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Intelligent Social Distance Crowd Management Systems for Pandemics - A Guided Tour

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Abstract- Ever since the Covid-19 pandemic started, the world has seen many changes including the change in the lifestyle of people. To stop the spread of coronavirus, the major guidelines to be followed are wearing masks, sanitizing hands, and maintaining social distancing. The major problem is that most people fail to follow social distancing rules, which is flouted in public places. The need for a social distancing monitoring system has become one of the much-needed research areas in the present scenario such monitoring systems will alert the public when they refuse or fail to follow social distancing rules. In this paper we review the research carried out with respect to crowd management and social distance monitoring.

Keywords – Social distancing, crowd management, human detection, image processing

I. Introduction

Crowd management has become one of the challenging research topic which directly impacts the urban infrastructure like railway stations, markets, bus station, commercials spaces, schools, colleges, shopping malls, etc. This has escalated even more so, after the onset of the Covid-19 pandemic, it has become essential to address this problem in order to stop the virus chain. Among various measures taken to prevent spread of the covid pandemic, the most critical control measure is to maintain minimum physical distance between two individuals which is now popularly known as social distance.

Physical distancing is country-specific, and it ranges from 1meter in China and France, as recommended by WHO, up to 2 meters in India, UK and Canada, being 1.5 meter in the Netherlands (as shown in Table 1) and some countries, it is even adjusted over time. As there is a relatively widespread suspicion that we may have to live with these requirements of physical distancing for months to come in future, it is therefore natural that this is becoming a design requirement for public infrastructures.

Social distancing plays a major role in controlling the spread of the coronavirus. In most of the countries, the Covid-19 cases had increased rapidly, and the healthcare facilities were not able to fulfil the needs of all the affected patients. Many patients didn't get ventilators and there were more deaths because of not having a big healthcare infrastructure during the rapid increase of the cases. Preventive measures like wearing masks, sanitizing your hands and social distancing has helped in controlling the spread of Covid-19 to a larger extent, figure 1 shows the comparison of covid cases reported with and without preventive measures.

Table 1. Social distance norms country wise

Countries	Social Distance
China, France	1 meter
Germany, Netherlands, Australia	1.5 meter
India, Japan, Canada, UK, USA	2 meters

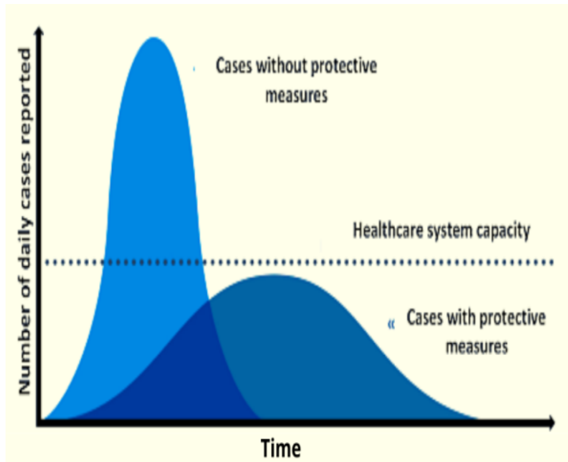

Figure.1 Covid cases reported with and without protective measures

However, there are many challenges associated with the automated monitoring of physical distancing or social distancing in large crowds. Respecting individual privacy while employing sensors and techniques while at the same time providing accurate distance-time information is one of the main challenges. Secondly, the algorithms developed should, in addition to preserving privacy, should autonomously discern, with a good degree of accuracy. This identification can be performed in real-time, raising several non-trivial technical challenges. In the last two years, some countries have developed tracing apps that allow receiving an alert when somebody has been in close contact with somebody that, or later on, will turn out to be affected with the Covid-19 [2].

In this paper we analyze various research conducted on social distance management and crowd management during the pandemic situation. The review focusses on social distance monitoring system based on the parameters used, such as camera view, algorithms used for object detection, distance finding technique between the detected objects. To provide more insight on the problem papers related to object detection research are also analyzed in this review.

II. Methods

2.1 Crowd Management

Crowd management is needed for proper planning and organizing any event such as concerts, managing public spaces like airports, bus stations, shopping malls and places of worship. Crowd management involves counting people, tracking individuals, congestion detection and queue analysis [1]. Effective crowd management requires deliberation of effective planning before an event is started, crowd monitoring and control during the occurrence of the event, taking feedback after the end of the event and reporting lesson learned for more effective systems in the future. The architectural and infrastructural design aspects along with technologies and mechanisms are to be considered for crowd monitoring and control, these aspects are necessary to manage huge crowds and to avoid any potential disaster. During the planning phase of a an event where huge crowds are expected it is crucial to find the crowd flow directions and crowd density threshold limits in different areas, simulation of different crowd scenarios can be performed for the area to be observed [2]. The location chosen for crowd management studies is significant as many parameters like the size of the crowd, movement of the crowd, motion patterns are to be considered. Some research on crowd management have chosen specific locations like Hajj, Kumbh Mela [2], Utrecht central station [3], Notte Biance festival [4] and pedestrian crowd [1][5][6] which are events with huge crowd.

A crowd management study proposed by Ali and Ahmed [1] focuses on event of interest detection method using motion atoms form the scene. Motion atoms demonstrate complex and unique motion patterns, and can be observed as mid-level characteristics to combine the gap between low-level features and high-level features in order to encode complex events. A single motion atom presents motion information in a short temporal window. The authors have conducted the analysis using the UCSD dataset, which is an annotated benchmark for the analysis of detection and localization in crowded scenes [1]. The dataset is collected using CCTV camera fixed at an elevation overlooking people pathways. The movement of non-people objects in the pathways, and anomalous pedestrian motion patterns are treated as abnormal situations [1]. Crowd monitoring using various crowd data acquisition techniques such as Vision, Wireless /Radio-Frequency and Web/Social-media data mining technologies have been discussed in detail by Sharma et.al [2]. The author's further state that web data mining based systems can bridge the information gap between the visitors, coordinators and other stakeholders of the event. Getting meaningful information and predicting outcomes for alerts from the voluminous data is the research challenge. They also conclude that the efficiency of real time system To improve the efficacy of real time crowd management system an integration of multiple technologies can also be performed, e.g. RFID tracking along with vision based monitoring and control. Development of IT solutions for managing crowded events (or situations) is another interesting area, e.g. an integrated In Utrecht central station, the data was acquired on platform 3 to track pedestrian detection. A camera that captures ten frames per second was collected as the dataset for individual tracking and analysis [3].

The videos recorded [1] were trained using support vector machine for classification and recognition. The experimental analysis had better performance with respect to image localization and segmentation. The authors in [2] discussed crowd information acquisition techniques based on vision technologies, wireless RF technologies, social media, and web data mining. Vision-based systems use a camera to capture the crowd, which is then used to analyses and track. The RF-based crowd management uses an RFID tag to identify, manage, and monitor people. A graph was plotted between people density and count of the people to find the crowd densities at different times in a day [3]. It also discusses the incidence of family groups, who form a group in public spaces, and the crowd density gets affected. The researchers Martella, Conrado and Vermeeran [5] suggested a method for crowd management in public events. Crowd management contains two different phases - preparation and execution. The preparation phase includes: Understanding visitor profiles; Location of the event; managing the clients and preparing for the weather and action plan. The execution phase consists of managing build-up and break-up, controlling flows and queues, monitoring the crowd, predicting and preventing accidents, and ensuring constant communication. Effective crowd management depends on using technology wisely and proper event arrangement [6]. Some of the important strategies to be considered for effective crowd management are predicting the capacity of a place to accommodate people, participants' composition, forecasting the participants' distribution, and early warning mechanisms.

Crowd management in urban areas is one of the most challenging tasks, whereby in 2050, 68% of the population might live in urban areas. Boukerche et al have addressed the challenges and methods of gathering data faced in urban crowd management [7]. Different methods can be employed to gather crowd information from a given location. Cellular network records or call detail records (CDR) record the call records and contain the user's location. This method helps to find the number of people in a particular place. The crowd can be analyzed by using the social media account location, and this can be used for a larger audience in the urban areas to gather the crowd data quickly. Other methods like transportation data, proximity data, positioning records, and city data catalogues are used to gather big data in urban places. The key challenges in crowd management research are privacy and security, crowd density detection, localization and spatial coverage and crowd situation. Using a camera to detect crowd density and crowd analysis would be easier than gathering the data from the CDR or social media locations.

Another effective way to gather data is by using a camera to capture the crowd. In [8], the researchers used a Logitech HD C920 to capture the crowd. Their primary research was to apply big data analytics for the data gathered from the camera. This system estimates the number of people standing in the queue. If generally there will be 5-7 people in the queue and suppose there is a massive rise in the number of people standing in the queue, it will intimate the concerned person to fill the need for all the people standing in the queue. The implementation of the proposed system was carried out in a 64-bit machine with Linux and Intel64 virtualisation environment provided by Oracle Virtual Box. Hadoop clusters with 3 Intel Xeon E5540 processors and 64GB RAM are used with 2 GB connectivity. In [9], the authors developed a system for crowd management in public places like schools, malls and stations. An abnormal crowd in a particular place can lead to crowd crush, mass panic, and overall control loss. Their system comprises two parts; the first part consists of an IP camera connected to the server-side application to monitor the crowd's activities in different entrances. This counts the number of people entering inside a place from different entrances. The second important part is the mobile application which intimates the public when there is a mass crowd entering that place in order to avoid crowd crush and mass panic, which can lead to abnormal activities.

Crowd management is studied for different perspectives in crowd behavior, including tracking, monitoring, movement and identification. The system developed by Farooqi [10] aims to monitor the crowd, improve the safety level of the people, use an interactive messaging system to receive or send a warning from the crowd, and connect the people with six different sensors used to detect fire and smoke and air poisoning. The sensors used in this system can be categorized into two: external and internal sensors. The external sensors are the outside temperature sensor, fire sensor and air sensor. The internal safety sensors are heart, movement, and body temperature sensors. The system is connected to a movement sensor and a heart sensor to measure the person's steps and heartbeats individually and then evaluate people's behavior in the same area according to their locations to detect any crush and stampede. The system is connected to an outside temperature sensor, air sensor, and fire sensor to evaluate the environment for groups of people in the same place that lead to detecting the following situations: sunstroke, air poisoning, and fire. The system is connected to a body temperature sensor and a heart sensor to measure the person's fever and heartbeats individually and then evaluate the situation to detect any health problems or side effects. The system records all data in the entire event, like a black box in an aero plane, which helps determine the causes of accidents. The black box is used for security purposes to discover hidden information.

Crowd management is a major challenge in many countries including Saudi Arabia, where millions of pilgrims gather all over the world to visit Mecca and perform the sacred act of Hajj [11]. It is a holy ritual that requires large crowds to perform the same activities during specific festivals, making crowd management critical and complex. Without proper crowd control and management, the occurrence of disasters such as stampedes, congestion, and suffocation becomes highly probable. The internet of things (IoT) enabling technologies represent efficient solutions for managing and controlling crowds, minimising casualties, and integrating different intelligent technologies. IoT allows intensive interaction and heterogeneous communication among different devices over the internet, thereby generating big data. The authors proposed an intelligent IoT approach for crowd management with congestion avoidance in the Mina area, located in Mecca. This approach implements a learning mechanism that classifies pilgrims based on the collected data and exploits the advantages of IoT and cloud infrastructures to monitor crowds within a congested area, identify pilgrims' evacuation paths, and guide the pilgrims to avoid congestion in real-time. Moreover, the approach attempts to maximize crowd safety based on different scenarios by controlling and adapting the people's movements according to the characteristics of the possible hazards, pilgrim behavior, and environmental conditions. This system was evaluated by performing simulations based on real data sets and scenarios.

2.2 Social Distancing Systems:

After the Covid-19 pandemic had started, many kinds of research were done to monitor the safety protocols to reduce coronavirus spread. The research paper by Yew Cheong Hou, Mohd Zafri Baharuddin, Salman Yussof, Sumayyah Dzulkifly in 2020 [12], discusses social distancing detection to alert people to maintain distance by evaluating the video feed. This system was developed for pedestrian detection with the help of a pre-trained model based on the Yolo v3 algorithm. The video frame was transformed into a top-down view for distance measurement from the 2D plane. This proposed method was able to find the social distance between the people. The study by Limbasiya and Raut [13], the proposed system monitors the face mask and social distancing. The proposed system uses a transfer learning approach to perform better optimization with a deep learning (DL) algorithm and a computer vision to automatically monitor people in public places with a camera integrated with a local machine and detect people with masks or without masks. The video frames were converted into grayscale and then processed for higher accuracy and improved speed. Real-time person or human detection is done with the help of YOLO v3 using RestNet50and OpenCV, achieving 91.2% mAP, outperforming the comparable state-of-the-art Faster R-CNN model. The distance between the ground and camera was calculated with the help of the focal length of the camera. The pairwise distance between the two detected objects was calculated by Euclid's formula. Also, the authors Imran Ahmed, Misbah Ahmad, Joel J.P.C. Rodrigues, Gwanggil Jeon, Sadia Din [14] also took a similar approach to develop a social distance monitoring system. YOLO v3 algorithm was used for object detection; YOLO v3 is pre-trained on the COCO dataset. Distance between the objects was calculated by finding the distance between the two centroids of the bounding box. To check the social distance violations, an approximate distance in pixels was set as threshold distance.

Saponara et al [15] have proposed an AI system for the social distancing classification of persons using thermal images. By exploiting the YOLOv2 approach, a novel deep learning detection technique was developed to detect and track people in indoor and outdoor places. The training for the model was done with two datasets one with 775 thermal images and another with 800 thermal images. This system can be used for social distance monitoring and body temperature of the people. This model was deployed on a Jetson nano embedded device. The experiment showed best results upto 27 FPS in Jetson nano device. The researchers [16] proposed a method that utilizes the YOLO v3 algorithm to separate people or objects from the background. The deep sort technique was used to provide id's to the detected objects and track them. They have also used the Convolutional Neural Network (CNN), faster region-based CNN and single shot detector. Still, the YOLO v3 algorithm was more efficient and effective in mean average precision (mAP), frames per second (FPS) and loss values defined by object classification and localization. The pairwise distance was found out by using the coordinates of the centroid of the bounding boxes. The experimental analysis says YOLO v3 illustrated the efficient performance with balanced FPS and mAP scores.

A framework to develop a social distance monitoring system for various low light conditions has been proposed by Rahim et al [17]. This system uses a time of flight camera since it can find the distance between the camera and subject for each image point. A custom dataset was used to train the system with the YOLO v4 algorithm. Euclidean distance was used to find the pairwise distance. The distance threshold between two objects was kept 100cm as prescribed by WHO. To conduct the experiment, the camera was positioned at three different distances 400cm, 500cm, 600cm, and test frames were collected. The experimental analysis showed that the YOLO v4 algorithm achieves the best results in different low-light environments with good mAP.

The social distancing detector developed by Keniya and Mehendale [18] uses the Net-19 network method. They have developed their model of social distance monitoring with 19 layer architecture. This network consisted of two sub networks for feature extraction and feature detection. The feature extraction was carried out by a pre-trained Convolutional Neural Network. The accuracy of this model was 92.8% which showed better results than the ResNet-50 network and ResNet-18 network accuracy. Also, in [19], the authors developed a social distance analyzer using deep learning. The video input is changed into a 2D bird's eye view and fed into the YOLO v3 model. It was developed for pre-recorded videos and not for live video input. If the distance is below the threshold, it will display the bounding boxes in red color, else in green color. The proposed framework [20] contains four major tasks - person detection, person tracking, distance from camera estimation and pairwise social distance calculation. This framework uses Mask R-CNN for person detection in a video. Mask R-CNN can create masks for the detected objects to distinguish individual persons in the frame more easily. It can efficiently take 30 frames per second and detect the objects. A centroid tracking algorithm does person tracking. This model was evaluated on custom video datasets and was effective.

Table II: Comparison of the various crowd management studies

Paper Title	Authors	Algorithm Used	Distance Finding Technique	Camera view	Constraints	Efficiency
COVID-19 Face Mask and Social Distancing Detector using Machine Learning	Bhavik Limbasiya, Chinmay Raut	YOLO v3 using RestNet50 and Open CV	Centroid Method	Pedestrian view	There were occlusions in the object detection	91.70%
Implementing a real-time, AI-based, people detection and social distancing measuring system for Covid-19	Sergio Saponara, Abdussalam Elhanashi, Alessio Gagliardi1	YOLO v2 with Thermal Images	Centroid Method	Straight view	There are high occlusions in the detection	95.60%
A deep learning-based social distance monitoring framework for COVID-19	Imran Ahmed, Misbah Ahmad, Joel J.P.C. Rodrigues,Gwanggil Jeon, Sadia Din	YOLO v3 with transfer learning	Centroid Method	Overhead view	It was designed for a certain hall and cannot be used in outdoor environments	95%
Monitoring COVID-19 social distancing with person detection and tracking via fine-tuned YOLO v3 and Deepsort techniques	Narinder Singh Punn, Sanjay Kumar Sonbhadra, Sonali Agarwal and Gaurav Rai	YOLO v3 and Deepsort Technique	Centroid Method	Pedestrian view	Higher number of false positive may raise discomfort and panic situation among people being observed.	Not given
Monitoring social distancing under various low light conditions with deep learning and a single motionless time of flight camera	Adina RahimI, Ayesha MaqboolI, Tauseef Rana	YOLO v4	Centroid Method	Pedestrian view	Two temporary targets are required for monitoring.	97.40%
Real Time social distancing detector using Social distancing Net-19 deep learning network	Rinkal Keniya, Ninad Mehendale	YOLO	Centroid Method	Pedestrian view	While moving the webcam, people should be moving or else the detection will be wrong	93.30%
Social Distancing Analyzer Using Computer Vision and Deep Learning	G V Shalini1, M Kavitha Margret, M J Sufiya Niraimathi, S Subashree	YOLO v3	Centroid Method	Pedestrian view	Occlusions are there in this detection	Not given
Social Distancing Detection with Deep Learning Model	Yew Cheong Hou, Mohd Zafri Baharuddin, Salman Yussof, Sumayyah Dzulkifly	YOLO v3	Centroid Method	Pedestrian view	Camera's perspective view	Not given
SD-Measure: A Social Distancing Detector	Savyasachi Gupta, Rudraksh Kapil, Goutham Kanahasabai, Shreyas Srinivas Joshi, Aniruddha Srinivas Joshi	R CNN	Centroid Method	Straight view	Correct estimation of social distancing was not done	94.26%

From the various researches conducted, most authors used the YOLO algorithm for object detection. YOLO (You Only Look Once) algorithm uses neural network and provides real-time object detection. YOLO algorithm is based on regression; instead of selecting the interesting part of an Image, it predicts classes and bounding boxes for the whole image in one run of the algorithm**.** It gives better performance with high fps for real-time usage. The significant advantage of this algorithm is its high speed, as it can process 45 frames per second. First, YOLO takes an image as input and then divides the input frame into grids. On each grid, image classification and localization are applied. Then YOLO predicts the bounding boxes and their corresponding class probability for the objects. It looks at the probability of each object detected and takes the one which has a high probability. The boxes which have high IoU (Intersection over Union) with the current box are suppressed. YOLO algorithm is used widely because of its high speed and high accuracy.

All the researchers used the "Centroid method" to estimate the social distancing between the two detected objects. Once the bounding boxes have been detected for the object, the centroid of the bounding box is found. The distance between two objects is found using the Euclidean distance between the two calculated centroids. A specific threshold pixel is set as the distance between the two objects. If the social distance is below the threshold, then social distance rules have been violated. The comparison of various studies on crowd management is shown in Table II.

IV.CONCLUSION

Due to population growth, improved transportation and urbanization the frequencies of crowded situations are increasing globally. In this limited review which aimed at focusing on addressing social distancing based research various s technological advancements for managing large crowds have been discussed. Most of the technologies used in crowd management studies have been verified under limited environments, especially RF and Social-media/Web data mining based studies. Their efficiency in integrated crowd management for large crowds is yet to be experimentally verified. Crowd modeling and simulations can be effectively used in planning of crowd based events and in the prediction of crowd anomalies for real time crowd management systems. It will also be helpful in understanding the psychology and behavior of crowds (including pedestrian, crowd and group dynamics). Crowd modeling and simulations can be useful in assessing the infrastructure and the effectiveness of the current crowd control measures in diverse crowd scenarios, also it can assist in the design and development of improved crowd control measures.

Crowd management and social distancing is one of the main areas of research during this pandemic period our study shows that most of the social distancing systems used the YOLO algorithm for object detection as it can process higher frames per second than CNN, RCNN and Fast RCNN. The YOLO algorithm with transfer leaning approach showed higher accuracy than YOLO v3 algorithm. The object detection with the pedestrian view gave more occlusions, which can be reduced by taking overhead data. These systems have been used to monitor the people in public places to reduce the spread of Covid-19. Developing realistic crowd models, which can imitate the real life crowd conduct and its interface with other objects, is still a challenging and open research area.

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