Optik 125 (2014) 3428–3433

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Abnormal crowd behavior detection by using the particle entropy

Xuxin Gu [a,*], Jinrong Cui [a], Qi Zhu [b]

[a] Key Laboratory of Network, Oriented Intelligent Computation, Shenzhen Graduate School, Harbin Institute of Technology, Shenzhen 518055, China
[b] Department of Computer Science and Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

ARTICLE INFO

Article history:
Received 7 July 2013
Accepted 2 January 2014

Keywords:
Abnormal behaviors detection
GMM
Crowd distribution information
Crowd speed information

ABSTRACT

The crowd distribution information is the crucial information for abnormal behaviors detection in the crowd scenes. In this paper, we firstly refer to the definition of the entropy and propose an algorithm effectively and accurately representing the crowd distribution information in the crowd scenes. The proposed algorithm not only avoids unstable foreground extraction, but also owns low computational complexity. To detect the abnormal crowd behaviors, we use the Gaussian Mixture Model (GMM) over the normal crowd behaviors to predict the abnormal crowd behaviors since GMM usually can deal well with the unbalanced problem. In this paper we simultaneously use the crowd distribution information and the crowd speed information to estimate the parameters of GMM over the normal crowd behaviors and predict abnormal crowd behaviors. Experiment conducted on publicly available dataset consisting of gathering and dispersion events validates that the proposed approach can preeminently reflect the crowd distribution information. In addition, experiments conducted on publicly UMN dataset demonstrate that the proposed abnormal crowd behavior detection method has an excellent performance and outperforms the state-of-the-art methods.

1. Introduction

In the past decades, public safety has drawn a lot of attention around the whole world. Terrorist attacks and unexpected mass incident, etc. have challenged the baseline of the city's defenses. It is emergent to detect these events as quickly as possible and take some actions to reduce the loss and save the public's lives. With the increasing development of the technology in computer vision, many aspects such as background modeling [1,2], object tracking [3,4], face recognition [5,6] and people counting [7] have been the fundamental elements that compose an intelligent surveillance system for anomaly detection. In this paper, we aim to detect the abnormal crowd behavior [8–14] based on the computer vision technology.

Abnormal crowd behavior detection has been an active area of research in recent years, and various approaches have been proposed. To distinguish between the normal crowd behaviors and abnormal crowd behaviors, many common features such as the optical flow [15–17], gradient [18,19], dynamic textures [20], have been widely used to describe the context information. For example, in [15], Multi-scale Histogram of Optical Flow (MHOF) is used to detect abnormal event. In [18], Grids of Histograms of Oriented Gradient (HOG) descriptors are used for human detection. Mahadevan et al. [20] model normal crowd behavior by using mixtures of dynamic textures and consider outliers under the model as anomalies. Xiong et al. [21] firstly calculate the probability distribution of the foreground object and then define crowd entropy to represent the spatial distribution of the crowd.

During the recent years, for the crowd scene, many researchers concentrate their attention on particle advection schemes similar to [22] that a grid of particles are placed on frame to simulate individuals in the crowd and advected with the potential optical flow. Particle advection schemes can overcome the limitations of complex foreground extraction in high density crowds. In [24], the social force model [23] is built to estimate the particles' interactions for abnormal crowd event detection. Firstly, bag of words is used to detect abnormal frame. Then the interaction forces are used to determine the regions of anomalies. In [26], the clustered particle trajectories [25] are used to represent the trajectories for a crowd flow. The chaotic dynamics of all clustered trajectories are extracted and quantified as maximal Lyapunov exponent and correlation dimension.

In this paper, we refer to particle advection scheme. In this way, we use the distribution of the particles in the frame to simulate the distribution of the individuals in the crowd, and use the speed of the particles in the frame to simulate the speed of the individuals in the crowd. And we refer to the concept of the entropy and propose an approach which is named particle entropy by us and effectively

* Corresponding author.
E-mail address: guxuxin@gmail.com (X. Gu).

http://dx.doi.org/10.1016/j.ijleo.2014.01.041

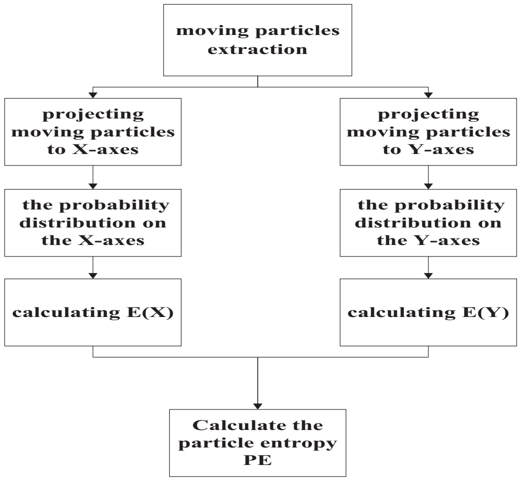

Fig. 1. Block diagram of the proposed particle entropy.

represent the crowd distribution information. As the number of frames with abnormal crowd behaviors is only a small portion of the entire video about the crowd behaviors, it is obvious that abnormal crowd behavior detection is an unbalanced problem. The GMM is usually used to solve the unbalanced problem, so we use the GMM to model the normal crowd behaviors. Through observation, we find out that the speed and distribution of the abnormal crowd are quite different from the normal ones. In the paper we simultaneously use the crowd speed and distribution information to predict abnormal crowd behaviors. Comparison experiments conducted on publicly dataset validate the advantages of the proposed method.

The remainder of the paper is organized as follows: In Section 2, we introduce the procedures for calculating the particle entropy. In the Section 3, we present experimental results and the comparisons with other methods. Finally, we will conclude the paper in Section 4.

2. Proposed particle entropy

2.1. Method overview

In statistical mechanics, the thermodynamic system and the information theory, entropy have been widely applied and made many remarkable achievements. In statistical mechanics, entropy is used to measure uncertainty, and the greater entropy means the higher disorder [27]. In a thermodynamic system, entropy is also usually related to the notions of disorder and chaos [28]. In the information theory, entropy is also often taken to measure the uncertainty and disorder in a random variable [29,30]. Based on the above, we know that the entropy usually is related to measure the disorder.

In [22], they refer to the definition of the entropy and propose the crowd entropy by using the foreground object. However, it is very difficult to extract an integral foreground in the crowd scenes. In this paper, we propose the novel particle entropy approach to represent the crowd distribution. We refer to particle advection schemes to first put a grid of particles over every frame and use the distribution of the moving particles to simulate the distribution of the pedestrians in the crowd. In order to measure the disorder of the moving particles, we refer to [22] and propose the particle entropy approach to estimate the distribution of the moving particles. The main steps of the particle entropy approach are summarized in Fig. 1 and described in following sections.

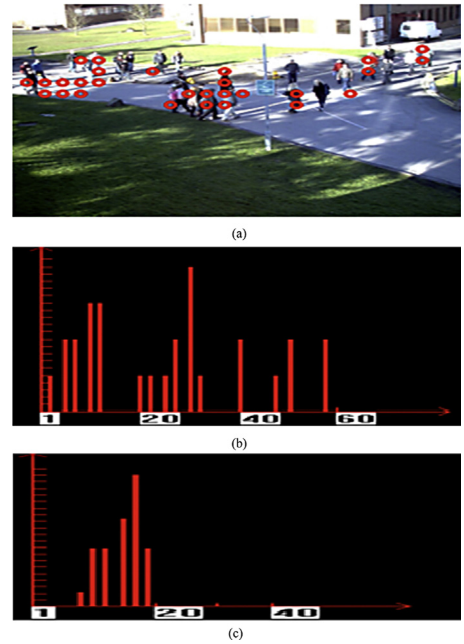

Fig. 2. (a) Every red circle represents a moving particle. (b) The height of every bin describes the number of the moving particles projected to X-axes at the bin. (c) The height of every bin describes the number of the moving particles projected to Y-axes at the bin. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2.2. Moving particles extraction

As the moving pedestrians are able to cause the abnormal crowd behaviors, we only need be concerned about the moving pedestrians. As we use the moving particles to represent the moving pedestrians, we only need be concerned about the moving particles. The moving particles extraction stated as follows. Firstly, we place a grid of particles over every frame. Secondly we estimate every particle' velocity with the average velocity of its neighbor pixels. In addition, the velocity of every pixel is calculated by using optical flow. Finally, we obtain the velocity of every particle, and regard the particles whose velocity is higher than a predefine threshold as the moving particles.

In the Fig. 2 (a), we first put 77×58 particles over image with a resolution of 768×576, then estimate every particle' velocity with the average optical flow of its 10×10 neighbor pixels. At last, the particles whose velocity is higher than the predefined threshold are taken as the moving particles which are marked by the red circle in the Fig. 2 (a).

2.3. Calculate the particle entropy E(X) in the horizontal direction.

At first, we project moving particles to n_1 bins of X-axes with the same wide. Then we use $h_x(i)\,(0 < i \le n_1)$ to represent the number of moving particles projected to X-axes at the ith bin, where n_1 represents the numbers of bins on the X-axes. The probability distribution of moving particles on X-axes can be easily computed as follows:

$$f_x(i) = \frac{h_x(i)}{T}, \quad 0 < i \le n_1 \tag{1}$$

where T denotes the number of all moving particles. At last, the particle entropy $E(x)$ on the X-axes is calculated as following,

$$E(X) = \sum_{i=1}^{n_1} f_x(i) log \frac{1}{f_x(i)}, \quad 0 < i \le n_1, \quad f_x(i) \ne 0 \tag{2}$$