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RESEARCH ON RISK CLASSIFICATION METHOD OF ASSEMBLY OCCUPANCIES

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ABSTRACT

Due to the densely population and mobility characteristics of the crowd, generally accidents happened in assembly occupancies will trigger a chain reaction, and then bring heavy casualties and property loss, and result disastrous consequences. In the context of safety regulation resources limited, building risk classification system of assembly occupancies is important for "scientific predicting, and hierarchical controlling" In this paper, a software with a graphical user interface is designed using MATLAB GUI to analyze and calculate risks of stampede accident caused by gathered crowds in the video. A velocity extraction method based on cross-correlation algorithm is adopted, and the risk characteristic parameters such as velocity variance is also applied. In this way, real-time analysis and early-warning for risks of stampede accident in time and space can be achieved. Also, the algorithm is applied to the surveillance video of the stampede in Shanghai and its feasibility is proved. Empirical research shows that, the assembly occupancies risk rating model built in this paper has good effectiveness, simplicity and practicability, applies to the government safety regulation and organization safety management, and can improve the safety situation of assembly occupancies effectively.

KEYWORDS

Assembly occupancies; risk analysis; velocity variance; accident forewarning

INTRODUCTION

Since the 21st century, the modern public gathering places in the city have become common, and some undertake public functions such as religious places, sports venues, the public meeting places, etc. They are faced with potential threat in all kinds of large-scale activities, such as a large number of participants, complex risk factors, wide social impact and serious accident consequence. According to statistics, since 150 major crowded stampede, has killed 5867 people, and 12722 people were injured, Asian areas are prone to this kind of accident in this century [1]. In China, the 2004 Beijing miyun county crowded stampede accident on Rainbow Bridge, 37 people were killed and 37 injured [2]. In 2014, at Shanghai Chenyi square, the opponent of people form a hedge and caused crowded stampede, 36 people were killed and 49 injured [3]. This shows that this kind of crowded stampede happened in crowded places, large public activities have several prominent features, namely, complex causes, sudden, difficult to control, and easy to cause wounds and dies in groups [4]. It also makes study and guard against crowded stampede become extremely urgent demand in developing countries with the rapid population growth and relatively backward management.

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Traditional large public activity dense crowd management mainly based on the human field monitoring and artificial video monitoring, which is very difficult to implement in the populated areas, and requires a lot of manpower and material resources. Moreover, omission, false positives, appear easily and it is difficult to ensure its accuracy and could not meet the needs of large public activity dense crowd management [5]. Therefore, to take effective intelligent video analysis technology is one of the ideal ways to solve this difficulty.

At present, the method based on intelligent video analysis is not only used in scientific research, but also in the safety management to the crowd in practice. This method has gradually become mature for dynamic scene visual surveillance technology. With strong applicability and credibility [6], it has derived a series of intelligent video surveillance system. For example, W4 system can be used to detect and track crowds in outdoor environment, and monitor their abnormal behaviour [7]; Pfinder system can make three dimensional reconstruction for indoor individual, and track individual in complex scene [8]; System developed by Carnegie Mellon university can monitor scenario group activities through networked multiple cameras and complete a long-time detection and tracking of multiple moving targets under complex scene [9]. But, basically, this kind of monitoring and control system is based on the monitoring and analysis of the individual. However, when large crowds gathered and crowded with each other, the human body movement is a kind of group behaviour, and the individual role is nearly lost [10]. So it is difficult to reflect crowd movement trend through detecting individuals, moreover, once overlap appears the detection and tracking error will increase. The most important thing is that the original system did not involve the inner mechanism of the crowded stampede happened in large public crowds gathering activities, so it cannot give a real and precise risk early warning information.

To make a real-time risk analysis for possible stampede of crowds that gathered in the large public activities, and to serve safety management of large public activity, this paper has designed a software algorithm which can be used to analyze the risk of crowded stampede, and has adopted image processing techniques based on cross-correlation theory to extract the crowd movement velocity field [11]. Besides it also uses the risk characterization method, which put forward by the Helbing and others [12], to extract the crowd movement velocity field information in risk quantification, and through man-machine interactive graphical user interface designed by the platform of MATLAB GUI, it allows the user to make synchronous risk analysis of imported video.

ALGORITHM DESIGN

(1) MATLAB GUI platform

MATLAB GUI is a powerful extensible system development platform, it provides the GUIDE development environment, which can be easy for the design of man-machine interactive graphical user interface and the corresponding function module development. By using the development environment, this paper has designed the algorithm software with a graphical user interface, which can be used to conduct risk analysis and calculation for monitoring video.

(2) Velocity field extraction algorithm

The velocity field is a physical field of velocity vectors at each moment, at each point. The velocity field algorithm was first proposed by Helman and Hesselink [13]. The core idea of this method is that the coordinate point of velocity field can be divided into two categories: the velocity vector of non-zero often singularity point and the velocity vector 0, and the singularity of the

streamline through the singularity and to describe the shape of the velocity field, the structure and evolution process.

Based on video analysis, traditional speed extraction algorithm which adopts the individual motion detection and tracking has formed many applications algorithm in the field of crowd's analysis [14]. Also some scholars use methods based on clustering low levels of particle trajectory [15] and simplify velocity field [15] to extract the mainstream of the crowd movement information, but they are not very accurate, especially under the condition of the population increased significantly. The applicability of the methods above is facing huge challenges, and its operation efficiency also falls sharply.

Therefore, this article uses the velocity field extraction algorithm based on cross-correlation algorithm [16-17], and the process of this method is as follows:

(1) To divide every frame image into smaller diagnosis windows, and define the centre of the window as a calculation point;

(2) The fast Fourier transform can be used to convert the original image from time domain to frequency domain;

(3) In the frequency domain, the two consecutive frames in the same position of two diagnostic window cross-correlation calculations, then the above results are fast Fourier inverse transformation.

(4) The origin of the displacement peak migration is the displacement of the window in the pixel space. In order to get real physical space displacement orthogonal projection transformation is also required. The displacement value and the time interval for two consecutive frames division can get the speed of the calculation point, which is the average speed of the diagnostic window.

(3) Risk characterization methods

Many researchers have tried to study the inner mechanism of the stampede occurred through the analysis of video data from the real crowded stampede, and analysis the dynamic process of crowd movement status and movement characteristic parameters before and after the accident, in order to get measured crowded stampede risk parameters and the threshold value.

The most representative is Helbing, who has put forward the concept of "population pressure", and is used to quantify 2006 hajj stampede in the change process of the risk, which can make warning for crowded stampede in advance. Its computation formula is:

$$P(\vec{r}) = \rho(\vec{r}) \cdot Var_r(\vec{V}) \quad (1)$$

The speed variance press type calculation as follows:

$$Var_r(\vec{V}) = \left\{ \left[V(\vec{r},t) - \vec{U}(\vec{r}) \right]^2 \right\}_t \quad (2)$$

In formula, $\vec{U}(\vec{r})$ is the time t in the average velocity field.

Since then, Helbing and others also organize experiments and use the simulation verify the applicability and accuracy of "population pressure" [18]. Considering the case with large population, although local density is not completely consistent, but the difference is little, so speed variance can react time and space distribution characteristics of risk to a certain extent [19].

On the one hand, algorithm designed in this paper can make use of the velocity field information of extraction to draw the real-time velocity vector diagram and flow chart, and used to observe the whole crowd motion state; At the same time, calculate the scene of average speed of graph in the crowd , which along with the change of time, so that to see whether it has appeared in speed drop; Then the average speed of over a period of time is used to calculate the real-time speed variance spatial distribution, and to characterize the time-space distribution characteristics of risk.

On the other hand, in order to reduce the random interference in real-time information, also needs to take a fixed time interval, and to take average of the velocity field. It can draw the average velocity vector diagram and vector flow chart, watching the movement of population overall in a certain time period; At the same time, drawing the histogram of speed size distribution , used to observe the velocity distribution state, judge whether the crowd movement in a laminar flow, and other special stage go stop wave; In addition, drawing the direction of speed distribution, used to observe the crowd distribution state of direction of motion , judge whether the crowd movement in the one-way flow, two-way flow or the main direction of mixed and disorderly state; Finally is drawing space distribution, the average velocity variance need to calculate the overall average velocity field over a period of time, then the type (3) is used to calculate the speed of each moment, spatial distribution of variance matrix and average velocity variance for space distribution matrix, it can be more accurate and comprehensive description population as a whole movement lead to accumulation of risk distribution within a certain time.

APPLICATION CASE

(1) Video source

Based on the stampede of surveillance video to verify this algorithm, which happened in the Shanghai "12.31" Chenyi square, and the monitoring point is in the south of Chenyi square and time is December 31, 2014, and the frame rate is 25 frames/s, 704 x 576 pixels, 23:35:32, 23:31:18 - a total of 254 seconds to capture the analysis.

It can be observed from the surveillance video, the scenario is at a viewing platform, stairs in 23:35:05, namely someone in the bottom of the stairs down at the interception of 227 seconds in the video compression, and happened crowded stampede subsequently.

(2) Parameter input

In order to take projection transformation for the scene in the monitor video, and acquire real space displacement and velocity information, the software requires the user to input scene space coordinate parameters in turn. The process of parameter input needs to guarantee the corresponding of space coordinates and the pixel coordinates points, and the software also allows the user to check by the means of images, so that more intuitive to corresponding display the actual location and pixels points, and easy to check.

(3) Risk calculation

This software can implement synchronization analysis of risk profile of the crowded stampede in the crowd gathered in the video broadcast video. First by using the parameter calculation of space projection transformation matrix, at the same time to get the velocity field of each point in the pixel field and the actual space abscissa and ordinate matrix, and the information stored in the suffix for the .mat files and added to the GUI handles variable. Intervals of 1 s, after taking two frames to calculate a real-time velocity field, the two frames for 0.2 s between before and after two consecutive images. Games to calculate the speed of information including the pixels in the x, y direction matrix, the speed of the actual space x, y direction matrix, the actual speed

scalar matrix and the space average speed of the time value, the above information will be saved to the frame number naming suffix for the .mat, which on behalf of the real-time velocity information of the moment. In addition, the real-time speed calculation of variance of process will be carried out in accordance with the method of mentioned above, the actual average velocity in the x, y direction matrix, the speed of real-time speed variance matrix, maximum variance and spatial information such as the average value of variance can also be saved to a suffix for the mat files. Finally, the software will call all .mat data in the file into various analysis results, for users to real-time observation and judgment the crowds gathered the risks and their distribution state.

(4) Results analysis

Through analysis and calculation, we can get the average velocity vector diagram as shown in Figure 1, they represent respectively the accident before 75 ~ 100 s, 25 ~ 50 ~ 75 s, 50 s and between 0~25 s the average results of velocity vector field. We can find that, the crowd movement speed itself is not big due to the extremely crowded, but the individual has lost his self-control and had to follow the whole crowd surging, so the speed and direction is mixed and disorderly, and speed appears obvious zoning phenomenon, namely the speed of populations in an area is larger, and its neighbouring areas of the crowd movement did not occur. In the process of the crowd movement, accident within 0 ~ 25 s before the crowd movement speed increases suddenly, as shown in Figure 1 (d), it is extremely dangerous cause to crowd, in which the stampede immediately after this period of time.

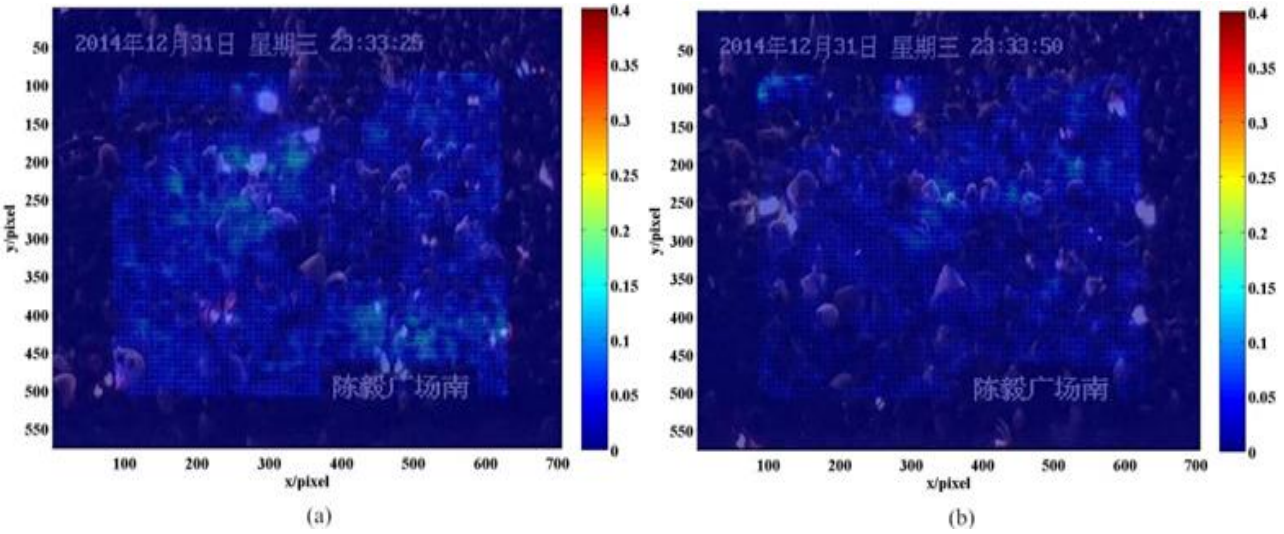

Fig. 1 - Respectively before the accident of 75 ~ 100 s, 50 ~ 75 s (a) (b)

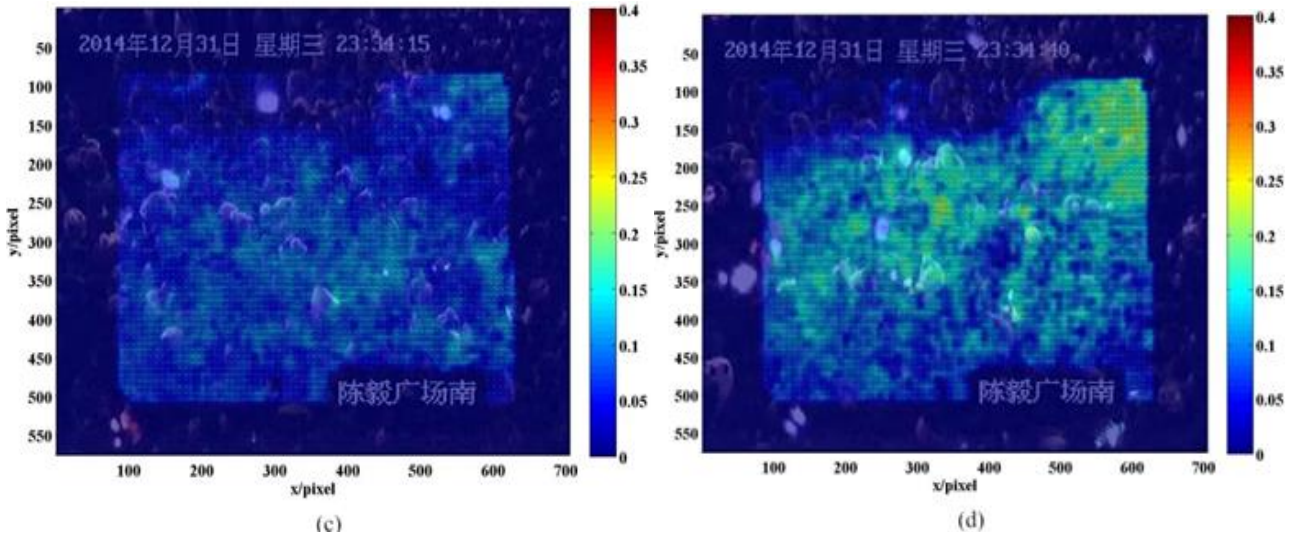

Fig. 1 - Respectively before the accident of 75 ~ 100 s, 50 ~ 75 s (a) (b), 25 to 50 s (c), and 0 ~ 25 s (d) the average velocity vector distribution.

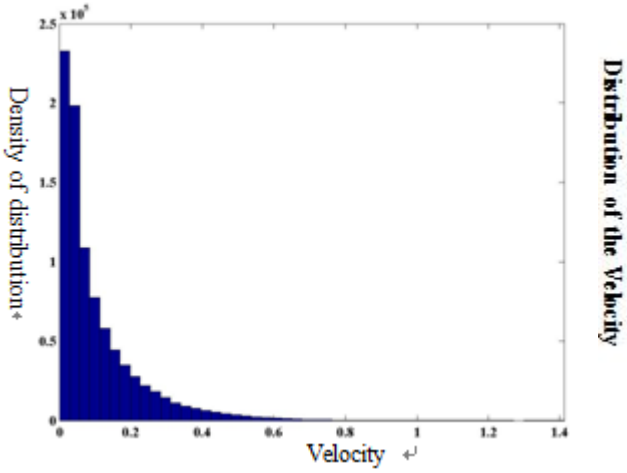

Fig. 2 - The velocity profile of the video time scale

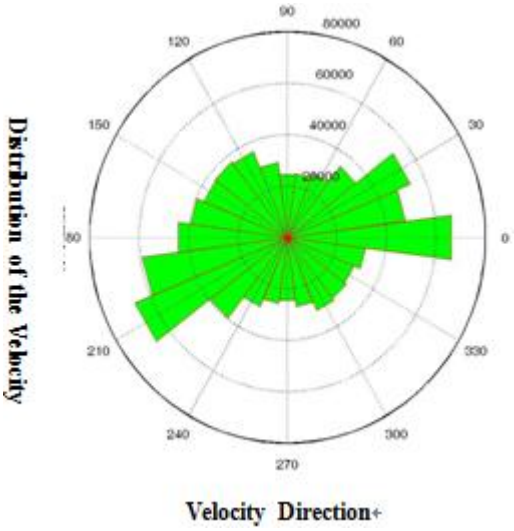

Fig. 3 - The velocity direction of the video time range

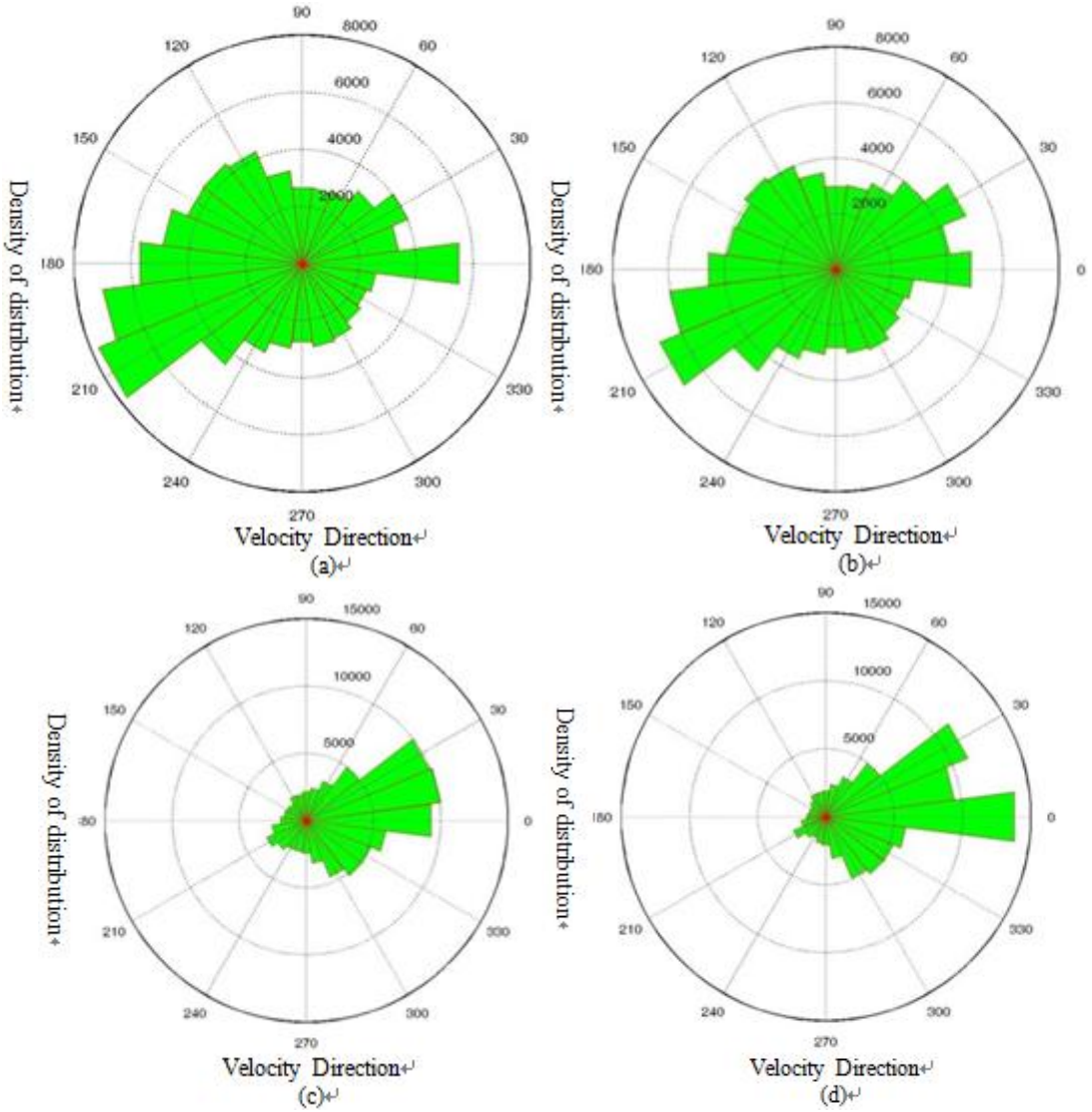

Fig. 4 - Respectively before the accident of 75 ~ 100 s, 50 ~ 75 s (a) (b), 25 to 50 s (c), and 0 ~ 25 s (d) direction of the velocity distribution

Figure 2 shows the velocity size map of the overall video time scale, and Figure 3 maps the velocity direction of the overall video time range. It can be found that the population moving speed is relatively slow from the overall, and flowing direction is random, so that every direction exists. It is difficult to ensure consistency of movement direction, and easy to make people into chaos. It can be observed viewing platform on the basic of stream of people is in a state of movement to the left, then a sudden change of direction, rapid movement to the right in the video before the accident of a period of time, which directly caused the stampede, as shown in Figure 4 (a, b, c, d).

The results of the analysis above can help managers to identify closely risk from multiple angles, but it belongs to the qualitative judgment basically, which needs to be combined with existing knowledge experience. Therefore, software also provides a more intuitive risk analysis results from the time and space.

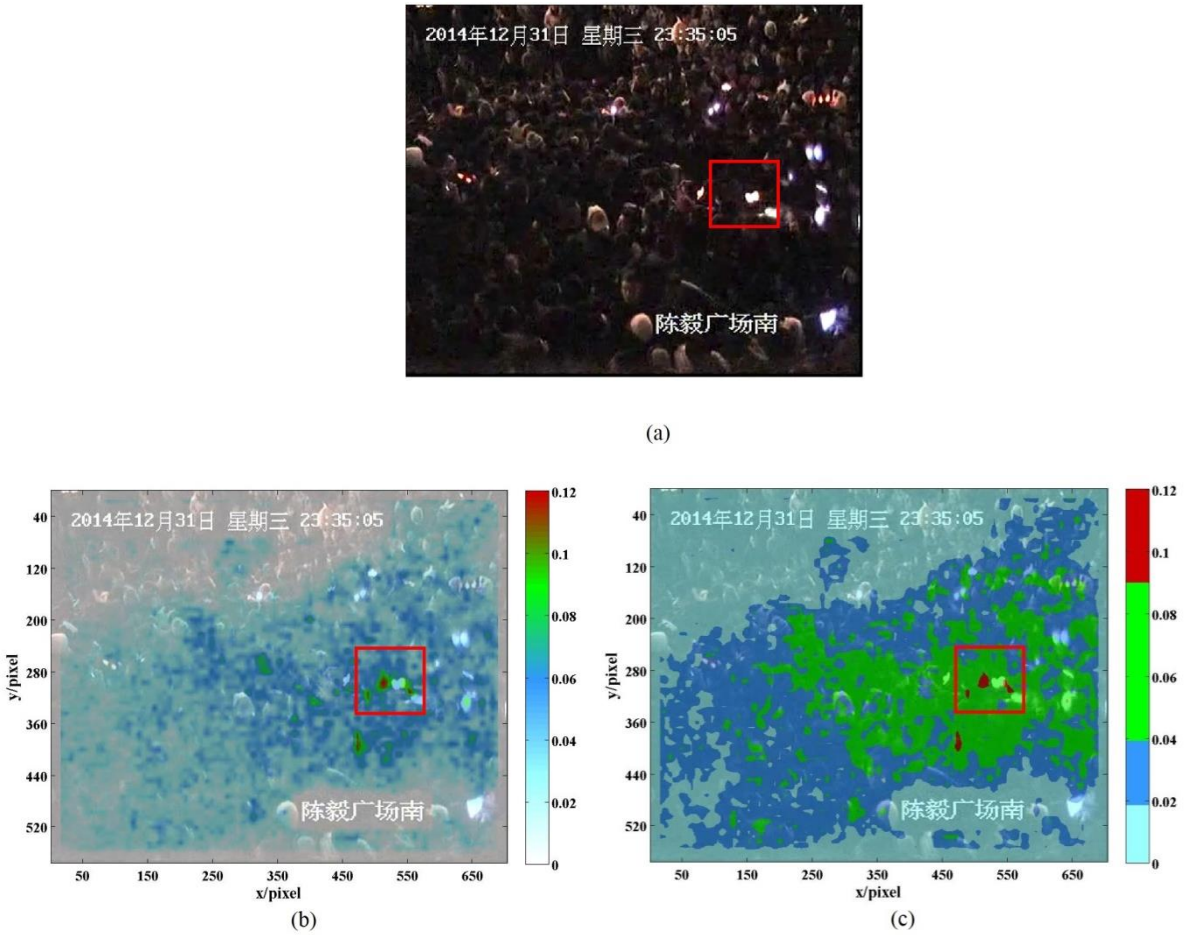

Fig. 5 - Video capture the accident moment (a), 210s~235s (accident happened in the 227s, namely 23:35:05) the average speed of spatial distribution of variance (b) And the space of the 210s ~235s risk classification figure (c)

From the point of the judgment of the time of an accident, it can be obviously found that speed in the whole period of time within the scope of the near peak appeared in the 200s and 215s, and trample accident occurs in the later 227s; Also appeared in 210s near peak velocity variance, and the difference is very apparent before and after the peak. This means that both of them above have crowded stampede's ability to provide risk early warning in advance in certain circumstances; From the angle of estimate the location of the accident, as shown in Figure 3, for the 210 s to 235 s in the video, that is a total of 25s average velocity variance of space distribution, and accident happened in the 227s. Darker area means higher risk, and it can be found in the figure that more obvious high-risk areas have basic match the actual position of stampede, and the specific area of the accidents can be roughly estimated, as shown in Figure 3 (a, b). If carried out in accordance with the spatial distribution of the average velocity variance risk classification, the crowd movement can be described as "sparse - normal - crowded - dangerous" four levels, corresponding to different velocity variance interval, as shown in Figure 3 (c). Speed variance is more conducive to take distinguish of the crowd gathered compared to make grade of crowd motion state from the angle of the speed size, and launched the emergency response plan to provide more reliable basis for emergency treatment.

DISCUSSION

(1) In this study, we also need to realize that as a result of the crowded stampede mechanism understanding is not deep, we have some limitations in risk calculation and analysis methods, and it cannot apply to all situations.

(2) In addition, before the accident monitoring phase, the corresponding risk characterization of threshold parameters is of great importance, both to reduce the false alarm and avoid the occurrence of omission, so that we need further research to better applied to crowd safety management of the crowd gathering filed, and provide accurate information for the accident early warning and things.

CONCLUSIONS

(1) This research in view of the crowds gathering places may be crowded stampede, to help management to better identify and analyze the crowded stampede risks brought by the crowds gathered, has carried on the related algorithm and the software design.

(2) Using the MATLAB GUI software development platform, design the relatively friendly graphical user interface, the velocity field extraction method based on cross-correlation algorithm, and the extraction of the velocity field and the velocity and quantitative calculation, the parameters of variance told the crowd gathered from the time and space at the same time the scene may be crowded stampede of risk analysis.

(3) This research verifying the Shanghai "12.31" stampede video data by using the algorithm, acquire consistent results, and prove the applicability of the algorithm has certain.

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