages. First, the method has relatively low requirement on the input quantity of jumping site data, and only needs to input the lane vector data to meet the demand of the animation expression; secondly, the efficiency of real-time simulation is almost independent of the number of athletes, which make the method suitable for the simulation of jumping events of track and field; finally, the method can make a detailed description about when and how athletes change the lane, and improve the simulation fidelity and accuracy.

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