Crowd Analysis and Its Applications

Conference Paper *in* Communications in Computer and Information Science · January 2011

DOI: 10.1007/978-3-642-22170-5_59 · Source: DBLP

CITATIONS
9

READS
1,529

4 authors:

Nilam Nur Amir Sjarif
Universiti Teknologi Malaysia
15 PUBLICATIONS **33** CITATIONS
SEE PROFILE

Siti Mariyam Shamsuddin
Universiti Teknologi Malaysia
386 PUBLICATIONS **3,201** CITATIONS
SEE PROFILE

Siti Z Mohd Hashim
Universiti Teknologi Malaysia
177 PUBLICATIONS **2,039** CITATIONS
SEE PROFILE

Siti Yuhaniz
Universiti Teknologi Malaysia
35 PUBLICATIONS **581** CITATIONS
SEE PROFILE

Crowd Analysis and Its Applications

Nilam Nur Amir Sjarif[1], Siti Mariyam Shamsuddin[2],
Siti Zaiton Mohd Hashim[3], and Siti Sophiayati Yuhaniz[4]

Soft Computing Research Group,
K-Economy Research Alliance
Universiti Teknologi Malaysia, Skudai, Johor
nilamnini@gmail.com, mariyam@utm.my,
sitizaiton@utm.my, sophia@utm.my

Abstract. Crowd is a unique group of individual or something involves community or society. The phenomena of the crowd are very familiar in a variety of research discipline such as sociology, civil and physic. Nowadays, it becomes the most active-oriented research and trendy topic in computer vision. Traditionally, three processing steps involve in crowd analysis, and these include pre-processing, object detection and event/behavior recognition. Meanwhile, the common process for analysis in video sequence of crowd information extraction consists of Pre-Processing, Object Tracking, and Event/Behavior Recognition. In terms of behavior detection, the crowd density estimation, crowd motion detection, crowd tracking and crowd behavior recognition are adopted. In this paper, we give the general framework and taxonomy of pattern in detecting abnormal behavior in a crowd scene. This study presents the state of art of crowd analysis, taxonomy of the common approach of the crowd analysis and it can be useful to researchers and would serve as a good introduction related to the field undertaken.

Keywords: Crowd analysis, pre-processing, object tracking, event behavior recognition.

1 Introduction

Handling the situation that is related with the abnormal in a crowd is not as simple easy [1]. The most important think that the researcher should consider in probing the problem of the crowd includes: i) How crowded the scene is, and ii) whether the situation is normal or abnormal. The issue such as complexity and abstraction of identifying and detecting abnormal behavior in crowd scene has attracted many researchers [2]. However, there are some difficulties in analyzing behavior in a crowd scene. In order to achieve the goal, the analyzing procedure must be done comprehensively through video surveillance; hence earlier works have been excellently reviewed by [3-5].

With the intelligent digital camera technology Closed-Circuit Television (CCTV), video surveillance has becoming more important. CCTV is used to observe parts of a process from control environment which is required in every intelligent crowded

J.M. Zain et al. (Eds.): ICSECS 2011, Part I, CCIS 179, pp. 687–697, 2011.

scene. One of the trendy topics in video surveillance is on crowd analysis to automatically detect the anomalies and alarms [5]. Crowd analysis consists of four phases: crowd density estimation, crowd motion detection, crowd tracking and crowd behavior understanding [2-4, 6].

The remainder of the paper is organized as follows: Section 2 presents the crowd analysis and related studies. Section 3 consists of framework of crowd analysis. Section 4 describes common approaches of crowd analysis. Section 5 consists of application of crowd analysis. Finally, in Section 6 we draw the conclusion together with some discussion.

2 Crowd Analysis and Related Studies

The terms of crowd or known as 'mob' or 'mob rule' can be define as a collective characteristic such as 'an angry crowd', a peaceful crowd', and 'a panic crowd' are well accepted. Crowd is made up of the independent individual's parts, whereby each of them have their own objectives and behavior pattern which differ from the expected individually from its participants. In a crowded scene, the individual making much more variable and complex and need to do some mathematical rules of behavior that might be useful to approximate the behavior [7]. There are various ways in analyzing the crowd for detection the abnormal such as using crowd density estimation, crowd motion detection, crowd tracking and crowd behavior recognition.

Crowd scene can be divided into two types: structured crowded scene and unstructured crowded scene [8] . The terms *structured crowded scene* can be described as crowd moves coherently in common direction, motion direction does not very time, each spatial locations of the scene supports only one dominant crowd behavior over the time. For example marathon race, queues of people event and traffic on the road. Meanwhile the term *unstructured crowded scene* represents the random crowd motion; different participants moving different direction at different times, each spatial location supports multi –modal, and crowd behavior. For example people walking on a zebra crossing in opposite directions, exhibitions, sporting event, railway stations, airport and motion biological cells. Fig 1 shows the sample of image structured and unstructured crowded scene based on human.

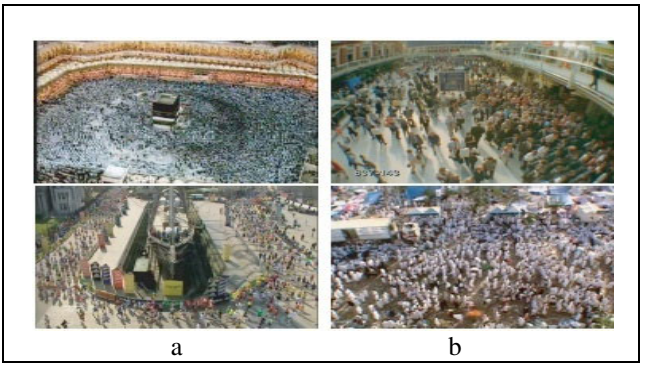

Fig. 1. Image of crowded scene (a) Structured, (b) Unstructured [8]

3 A Framework of Crowd Analysis

The important component attributes in a crowd consists of density, location, speed, color and etc. By using the computer visions, the information can be extracted either automatically or manually. Two types of sensors are used to capture the scene process include typology sensor and topology sensor. To get more accurate information in a crowd scene, the process of extraction information should be depending on the conditions of environment such as illumination changes (transition from day to night, shadow of background images and non static background like leaves blown by the wind could be detected as moving object), handling the occlusion, multiple input channel and amount number of cameras, the changes of motion and detecting different characteristic either human or object. Usually the crowd model is developed base on the extracted information that represent the status either implicitly or explicitly while the event discovery is accomplished using the computational model. Both of models are updated with the new information extraction [5]. Fig 2 illustrates the framework of crowd analysis and its processing.

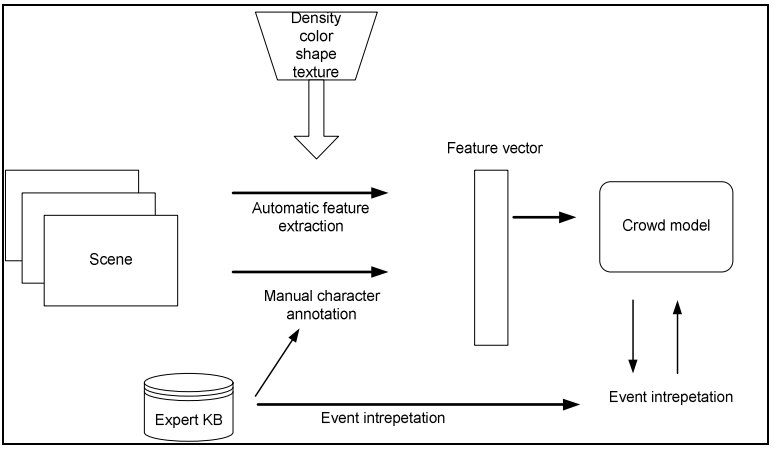

Fig. 2. A framework of crowd analysis

The potential of crowd analysis lend itself to a new application domain such as automatic detection of riots or chaotic acts in crowds and localization of the abnormal regions in scenes for high resolution. The common process for analysis in video sequence of crowd information extraction composed the following main three steps include [6, 9-11] i) Pre-Processing, ii) Object Tracking, iii) Event/Behavior Recognition. In addition, Microscopic, Macroscopic and Mesoscopic or Hybrid are the three main category modeling approaches which are familiar in the crowd [12]. Table 1 shows the description of categories of crowd scene.

Table 1. Terms and description in crowd analysis and modeling

Terms	Description
Crowd Density Estimation	To measure a crowd status. Find out the level of the crowd in a space or to detect abnormal changes of the crowd overtime
Crowd Motion Detection	To describe the characteristic of a crowd. Identify pattern of behavior in crowd
Crowd Tracking	To acquire the trajectories of movement. Determine whether abnormalities occur.
Crowd Behavior Recognition	To analyze the behavior of the crowd. Extract motion information and Model abnormal crowd
Structured Crowded Scene	Crowd moves coherently in common direction, motion direction does not very time, each spatial locations of the scene supports only one dominant crowd behavior over the time. *Example:* Marathon race, queues of people event, traffic on the road.
Unstructured Crowded Scene	Crowd motion is appeared random, different participants moving different direction at different times, each spatial location supports multi –modal, crowd behavior. *Example:* People walking on a zebra crossing in opposite directions, exhibitions, sporting event, railway stations, airport, motion biological cells.
Pre-Processing	*Responsibility* : Detect and classify *Category :* Rigid object or Non-Rigid Object *Analysis/ Features/ Approach :* Pixel Based Analysis, Texture Based Analysis, Region Based Analysis, Frame Based Analysis. *Example :* Feature extraction (foreground detection, optical flow), object detection, classification (color, edge, shape, head, body)
Object Tracking	*Responsibility :* Analyze target movement *Category:* Tracking individual objects and tracking the group of object. *Analysis/ Features/ Approach :* Region-based, active contour-based, feature-based, model-based tracking *Example :* Tracking speed and direction
Event/Behavior Recognition	*Responsibility:* Analyze pattern or behavior of the object. *Category :* Individual or crowd behavior recognition *Analysis/ Features/ Approach :* Object approach, Holistic approach *Example:* Occlusion, moving object (running, walking, jumping).

Table 1. (*continued*)

Microscopic	Defines the object movement and treats crowd behaviors as a result of a self organization process.
Macroscopic	Focus on goal-oriented crowds which determined a set of group-habits based on the goals and destination of the scene.
Mesoscopic / Hybrid	Inherit from Microscopic and Macroscopic

4 Common Approaches in Crowd Analysis

Fig 3 below shows the common crowd analysis approaches that is used to detect abnormal behavior in crowd scene. Preprocessing consist of; pixel level analysis, texture level analysis; object level analysis; frame level analysis. Object tracking consist of; region based approach; active contour based approach; feature based approach; model based approach. Event/ behavior recognition consist of object approach and holistic approach.

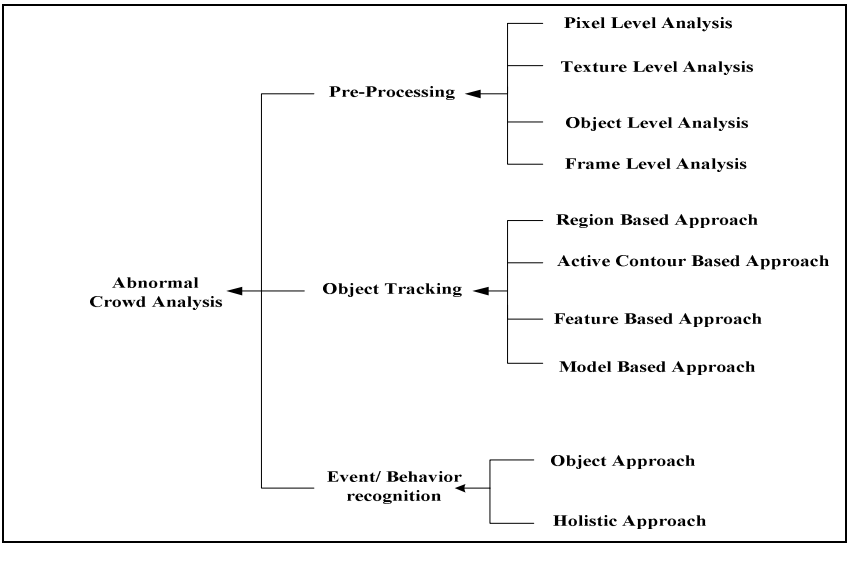

Fig. 3. Taxonomy approaches in crowd analysis

4.1 Preprocessing

One of the important steps in pre-processing is feature extraction. Feature extraction always deal with the crowd density which is very useful in source information. Due to

the strength of the feature extraction in detection, most of the researchers are intended to analyze and learn the pattern of abnormal in crowd scene through this analysis. The common analysis uses during the preprocessing are pixel level analysis, texture level analysis, object level analysis and frame level analysis. *Pixel level analysis* is obtained through edge detection or background/foreground subtraction. Mostly focus on a low level features where extract the information based on density estimation rather than counting. For example Andrade and colleagues [9] used Expectation Maximization (EM) algorithm by analyzing pixel based to determine the variables and to update the equation of the probability distribution function. In Xiaogang and colleagues [13] works, simple "atomic" activities and interaction in low level features is proposed for unsupervised learning framework. Both activities and interaction are clustered into different class (eg : moving pixel- atomic; short video clips - interaction). The solution such as transparent, clean and probabilistic are formulated for solving the surveillance issues. *Texture level analysis* is similar like pixel level analysis that is used to estimate the number of people rather than identifying individual in a scene. The analysis of image patches is required for modeling and mostly focus on high level features. For example Xinyu and colleagues [14] is analyzing the texture based on the contour for human blob in order to learn different scale of group using Gauss Lapcian kernel function. Another author that learning the abnormal detection based in texture is Kilambi and colleagues [15] by learning the shape model to estimate the accurate people in the scene *Object level analysis*: is identifying individual object in a scene. More accurate result will be produced when compared to pixel and texture analysis. For example, in Khansari and colleagues [16] works, the direction and speed of the object motion is found, and inter frame texture analysis is adapted for the searching window. To perform the best matching region, frame is successfully generated with feature vector in a search window. *Frame level analysis* model behaviors of the full scene within the field of view of a camera. For example, in Oliver and colleagues [17], robust 2D blob features is presented in which the Eigenspace describes the appearance in a covariance data whilst principal component analysis is used to reduce the dimensionality space. However, eigenspace could not distribute the moving object efficiently in the background. Therefore, to get more accurately detection of abnormal to characterize the shape of each person, the portions of containing image moving present in the scene is well managed using frame by frame examination.

4.2 Object Tracking

The next steps after extracting the features from the image sequence is object tracking. Object tracking in a crowd attempt to minimizing the constraint such as occlusion, color intensity, illumination condition, appearance and etc. Past few years, multiple human objects tracking approach has been applied by researcher for recognize and detecting the behavior in a crowd, which is consist of identifying the position of each person in the same video sequence. There is various effective parameters ways. For example color, trajectory, body contour (head, hand, foot), and

etc. Color distribution is commonly used in tracking to differentiate the object in a crowd [18] [16] [19]. Note that, it is easier way to track and understand the behavior of the people in crowd rather that individually as long as their moving in the same direction. By assigning the object distance , the occlusion in a crowd could easily track independently, as in [18]. However, if the pixel could not classify in the object, it is difficult to find the reliable central of the occlusion as long as the presence probability is updated for every pixel in the frame correctly.

Categories of object tracking approach include region based approach, active contour based approach, feature based approach and model based approach. *Region Based approach* is a robust computer vision in unconstrained crowd scene which is the information such as density, direction and velocity is extracted using optical flow technique. For example Weighted Maximum Cardinality Matching scheme with disparity estimation technique are presented by Kellly and colleagues [19] to evaluate both environment condition either indoor and outdoor (eg : varying cloud clover, shadows, reflections on windows and moving background). *Active Contour Based approach* is used to model the target partial occlusion and to extent some noise. Typically has been used a color histogram, however the weaknesses by using this technique is hardly change the color histogram when impair with similar object such as head in a crowd Khansari and colleagues [16]. *Feature based approach* is presented in feature image by describing the blob level feature. The examples are size, shape, elongatedness, luminance histogram and displacement histogram. Each feature image is transform from original blob level features into probabilistic appearance manifolds for each class. For example Peng and colleagues [20] introduces a pixel wise to detect anomalies in individual events sequence by constructing feature images. Each feature image is transform from original blob level features into probabilistic appearance manifolds for each class. *Model based approach* can solve blob merge and split constraint. This approach is used to segment and track multiple people occlusion. Bottom up image analysis is used to improve efficiency in computer vision. For example Yao-Te and colleagues [18]introduces model based object to estimate the positions corresponding to optical segmentation, which allow multiple object to be detected and track in crowded scene. To differentiate each object, color model of two region of body is presented called torso and bottom.

4.3 Event/Behavior Recognition

Another important process in a crowd analysis is event/behavior recognition. It can be characterized by regular motion patterns such as direction, speed, etc [6]. In the early work, crowd behavior analysis has been attempted in research topic of the computer vision especially in simulation [21-24] and graphic field. Monitoring and modeling the crowd is not so much to analyze normal crowd behavior, but to detect something different behavior from it. These are referred to as anomalous or abnormal.

Two types of approach are commonly used in this analysis includes object based approach and holistic based approach. *Object based approach* means a crowd is

analyzes by treating a collection of individual to estimate the velocities, direction and abnormal motion. The complexity occur when the occlusion exist that maybe could be affected the process of analyzing such as detection of object, tracking trajectories and recognizing activities in a dense crowd. For example Weina Ge and colleagues [25]. Jacques and colleagues [26] use a position of each individual in parameter to obtain and characterize (voluntary or involuntary) the formation in a group and Voronoi diagram was used to understand people motion. Two approaches were proposed include feature correlation and binary function. Feature correlation was use to find the approximate position of the center of head while binary function is defined to represent distance between agents. *Hollistic based approach* means a crowd is analyzes by treating a single entity to estimate the velocities, direction and abnormal motion. The analysis covers medium to high density scene in global entity. For example Mehran and colleagues [12] integrates holistic approach with a particle advection method. They underlie the flow field with social force to extract interaction to determine the change interaction of time of behavior of the crowd for mapping to the image frame. However, using holistic approach application is still have weaknesses because in the dense crowd image of the object have a low resolution; and consists of dynamic and static occlusions. Thus, to get more accurate estimation parameter, the object based approach is still better.

5 Applications of Crowd Analysis

Crowd analysis becomes the most oriented research and trendy topic in computer vision and pattern recognition nowadays. The crowd phenomenon has been growth along urbanization frequently which gives the great interest in a large number of applications such as crowd management, public space design, virtual environments, visual surveillance, and intelligent environments (Fig 4) [5] and Table 2 describes the applications of crowd analysis.

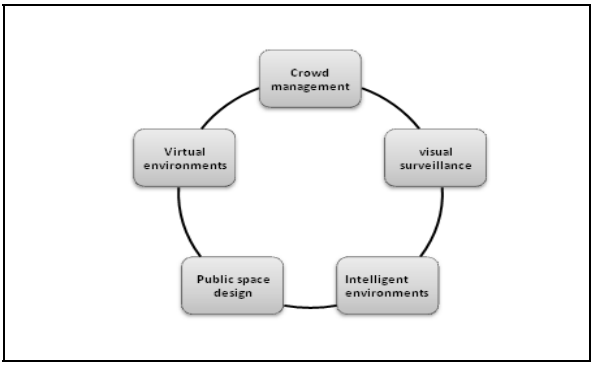

Fig. 4. Application of crowd analysis

Table 2. Applications of Crowd Analysis

Application	Description
Crowd management	Consist of developing crowd management strategies especially for increasingly more frequent and popular events like sport matches, concert events, public demonstrations and etc in order to avoid crowd disasters and ensure the public safety. Crowd management mostly studied by the sociologist, psychologist and civil engineers.
Virtual environments	Consist of mathematical models of crowds can be employed in virtual environment in order to enhance the simulations of crowd phenomena, to enrich the human life experience. Virtual environment are commonly studied by the computer graphic researchers.
Visual surveillance	It is used to detect anomalies and alarms automatically. Virtual surveillance is commonly studied by computer vision.
Intelligent environment	Involve a pre-requisite for assisting the crowd or an individual in the crowd. For example how to divert a crowd based on the pattern of crowd in a outdoor environment like parking lot.
Public space design	Consist of guidelines for the design of public space for example to optimize the space usage of an office.

6 Conclusion

In this paper, we present the state of the art of crowd analysis and the taxonomy of the common approach of the crowd analysis that could be useful to researchers and would serve as a good introduction related to the field undertaken. Crowd analysis is the most important concept for understanding the behavior especially in analyzing the abnormal behavior in a crowded scene. Three processing steps are involved in crowd analysis: preprocessing, object tracking and event/behavior recognition. Every step in crowd analysis has different analysis such as for pre-processing phase: the analysis for pixel level analysis, texture level analysis, object level analysis and frame level analysis is different. While for object tracking phase, which includes region based approach, active contour based approach, feature based approach and model based approach, the performance are measured differently. Finally, for event/behavior recognition phase, the object based approach and holistic based approach scene is normally used to probe the significant of the method. Most of the researchers used these procedures to analyze, detect and recognize the abnormal in crowded scene. However, what we have indentified here, only a little attention has been paid to learning the motion pattern in a crowded scene despite its importance in video surveillance in which reliable track are harder to obtain. For future work, we will explore and classify the variant learning based motion pattern in a crowded scene.

Acknowledgement

This work is supported by Ministry of Higher Education (MOHE) under fundamental Reseach Grant Scheme (Vote No 78509) and Zamalah Scholarship, Universiti Teknologi Malaysia (UTM). Authors would like to thank *Soft Computing Research Group* (SCRG), for their continuous support and motivation in making this research a success.

References

1. Yufeng, C., Guoyuan, L., Ka Keung, L., Yangsheng, X.: Abnormal Behavior Detection by Multi-SVM-Based Bayesian Network. In: International Conference of Information Acquisition, ICIA 2007 (2007)
2. Husni, M., Suryana, N.: Crowd event detection in computer vision. In: 2nd International Conference Signal Processing Systems, ICSPS (2010)
3. Saxena, S., Brémond, F., Thonnat, M., Ma, R.: Crowd Behavior Recognition for Video Surveillance. In: Blanc-Talon, J., Bourennane, S., Philips, W., Popescu, D., Scheunders, P. (eds.) ACIVS 2008. LNCS, vol. 5259, pp. 970–981. Springer, Heidelberg (2008)
4. Jacques Junior, J.C.S., Mussef, S.R., Jung, C.R.: Crowd Analysis Using Computer Vision Techniques. IEEE Signal Processing Magazine 27(5), 66–77 (2010)
5. Zhan, B., Jacques Junior, J.C.S., Mussef, S.R., Jung, C.R.: Crowd analysis: a survey. Machine Vision and Applications 19(5), 345–357 (2008)
6. Garate, C., Bilinsky, P., Bremond, F.: Crowd event recognition using HOG tracker. In: Twelfth IEEE International Workshop Performance Evaluation of Tracking and Surveillance, PETS-Winter (2009)
7. Davies, A.C., Jia Hong, Y., Velastin, S.A.: Crowd monitoring using image processing. Electronics & Communication Engineering Journal 7(1), 37–47 (1995)
8. Rodriguez, M., Ali, S., Kanade, T.: Tracking in unstructured crowded scenes. In: IEEE 12th International Conference of Computer Vision (2009)
9. Andrade, E.L., Blunsden, S., Fisher, R.B.: Hidden Markov Models for Optical Flow Analysis in Crowds. In: 18th International Conference Pattern Recognition, ICPR 2006 (2006)
10. Andrade, E.L., Blunsden, S., Fisher, R.B.: Modelling Crowd Scenes for Event Detection. In: 18th International Conference Pattern Recognition, ICPR 2006 (2006)
11. Andrade, E.L., Fisher, R.B., Blunsden, S.: Detection of Emergency Events in Crowded Scenes. In: The Institution of Engineering and Technology Conference on Crime and Security (2006)
12. Mehran, R., Oyama, A., Shah, M.: Abnormal crowd behavior detection using social force model. In: IEEE Conference Computer Vision and Pattern Recognition, CVPR 2009 (2009)
13. Xiaogang, W., Xiaoxu, M., Grimson, W.E.L.: Unsupervised Activity Perception in Crowded and Complicated Scenes Using Hierarchical Bayesian Models. IEEE Transactions Pattern Analysis and Machine Intelligence 31(3), 539–555 (2009)
14. Xinyu, W., Guoyuan, L., Ka Keung, L., Yangsheng, X.: Crowd Density Estimation Using Texture Analysis and Learning. In: IEEE International Conference Robotics and Biomimetics, ROBIO 2006 (2006)
15. Kilambi, P., Masoud, O., Papanikolopoulos, N.: Crowd Analysis at Mass Transit Sites. In: Intelligent Transportation Systems Conference, ITSC 2006. IEEE, Los Alamitos (2006)

16. Khansari, M., Rabiee, H.R., Asadi, M., Ghanbari, M.: Crowded scene object tracking in presence of Gaussian White noise using undecimated wavelet features. In: 9th International Symposium Signal Processing and Its Applications, ISSPA 2007 (2007)
17. Oliver, N.M., Rosario, B., Pentland, A.P.: A Bayesian computer vision system for modeling human interactions. IEEE Transactions Pattern Analysis and Machine Intelligence 22(8), 831–843 (2000)
18. Yao-Te, T., Huang-Chia, S., Chung-Lin, H.: Multiple Human Objects Tracking in Crowded Scenes. In: 18th International Conference Pattern Recognition, ICPR 2006 (2006)
19. Kelly, P., O'Connor, N.E., Smeaton, A.F.: Robust pedestrian detection and tracking in crowded scenes. Image and Vision Computing 27(10), 1445–1458 (2009)
20. Peng, C., Li-Feng, S., Zhi-Qiang, L., Shi-Qiang, Y.: A Sequential Monte Carlo Approach to Anomaly Detection in Tracking Visual Events. In: IEEE Conference Computer Vision and Pattern Recognition, CVPR 2007 (2007)
21. Thalmann, D., Musse, S.R., Musse, S.: Relating Real Crowds with Virtual Crowds, in Crowd Simulation, pp. 125–148. Springer, London (2008)
22. Reynolds, C.: Steering Behaviors for Autonomous Characters. In: Game Developers Conference (1999)
23. Vigueras, G., Lozano, M., Orduña, J.M., Grimaldo, F.: A comparative study of partitioning methods for crowd simulations. Applied Soft Computing 10(1), 225–235 (2010)
24. Bruno, L., Tosin, A., Tricerri, P., Venuti, F.: Non-local first-order modelling of crowd dynamics: A multidimensional framework with applications. Applied Mathematical Modelling 35(1), 426–445 (2010)
25. Ge, W., Collins, R.T., Ruback, B.: Automatically detecting the small group structure of a crowd. In: Workshop Applications of Computer Vision, WACV (2009)
26. Jacques, J., Braun, A., Soldera, J., Musse, S., Jung, C.: Understanding people motion in video sequences using Voronoi diagrams. Pattern Analysis & Applications 10(4), 321–332 (2007)