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Crowd Detection, Monitoring and Management: A literature Review

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Abstract

The rapid increase in the global population has led to the emergence of large crowds during public events across various domains such as sports, music festivals, religious gatherings, and political campaigns. If these events are not properly organized and controlled, they have the potential to result in disasters. Tragically, stampedes occur every year, causing fatalities, disappearances, and injuries for many individuals. Therefore, crowd identification, monitoring, and control are problems that will be addressed and discussed in this paper in order to lessen casualties and prevent such catastrophes. The objective of this study is to present a thorough review of technologies and methods relevant to crowd management, planning, behaviour analysis, and counting. Furthermore, it aids researchers' future progress by examining recent technology developments in the field of crowd planning and monitoring.

Keywords: Crowd Detection, Crowd Monitoring, Crowd Management, Crowd behaviour, Crowd simulation, Crowd density estimation.

الملخص: بسبب التزايد السريع في عدد سكان الكوكب. ونتيجة لذلك، ظهرت حشود كبيرة من الناس خلال الأحداث العامة في العديد من مجالات الحياة، بما في ذلك الرياضة والمهرجانات الموسيقية والتجمعات الدينية والحملات السياسية وما إلى ذلك، والتي قد تؤدي إلى كوارث إذا لم يتم تنظيمها ومراقبتها بشكل صحيح. يعاني العديد من الأشخاص من الوفيات والاختفاء والإصابات نتيجة لحوادث التدافع كل عام. لذلك، سيتم مناقشة مشكلة تحديد الحشود ومراقبتها والسيطرة عليها في هذا البحث بهدف تقليل الخسائر ومنع مثل هذه الكوارث. الهدف من هذه الدراسة هو تقديم مراجعة شاملة للتقنيات والأساليب المتعلقة بإدارة الحشود وتخطيطها وتحليل سلوكها وعد الأفراد. علاوة على ذلك، يساعد هذا البحث على تقدم الباحثين في المستقبل من خلال دراسة التطورات التكنولوجية الحديثة في مجال تخطيط ومراقبة الحشود.

1. Introduction

During the Hajj period in 2015, over 2,000 individuals perished and over 850 sustained injuries [1]. Additionally, a range of applications can benefit greatly from the knowledge of crowd counting and density estimation [2] such as the psychological impacts of individuals congregating in groups [3], animal migration [4], and bacterial activity [5]. In general, crowd counting is applicable to a wide range of situations where it is essential to comprehend crowd behaviour such as Safety monitoring [6-8], Design of public spaces [9, 10], Evidence-based decision-making [9, 11], Disaster management [12, 13], and Virtual environments [14, 15].

Three recent techniques have been developed for gathering crowd data: wireless/radio frequency (RF), vision, and web/social media data extraction. Mobile phones, wireless sensor networks (WSN), radio frequency identification (RFID), and near-field communication (NFC)-based systems for gathering crowd data have also been taken into consideration. Two methods have been proposed by researchers to gather data on crowds. These strategies are both device-based (everyone carrying an RF-based device) and device-free (no participants carrying any RF devices).

The size of the crowd population that is in need of tracking has a direct impact on the monitoring system accuracy and the difficulties encountered. Table I and Fig. 1 illustrate the crowd scale depending on the number of people in each frame. The population density can be divided into three crowd levels identified with the crowd monitoring system (low-scale, normal-scale, and large-scale), depending on the number of people in each frame.

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The rest of the paper is formatted as follows: The crowd detection models are revised in Section 2. In sections 3 and 4, the monitoring and management of crowd are examined, while one case study is discussed in section 5. Section 6 presents the conclusion of this article.

Table 1: Crowd scale levels

Crowd scale level	Count
Low Scale	<150
Normal Scale	150-550
Large Scale	>550

(a) Low scale

(b) Normal Scale

(c) Large scale

Fig 1: Crowd Scale Level: (a) low-scale, (b) normal-scale, and (c) large-scale **[16]**

2. Related Works

In this paper, we will divide the related works to three types which are crowd detection, crowd monitoring and crowd management as presented in the coming three sections.

3. Crowd Detection

There are several ways to locate a crowd; in the past, a person would typically report a congestion; on the other hand, several types of crowd detection systems, including Laser-based, Radio-based (wifi), Radio-based (RFID), Radio-based (Bluetooth), video-based, and thermal-based are recently presented. In order to manage a crowd (similar to the crowd in Fig. 2), you must first predict when it will form. This requires some accurate crowd detection techniques. Two examples of crowds are illustrated in Fig 2. The first one is a crowd of Black Lives Matter protest in Australia and the second demonstrates the pilgrims' path to the Jamaraat Bridge in Mecca, Saudi Arabia.

a) Black Lives Matter protest in Australia. b) Muslim pilgrims during Hajj

Fig 2. Examples of crowds

The authors of [17] present a system that makes advantage of smartphone users to scan nearby Bluetooth devices and assess population aspects in urban settings. The proposed system does more than just add devices up to more sophisticated capabilities. It examines flow direction and population density.

To examine the system described, a dataset of 200000 findings from 1000 scanning devices was compiled over the course of three days. The outcome demonstrates the effectiveness of Bluetooth devices as a reliable technique for crowd detection and monitoring.

Utilizing Bluetooth technology that was readily available and installed on the bus ceiling, a wireless system with innovative and affordable features was created [18] . The Bluetooth device in the bus then does a periodic scan for discoverable devices nearby. In order to identify an origin/destination relationship, the system postprocesses the data and compares it to bus position and ticket information.

Wi-Fi-based systems for counting crowds face some difficulties. The capacity to distinguish between those outside the bus and true passengers is one of these difficulties. Numerous articles have researched and debated this issue, including [19] and [20], which find a solution by filtering the probes with a sliding window in order to eliminate the MAC addresses that have not been detected for an extended period of time.
In [21], [22], and [23], people counters based on thermal cameras are introduced. Thermal camera-based systems, in contrast to optical cameras like those in Fig. 3, are less susceptible to background colour contrasts or ambient lighting levels, albeit the performance of the systems can be impacted by weather and heat sources. Real-time image processing models require a lot of computer power. Utilizing picture compression is one technique to cut down on the expensive computation [24].
For the detection-based methods, like Figure 1, researchers use a sliding window to detect the people in an image and then use this information to count the number of people 33, 34]. However, in the case of extremely crowded scenes, which are difficult to detect (e.g., dense density, severe occlusion) for classical methods, the regression-based method comes in handy.

(a) (b)

Fig 3. Crowd detection (a) The density estimation based on crowd counting (b) The detection based on crowd counting [25][37]

4. Crowd Monitoring

Crowd monitoring has drawn greater attention recently. The number of research publications has significantly expanded, as seen in Fig 4 below [26]. The figure shows an increasing especially from 2010 due to the increasing in the number of the casualties during the huge gathering in all over the world.

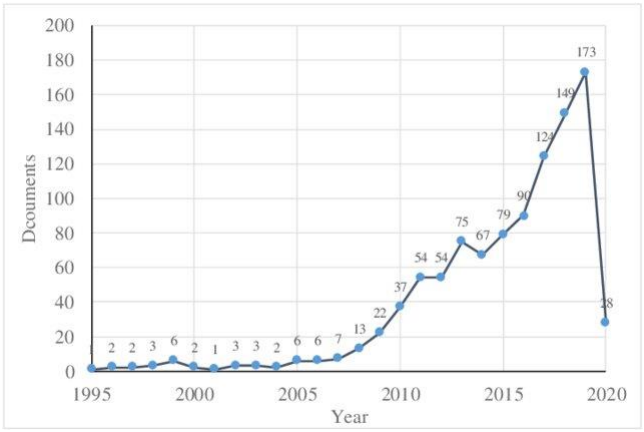

Fig 4: Documents published per year on "crowd monitoring". [in Scopus]

Monitoring the crowd is a crucial step in determining the crowd dynamics that will improve event management and public safety. As a result, event organizers are advised to keep a watch on the crowd in order to see any dangers early on and take the required precautions [27] . The primary objective of crowd surveillance equipment is to gather important data, such as crowd size and density. The volume of crowd assembling at a monitored site can be calculated by calculating the population for precise and effective managing and planning [28].

Closed-circuit television (CCTV) surveillance is the most common method of crowd monitoring in traditional crowd monitoring systems (CMSs) [29]. A system of video cameras that are used to relay signals from certain locations to a specific set of monitors or displays, typically for surveillance or security purposes, is known as a CCTV system [30]. Typically, CCTV systems have recording hardware that stores video signal for later use. Therefore, CCTV systems can be utilized in a variety of settings to keep an eye on and protect people, deter crime, and promote public safety. When there are obstacles or poor weather conditions at the monitored site, the CCTV camera cannot effectively distinguish strange actions or crowd situations.

For a number of abnormal scenarios, such as crowding, hail, conflicts, fire, violence attacks, and trampling, a high-efficiency crowd management and evacuation model utilizing communication technologies and artificial intelligence (AI) is required. Consequently, a multitude of sensors, quick decision transmission, and in-depth data analysis make up the fundamental parts of CMS [31].

The proposed system in [32] was constructed using two key parts. The information management component also contains a fuzzy logic module and a thermal video analyzer. Recent fuzzy models [33] and [34] can be used to improve performance.

5. Crowd Management

Crowd management is the examination of people who determine an area's capacity prior to its utilization. The systematic planning, coordination, and supervision of the orderly gathering and movement of people is known as crowd management [35]. Crowd management is the supportive, organized direction provided for the orderly movement of people. As a crucial component of crowd management, actions are done to limit or regulate crowd behaviour. Securing crowd safety may be a part of crowd control. Additionally, a set of acts and preparations that are made to use, facilitate, and move crowds can be referred to as crowd management.

It's crucial to clear up a common misunderstanding about the difference between crowd control and crowd management. Although these two terms are frequently used synonymously, it is important to understand their differences in order to behave more correctly throughout an event. Crowd management encompasses facilitating crowd activities and movement in addition to maintaining crowd safety. On the other hand, crowd control is primarily concerned with the problems that develop once a crowd starts behaving disorderly or gets out of control [36].

6. Conclusion

Globally, congested conditions are getting worse due to population expansion, global urbanization, high-speed transportation, and the spread of effective information. The paper discusses a number of technology developments for seeing, estimating, keeping an eye on, and controlling huge crowds. Furthermore, in integrated crowd control frameworks for varied crowd sizes, technologies, including RF, RFID, WIFI, Bluetooth, optical imaging, and CCTV cameras have been examined under specific conditions. Numerous uses of crowd modelling in the actual world for well-known disasters have been discussed for analysing of crowded situations and in anticipating crowd anomalies in real time crowd management systems.

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