Real-time Monitoring for Crowd Counting using Video Surveillance and GIS

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***Abstract*—In public venues, crowd size is a key indicator of crowd safety and stability. Monitor the people number and crowd density levels are important scientific research topics. In this paper, we present a framework that will enable real-time crowd counting and spatial-temporal analysis for the crowd of the monitoring region. Firstly, we obtain crowd counting models for each camera by statistics regression methods using sample data. Secondly, we integrate video surveillance system and geographic information system (GIS) for capturing, managing, analyzing and displaying all forms of geographically referenced camera information, such as location, monitor area, and real-time crowd counting data, etc. And then, we combine image processing with crowd counting models to estimate people number and crowd density of monitoring areas. Finally, we implement a system for real-time crowd counting based on video surveillance system and GIS. We can acquire real-time data of people number and crowd density levels for each camera, and display them by the way of map and curves. Also, we can retrieve history data and analyze them by spatial analysis tools. The experiment shows that this system can provide early warning information and scientific basis for safety and security decision making.**

Keywords-real time; spatial-temporal analysis; crowd counting; crowd density; decision making

I. INTRODUCTION

With the accelerated process of urbanization and socio-economic development, people gather in public more and more, which results in many crowded public emergencies. For reducing the number of crowd accidents, estimating the people number and crowd density should be very pivotal. As the crowd counting and crowd density are essential descriptors of all the status of crowd, it is very useful for us to learn the distribution of crowd and find out the tendency of abnormal behaviors, if we know more about the people number and density of the crowd. So crowd counting and crowd density are very useful information for security departments.

Detecting and counting people in surveillance systems is a challenging problem. In many years, there were many works dealing with estimating the people number and crowd density for crowds [1-6]. But most of them were related to algorithm research for a single camera. The goal of the crowd density detection is the basis for security sector's decision-making. During the emergency evacuation, potential factors are overcrowding and crushing caused by, for example, human stampede behaviors and structural problems of pedestrian facilities. In order to design effective and safe pedestrian facilities and egress routes, it is important to spatially and temporally understand the pedestrian behaviors and the egress efficiency.

GIS is a system to capture, store, manipulate, analyze, manage, and present all types of geographically referenced data [9]. In this paper, we design and implement a system that integrated GIS with video surveillance system. It can capture and analyze real-time crowd counting data in spatial-temporal pattern and give security sector useful information to help them make scientific decisions, as shown in Fig. 4 and Fig.5.

The rest of this paper is organized as follows. In section II, we describe the related works that have concerned with people counting in a crowd. In section III, the framework of our system and the process of system design and implementation. In section IV, we discuss the experimental results. In the last section, we summarize the approach and present some clues for the future research work.

II. EXISTING WORK

In the past, there were much works dealing with crowd counting and crowd density estimation. These techniques used can be classified into two categories. They are pixel counting based and feature-based. In pixel counting based methods [1, 2, 3]， background segmentation is first performed to extract the foreground, mainly made of moving people. Then people number is computed by a function of the number of foreground pixels, the function is obtained by learning, such as least squares method. In feature based methods [4, 5, 6], features are computed for the whole image, and segmentation may or may not be required, e.g. texture features are used on the observation that crowded areas exhibit textures and the higher the crowd density the stronger the texture features (contrast, homogeneity, energy, entropy). No matter the technique adopted, the estimation results were only for each individual camera. We can't analyze crowd density for an area where there are a lot of cameras at different locations in spatial perspective.

There have been some attempts to simulate the crowd density and pedestrian behavior in spatial and temporal. [7] presents a system to simulate the movement of individual agents in large-scale crowds performing the Wawaf. This approach uses a finite state machine to specify the behavior of

This work was supported by Key Projects in the National Science & Technology Pillar Program during the Twelfth Five-Year Plan Period (No.2012BAH35B02) and the Major Basic Research Funded Projects of Jiangsu Province (No.10KJA420025).

978-1-4673-0875-5/12/$31.00 ©2012 IEEE

the agents at each time step in conjunction with a geometric, agent based algorithm to specify how an agent interacts with its local neighbors to generate collision-free trajectories. [8] propose a framework for modeling lower-level pedestrian navigational behaviors. In this framework, spatial-temporal patterns are used to represent the situational perception. They construct a computational model to simulate pedestrian behaviors in a corridor with medium to relatively high density of pedestrians. But the simulation results are based on static or virtual data. These spatial-temporal analysis methods not take into account other spatial factors (spatial distribution of facilities, real-time road traffic conditions etc.), but confine their analysis region to a single area or only a large building.

Our work focus on real-time spatial-temporal analysis for crowd counting using GIS technology and video surveillance system. We propose a framework for crowd counting real-time surveillance. In our framework, we integrate each camera's real-time crowd counting data and other geospatial data. So we can make scientific decisions for security sectors with spatial-temporal analysis methods.

III. SYSTEM OVERVIEW

A. *Architecture of the System*

Real-time spatial and temporal analysis system for crowd counting consists of three parts, as shown in Fig. 1.

1) Data acquisition: In order to achieve the goal of real-time spatial and temporal analysis for crowd counting, we should capture data real-time by video surveillance system. So we can monitor the crowd and get images real-time in the surveillance center.

2) Data processing: After data acqiusition, we have to process them. These data are images, so we process them by image processing system. After that, use the crowd density estimation model to caculate the number of people in the crowd or the crowd density. Then the results was stored and managed in GIS.

3) Data management and analysis: With GIS, we can retrieve, analyze all kinds of geographic referenced data and display the analysis results in different types (maps, charts, curves etc.). The historical and real-time crowd density data already stored in GIS, so we can ayalyze crowd density, crowd flow with other types of spatial data in spatial-temporal pattern.

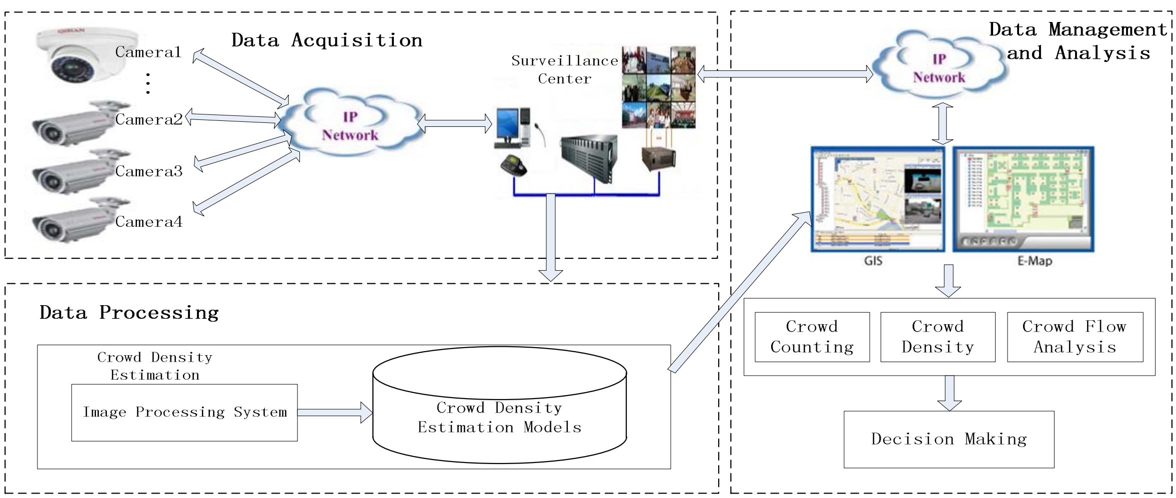

FIGURE I. THE FRAMEWORK OF REAL-TIME SPATIAL-TEMPORAL ANALYSIS SYSTEM FOR CROWD COUNTING

B. *Construction of the System*

This system is composed of three subsystems. They are video surveillance system, crowd density estimation models training system and geographic information system.

1) Video surveillance system: A video surveillance system is the use of video cameras to transmit signals to a specific place. Our research is based on the video surveillance system of Nanjing Public Security Bureau. We use this system to get real-time surveillance image for crowd counting.

2) Image analysis and models training system: This system is used to obtain crowd counting functions by the way of learning. In order to obtain the size of the crowd, we need to use iamge processing system to analyze those real-time image data, as shown in Fig. 2. This paper adopts the algorithm mentioned in [2] and [6] to estimate low density crowd and high density crowd respectively.

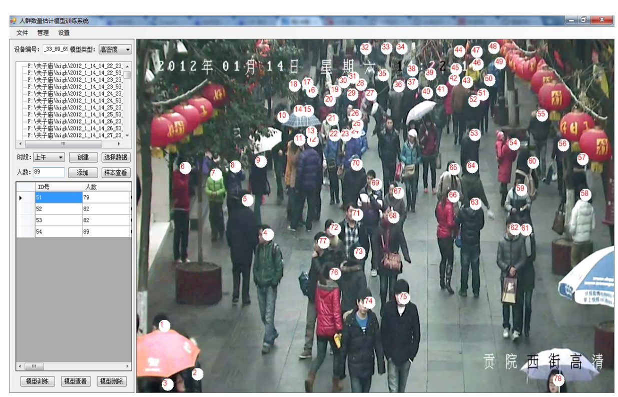

FIGURE II. THE INTERFACE OF MODELS TRAINING SYSTEM

3) Geographic information system: In this paper, we manage and analyze the crowd density data that has different locations using GIS. We can achieve joint analysis with other spatial data, such as traffic conditions, etc. And the results can be represented in different forms by the way of spatial-temporal pattern. So it can provide the basis for the crowd flow leading, traffic control, facilities layout during planning, etc.

4) System integration: The combination of GIS and video surveillance system makes the GIS system can receive the video signal, and using image analysis system for adaptive estimate the crowd size and crowd density for low and high density crowds. We can provide scientific basis with the real-time spatial-temporal analysis results for early warning and decision making.

C. *Implementation of the System*

We achieve real-time monitoring of crowd counting and crowd density by the way of spatial and temporal through the following steps, as shown in Fig. 3.

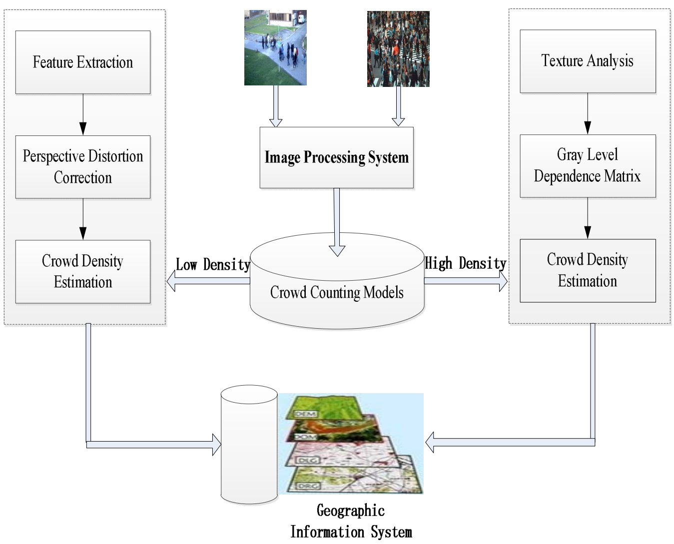

FIGURE III. DATA FLOW DIAGRAM OF REAL-TIME SPATIAL-TEMPORAL ANALYSIS SYSTEM FOR CROWD COUNTING

1) Models training: We divide the camera sample data into two categories of low-density crowd image and high-density crowd image. Then, we get low-density crowd estimation models and high-density crowd estimation models by the model training system respectively. The model parameters are stored in the models database, and associated with the GIS system.

2) Crowd counting estimation: Set the threshold to distinguish the high-density crowd and low-density crowd. We adopt low-density estimation model to estimate the people number of the crowd, if it is greater than the threshold, then choose the high-density estimation model.

3) Storage and management of crowd estimation results: After crowd estimation complete, the results were saved in the GIS database for the historical data query and analysis.

4) Spatial-temporal analysis and visualization: According to the estimation results, the number and density levels of current monituring areas can be displayed on the map. And each monitoring region's crowd flow were displayed in the form of statistical curve at the same time.

5) Early warning and decision making: Based on the analysis of real-time crowd monitoring, we can get early warning information for the areas of very high density crowd. In order to avoid emergency public events, combined with the current traffic conditions and develop evacuation strategies to ease the overcrowd in the region.

IV. EXPERIMENTAL AREA AND RESULTS

In order to test the viability and effectiveness of the approach the paper proposed, we conduct a simulation experiment with this system in Nanjing Confucius Temple area.

A. *Introduction to Experimental Area*

The Confucius Temple in Nanjing was originally constructed in the year of 1034 in the Song Dynasty. It was a place to worship and consecrate Confucius, the great philosopher and educator of ancient China. Centered around the ancient Confucius Temple is the place to be on weekends and holidays. Clothing shops and restaurants dominate the main streets. Therefore, this area usually has a lot of people.

In order to ensure security, the public security department has installed a large number of cameras at important junctions. We choose a range of 0.22 square kilometers around the Confucius Temple, and select 12 high-definition cameras for experiment.

B. *Experimental Results*

FIGURE IV. SPATIAL DISTRIBUTION PATTERN OF CROWD DENSITY LEVELS

The experiment shows that this system can achieve the goal of real-time spatial-temporal monitoring for the surveillance area. We can get real-time spatial pattern of crowd density levels by the map, as shown in Fig. 4. Also, we can obtain the real-time crowd counting curve for each camera. So according to the crowd density levels map and real-time curve, security management department can determine the current status and trends of crowd density in monitoring area, as shown in Fig. 5. When the crowd density is too high, the system will generate warning prompt.

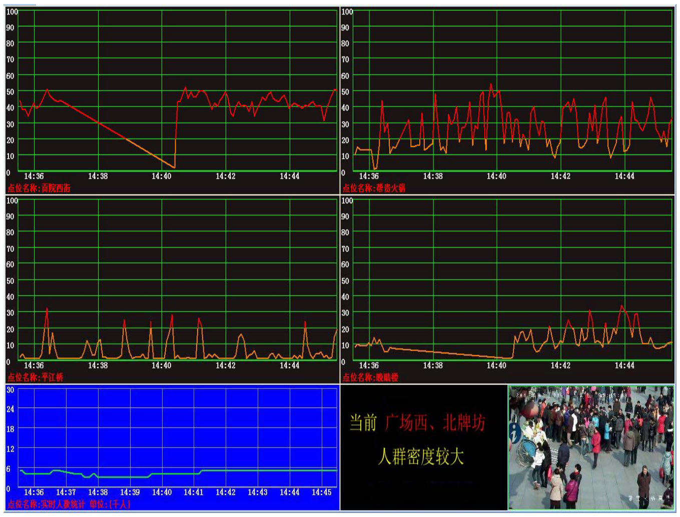

FIGURE V. REAL-TIME CROWD COUNTING CURVE AND EARLY WARNING FOR EACH CAMERA

As shown in Fig. 4 and Fig. 5, this system prompt that the crowd density is very high in Square West and Paifang North. In order to avoid public emergencies, we should use of spatial analysis combined with real-time traffic data to develop measures to guide the crowd. At the same time, we can provide the basis for the layout of facilities during planning according to the spatial-temporal analysis results for the historical data.

V. CONCLUSIONS AND FUTURE WORK

This paper designs a system framework of real-time monitoring crowd density combined video surveillance system with GIS. We implement the real-time monitoring and spatial-temporal analysis for crowd density based on this framework. Through experiments we verify the feasibility of the combination of intelligent video surveillance and GIS. This can provide basis for the security warning, crowd trends analysis and decision-making.

But this paper does not too much to consider the accuracy and efficiency of the crowd counting estimation model. If the monitoring area has a large number of cameras, we would have to do much work to obtain the cameras' crowd counting estimation model. So we should further study the crowd counting estimation model's accuracy, efficiency and their versatility.

In addition, the crowd density estimation in this paper is only for a single camera, we can analyze the crowd density spatial distribution pattern in point mode by the cameras' monitoring data distributed in different locations. However, we can't achieve the goal of spatial pattern analysis by the way of a trend surface. Because some places were covered seamlessly by a lot of collaborative cameras. So it is necessary to further combine intelligent video analysis and GIS, and study the real-time crowd density estimation for multi-camera collaboration in large area, crowd density levels generation on the surface, and the hot spots monitoring in crowd, etc.

ACKNOWLEDGMENT

This research is partially supported by Key Projects in the National Science & Technology Pillar Program during the Twelfth Five-Year Plan Period under Grant No. 2012BAH35B02 and the Major Basic Research Funded Projects of Jiangsu Province under Grant No. 10KJA420025.

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