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Analysis and Design of Public Places Crowd Stampede Early-Warning Simulating System

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***Abstract*—With the development of the society, in recent years, frequent crowd stampede accidents have posed great threats to public security. Based on the traditional video surveillance technology, making full use of computer vision, image processing, pattern recognition and other related technology to detect target and recognize abnormal human behavior in monitoring scene as well as conducting a risk assessment of the state of crowds in public places for timely warning has been the focus of attention around people.

In this paper, the requirements of public places crowd stampede early-warning simulating system were analyzed, and the basic design of the two aspects including system functions and system processes was presented. In addition, the basic functions of the system were initially realized.

Keywords- Crowd Stampede; Simulate early-warning system; Abnormal human behavior recognition

1. INTRODUCTION

With the development of urban society and economy, the flow of people is also growing in public places like piazzas, subway stations, railway stations and other locations, which causes the increasing risk of crowd stampedes in public places. (2015) [1] Though the possibility of the occurrence of crowd stampedes is low, the accidents usually lead to extremely terrible social impact. Giving the difficult controllability of this kind of accidents, the early-warning measure is a more appropriate choice for us. (2007) [2]

In the stampede early-warning process, the most important thing is to grasp the real-time state of the dense crowd. Before stampede, the dense crowd usually has certain characteristics, such as increasing crowd density, slow flow rate. if we are able to detect changes in crowd density, speed and other factors, control the exceptions of crowd by timely early-warning measures, the probability of the stampedes can be greatly reduced. Once stampede occurs, the harm of the consequence can be minimized by locating the position of the accidents, and scatter the crowd through staff guidance, radio, and so on. Generally speaking, the prevention of crowd stampede focuses on the early-warning measures. Timely judgment and reasonable warning measures are the cores of this article.

Currently, many public places are equipped with surveillance cameras, which are the effective early warning measures (2016) [2]. Taking the consideration of their convenience and widely application, we decide to make concrete analysis and design of the early-warning simulating system based on video surveillance in public places. In addition, we have write a program and successfully realize the main functions. It works great while testing and specific content will be mentioned below.

2. SYSTEM ANALYSIS AND DESIGN

A. Requirements Analysis

The first step to establish public places crowd stampede early-warning simulation system is to the dispose video image, including the extraction of moving object, and tracking moving objects continuously to capture targets' optical-flow features like speed, direction of movement, etc. Then the data will be used in the analysis of the public places crowd state.

The multi-dimensional analysis of the crowd's state such as target recognition, crowd flow, crowd behavior, crowd movement are necessary to evaluate the probability of crowd stampede occurrence in the process to realize the system.

On the one hand, different thresholds serving as key indicators of the accident's trigger should be designed to match different situations where the deadly degrees of crowd congestion differ greatly. On the other hand, abnormal behavior of people is also an important cause of the stampede accident, which requires the system ability to identify abnormal human behavior from video and give timely warning.

Once the crowd stampede occurs, the system should deliver emergency messages, execute contingency plans with the optimal evacuation route dynamic designed, and assist the related staff to transfer victims safely. (2009) [3]

B. System Design

1) System Functional Design

The system functions include initial value setting, moving object feature extraction, the crowd stampede risk estimates and evacuation guide. System functional schematic is shown in Figure 1.

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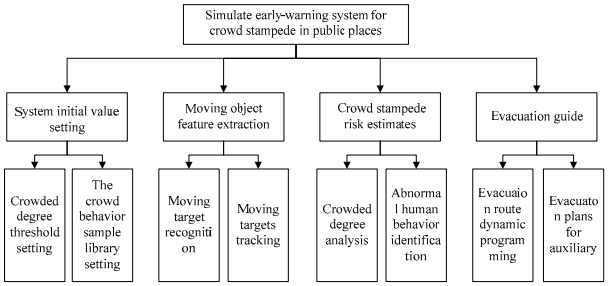

Figure 1. system functional schematic

The extraction of moving target feature is mainly carried on through video surveillance images modeling to isolate foreground moving object's characteristics like moving direction, velocity and other optical-flow information, which is key to the risk assessment of crowd stampede. Risk assessment of crowd stampede includes crowded analysis and abnormal human behavior recognition. On the basis of moving object extraction, we calculate the number of people based on the number of people in the accident. With the establishment of a large number of public places of crowd behavior video library, it's able to extract samples' optical-flow state using Bayesian networks for machine learning and training so that machine identification of abnormal human behavior can be realized. Combined with the degree of congestion and abnormal human behavior, the risk level of the current situation's state can be estimated precisely.

Once the system detects exceptional cases within a certain area, then it will deliver emergency messages automatically by the means like marking the target area and alarm, execute contingency plans with the optimal evacuation route dynamic designed, and assist the related staff to transfer victims safely.

2) System Process Design

After obtaining real-time video in public places through the monitoring device, the system identifies the moving target in the video to obtain its information of the optical-flow motion. The characteristics of head and shoulder are used to count the number of people and calculate the degree of crowd congestion, which will be compared with density threshold set in advance. At the same time, system will track the moving target in the following frames and recognize the abnormal human behavior by matching it with the enormous samples of crowd behavior in the sample library. Both the degree of crowd congestion and abnormal human behavior will play a important role in system's judgement for risk. Once system evaluates the high risk, the warning will be given timely as well as the contingency plans will be carried out. The system core processes are shown in Figure 2.

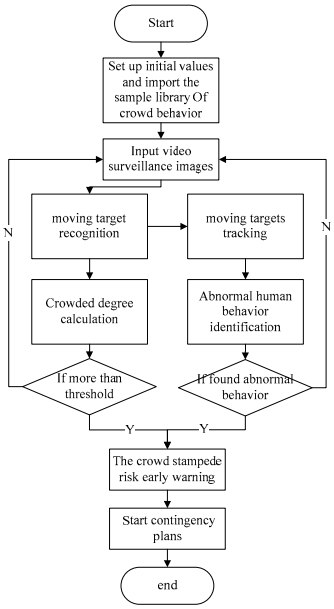

Figure 2 system processes design

3. IMPLEMENTATION OF THE SYSTEM

A. Identification of moving objects

Moving objects identification methods mainly include background subtraction, frame difference method, single Gauss background modeling and mixed Gauss background modeling. Single Gauss background modeling method is simulating every background pixel's value with a Gauss function, and the pixel of the subsequent frames whose value is not consistent with the function distribution will be judged as foreground pixel, while mixed Gauss background modeling method uses multiple Gauss functions to simulate the states of background pixels. Mixed Gauss background modeling method usually bases on 3-5 Gauss functions, effective on judging whether the pixel is foreground pixel through a more precise calculation. (2011) [4] So this paper chooses mixed Gauss background modeling to extract moving objects. Figure 3 shows the effect of moving objects extraction in the system.

Figure 3 moving objects are extracted in the system.

B. Tracking of moving objects

The principle of mean-shift includes non-parametric estimation, kernel function, derivative, mean-shift vector derivation and so on, reasoning proved that mean-shift vector always moves to the maximum probability density. Mean-shift algorithm iterates to the maximum probability density distribution, so finally it will always find the position of moving targets. (2012) [5] But it only searches single-frame image, while cam-shift algorithm operates on continuous multi-frame images with mean-shift algorithm. According to iteration in chronological order, we can achieve the goal of tracking in a part of a video.

In order to solve the problem of moving targets temporarily losing caused by factors such as occlusion, the algorithm needs to be optimized on the basis of cam-shift algorithm, and the prediction algorithm for tracking targets should be added to. (2012) [6] According to iteration in chronological order, we can achieve the goal of tracking in a part of a video.

To update the cam-shift algorithm, we set a flag for every target to save tracking status. When moving targets temporarily disappeared, its state will be update to "unknown". When moving targets was detected to have disappeared in multi-frame images, we think that it has left the area monitored, and its states will be updated to "lost". Multi-target tracking effect of the system is as following figure: the black thick lines are the tracking paths of each moving target.

Figure 4 tracking of multiple moving targets

C. Crowd counting and calculation of crowded degree

1) Set initial values

For each frame image, we need to set the following parameters at first including initial edge length of search box, reduced length of search box, value of moving speed (The faster search box moves, the faster it will traverse the image and the accuracy will decrease. On the contrary, the moving speed slow down and the accuracy increases), the ignored value(if the number of targets in search box is lower than the ignored value, the box will be judged to be invalid), Valid quantity of search boxes(the certain number of valid search boxes sorted and selected according to factors such as density), alert threshold(crowd density is higher than the threshold value is considered to have a greater risk of stampede), variance of all targets' distances(region with a smaller variance can be identified more crowded).

2) Crowd searching and number calculating

After mixed Gauss background modeling is established the initial parameters are determined, program starts searching moving target from (0,0) of the processed image to judge whether the target is in the search box one by one, and thereby obtain and write down the target number in the first search box. If the number recorded is less than the ignored value, skip that search box and move it to next position to start a new search, otherwise record all targets' information in the box. Then, move the search box to the next position with the initial speed and handle the objects in it in the same way the first search box handled. Repetition goes on until the whole image has been searched. After that, sort all qualified search boxes according to the variance of all targets' distances. If the total number of search boxes is larger than valid quantity of search boxes, then ignore the redundant search boxes behind valid boxes.

3) Calculation of density and result boxes marking

In the second stage, the density of valid search boxes first will be judged. If the value reaches the alert threshold, mark this box as a result box, otherwise, narrow left search boxes—set the global center of all targets calculated in the first stage as the center of search box, and reduce the size of search box by several units to get new search box. After that, record information of search boxes. If the density reaches the threshold, mark this box as a result box, otherwise, repeat the described shrink and judgment procedure until no search box can be narrowed again. In the system test screenshot, single targets identified are with red border, single targets judged through continuous tracking are with green border, and areas with a high density are with blue border. Algorithm flow chart of Calculation of density is shown below:

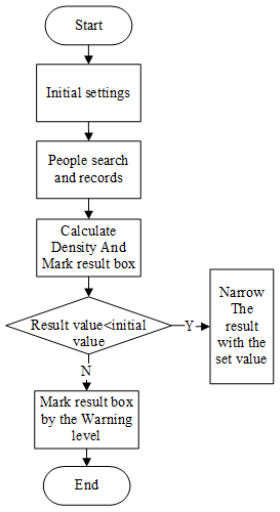

Figure 5 algorithm flow chart of Calculation of density

The moving objects in the foreground images are classified during this process, which make it possible to approximate

estimate the number of the moving objects. However, these moving objects not only include humans, but also cars, vehicles and so on. It's necessary to distinguish the specific persons from the moving objects. Compare with other moving objects, the characteristics of human's head and shoulder have significant difference and stable during the continuous images, which brings enormous convenience to extract specific persons from the video and count the precise number and intensity of the crowd. (2014) [7]

D. The early-warning of abnormal human behavior

The reasonable of human action information with the appropriate parameters is the so-called motion feature. Extracting a moving image is to extract the parameters that presents the state of motion to describe the behavior from the input video sequences. In addition to static characteristics of human behavior based on the appearance of the shape, the dynamic characteristics of motion such as the direction of movement, trajectory, position, speed and so on, reflect the dynamic behavior better. (2014) [8]

Abnormal human behavior recognition is to automatically detects abnormal human behavior through the analysis of human motion feature, based on the successful operation information capture, motion feature extraction. However, the complexity of human motion and many disturbances of video noise, lighting, background change bring the enormous difficulty to abnormal human behavior recognition. Throughout the process of detection and identification, characterization of human behavior plays a crucial role. Behavioral feature extraction and representation is the foundation to conduct follow-up action recognition, whose performance directly affects the subsequent detection of the identification process.

Optic flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer (an eye or a camera) and the scene. Optical flow can be used to obtain three-dimensional motion information of the objects corresponding to each pixel. Therefore, it’s able to extract the dynamic characteristics of the optical flow motion moving target in a continuous video image. Abnormal behavior identification purposes are to detect abnormal behavior and events and video sequences. According to optical-flow dynamic characteristics described, we can identify patterns of the abnormal human behavior in real-time video with a suitable dynamic Bayesian network model constructed by adjusting parameters through continuous learning in the sample library of crowd behavior.

4. CONCLUSIONS

In this paper, the requirements of public places crowd stampede early-warning simulation system were analyzed, the basic design of the two aspects of the system functions and system processes were presented, and the basic functions of the system were initially realized. The system has realized not only the functions of crowd counting and calculation of crowded degree through the use of Gaussian mixture model for background modeling system on the basis of the captured video data, but also the function of a multi-frame image tracking and identification of abnormal human behavior with cam-shift algorithm and optical-flow method.

Through testing, many application value of the system is confirmed in different situations including school, hospital and many other large-scale public places. With the help of preserving the public order as well as reducing the traditional manual work, our research has aroused the concern of the local public. Nonetheless, there are many aspects waiting to be improved including the more accurate human identification results, the ability to suit different public situation, etc.

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