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Hierarchical crowd analysis and anomaly detection ☆

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ABSTRACT

Objective: This work proposes a novel approach to model the spatiotemporal distribution of crowd motions and detect anomalous events.
Methods: We first learn the regions of interest (ROIs) which inform the behavioral patterns by trajectory analysis with Hierarchical Dirichlet Processes (HDP), so that the main trends of crowd motions can be modeled. Based on the ROIs, we then build a series of histograms both on global and local levels as the templates for the observed movement distribution, which statistically describes time-correlated crowd events. Once the template has been built hierarchically, we import real data containing the discrete trajectory observations from video surveillance and detect abnormal events for individuals and for crowds.
Results: Experimental results show the effectiveness of our approach, which is able to analyze and extract the crowd motion information from observed trajectory dataset, and achieve the anomaly detection at the hierarchical levels.
Conclusion: The proposed hierarchical approach can learn the moving trends of crowd both in global and local area and describe the crowd behaviors in statistical way, which build a template for pedestrian movement distribution that allows for the detection of time-correlated abnormal crowd events.

1. Introduction

Significant efforts have been devoted to anomaly detection in crowd surveillance data analysis over last decade. The general problem, however, is still open because of the wide variety of possible anomalies. There are two main approaches for crowd behavior analysis [1]: in the "object-based" approach a crowd is treated as a collection of individuals, while the "holistic" approach treats the crowd as a single entity without segmenting each individual. Generally, in denser scenes it is very difficult to track individual components in the crowd and hence the second approach tends to be more appropriate, while in sparse scenes the first method which covers more details is preferred. Our statistical representation for spatiotemporal distributions of motions will work with data from either approach, but we focus on using the holistic one. Obtaining more details is a benefit for fine analysis, so we prefer to collect individual motion information from a trajectory dataset and apply the knowledge extracted from individual components to the analysis of real crowds no matter whether it is dense or sparse.

The temporal properties of crowd movements are important to establish baseline expected behaviors. Many group motion events happen regularly and may be time-correlated; for example, a road might be crowded with workday commuter or holiday traffic while it could be quieter at midnight or on weekends, and workers may enter an office building at the start of the business day, leave for lunch and return, then go home at the end of the day. In these situations, we must consider the time and

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space correlations using statistical features of crowds such as the density, direction and speed of flow during certain time spans. These spatiotemporal patterns of crowd behaviors learned from historical trajectories should be taken into consideration when deciding whether some crowd events are anomalous or not.

In this paper, we propose a novel approach to hierarchically build a template for pedestrian movement distribution that allows for the detection of time-correlated abnormal crowd events. This template learns behavioral patterns and statistics of pedestrians from knowledge obtained from a historical training dataset of observed trajectories. Based on the template we detect anomalies. The trajectories dataset is only used in an off-line learning phase for modeling normal spatiotemporal movement distributions. During the on-line anomaly detection phase only the density and flow data stream are processed without needing to track individual trajectories.

The main framework of our work is as following and showed in Fig. 1.

Step 1: Learning regions of interest from historic trajectory sets. Given a set of trajectories obtained from surveillance data, the regions of interest (ROIs) are first learned and defined based on a Hierarchical Dirichlet Processes (HDP) grouping. ROI is modeled as a multinomial distribution over the space of the scene and moving directions, which means they imply the pattern of behaviors in a given region at a given time.

Step 2: Learning the statistical template of pedestrian distribution. The historic pedestrian dataset contains spatial features such as the coordinates of each moving object and temporal features such as their time stamped velocity (orientation and speed). Our templates include a global template which describes the overall crowd information and local regional templates which are based on the sematic regions and cover local details. Accordingly we name the statistical information in our work as Hierarchical Pedestrian Distribution.

Step 3: Anomaly detection. Instead of tracking an individual's trajectory, crowd positions, density and flow data streams are the basic features for statistical analysis. We detect anomaly on a global level as well as local level, and also permit individual suspicious behavior identification.

2. Related works

The study of crowd analysis is a subject of great scientific interest. With the advancement of techniques, some applications in this area, like video surveillance, human behavior understanding and anomaly detection have been well studied [2]. Crowd anomaly detection, also known as outlier detection [3], is the search for individuals or groups which do not conform to an expected moving pattern, and these detected anomalies are often translated into critical and actionable information in crowd [4].

Image based methods for anomaly detection have been widely explored in recent years. Li et al. [5] considered the problem of detection and localization of anomalous behaviors in crowded scenes, and proposed a joint detector of temporal and spatial anomalies. The detector was based on a video representation that accounted for both appearance and dynamics using a set of mixture of dynamic textures models. In [6], chaotic dynamics was introduced into the crowd context to characterize complicated crowd motions by regulating a set of chaotic invariant features, then a probabilistic framework for anomaly detection and localization was formulated. In [7], the scalable algorithms were used for large graph mining for billion-scale graphs on Hadoop, then graph algorithms were utilized that help with anomaly detection in relational data.

With the in-depth development of pedestrian recognition and tracking techniques, pedestrian trajectories can be obtained from video efficiently, so many ways to handle anomaly detection are generally based on trajectories, which can interpret more details for fine analysis. Clustering tracks and then comparing their similarity [8] is a fundamental method; however, pedestrian behaviors are

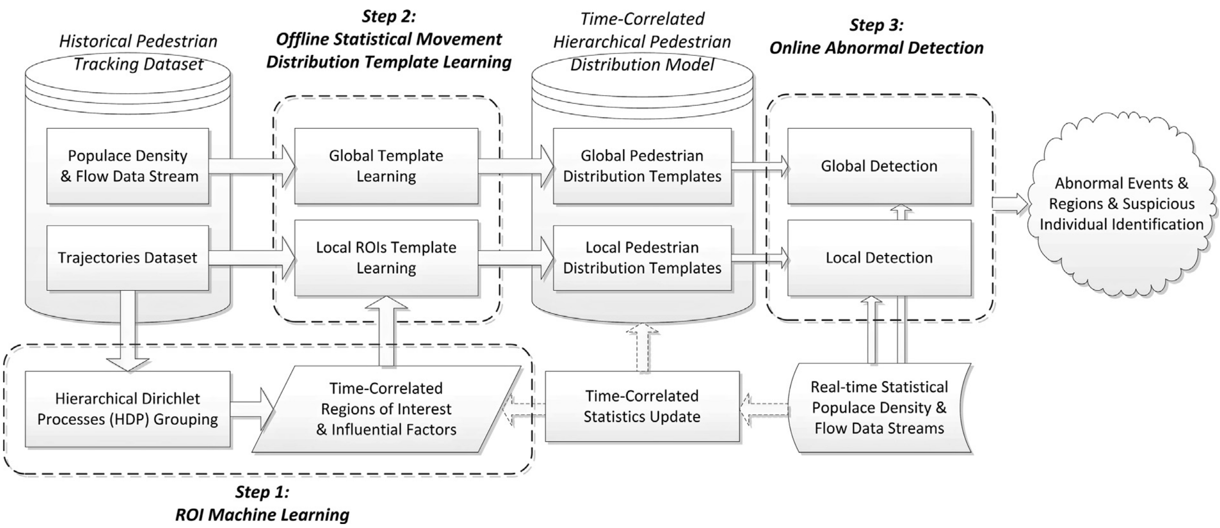

Fig. 1. Framework of hierarchical crowd analysis and anomaly detection.