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Crowd Aware Public Space Monitor

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Abstract- — Monitoring crowd density is a crucial task for ensuring safety and preventing overcrowding-related issues. The traditional methods for monitoring crowds involve manual observation and camera surveillance, which are time-consuming and require continuous monitoring. This paper proposes a hybrid approach for crowd detection using Raspberry Pi, incorporating wireless device detection, Bluetooth scanning, infrared sensing, and computer vision. The system estimates the crowd density based on wireless device detection and verifies the presence of people through OpenCV-based human detection. The infrared sensor is used to improve the accuracy of the system by tracking entry and exit movements. The hybrid approach is an improvement over traditional methods, reducing the limitations associated with each method. The paper also discusses different approaches to crowd detection, highlighting the advantages and limitations of these methods, and the benefits of a hybrid approach for real-time applications.

Keywords— Crowd Detection, Raspberry Pi, Wi-Fi, Bluetooth, IR Sensor, Computer Vision, OpenCV, IoT

I. INTRODUCTION

With the increase in the number of people moving into urban areas and the increased number of gatherings in public areas, monitoring the crowds is an essential part of the security system. Areas such as public transport and shopping malls are usually filled with large crowds, and hence, monitoring these areas is important to avoid congestion and security issues. It is often found that relying on traditional methods, such as using camera observations and the like, is not an efficient method and is not accurate.

With the advancements in the Internet of Things (IoT) technologies, various methods are being considered and implemented for the detection of crowds. The most commonly used methods are the detection of wireless signals and the use of computer vision, each having its own limitations in terms of the degree of accuracy and the environment.

For the efficient detection of crowds, the hybrid method is considered, using Raspberry Pi, as it helps overcome the limitations of the traditional methods. The method uses the combined effect of Wi-Fi, Bluetooth, and infrared signals.

II. LITERATURE SURVEY

A. Camera-Based Crowd Detection Systems

Dalal and Triggs [1] presented a human detection method based on Histogram of Oriented Gradients (HOG) features and a Support Vector Machine (SVM) classifier. The detection method uses edge and gradient information from images to detect human shapes efficiently.

The detection method performs reliably under controlled conditions and can be used in real-time applications. However, in crowded scenes, the detection accuracy reduces due to human overlap and occlusion, and lighting conditions also affect the accuracy.

B. Wireless Signal-Based Crowd Detection

Musa and Eriksson [2] presented a crowd estimation system using Wi-Fi probe request messages sent by devices such as smartphones and laptops. The system detects probe request messages and uses them to estimate the number of people in a particular area.

The system performs reliably in non-visual areas and is cost-effective. However, accuracy problems occur when there are multiple devices per person and devices with disabled Wi-Fi, leading to overestimation and underestimation of crowd size.

C. IoT-Based Crowd Monitoring Systems

Zhou et al. [3] presented a crowd monitoring system using Internet of Things (IoT) technologies, which integrate sensors and communication networks for collecting data from different areas. The system uses sensors and communication networks to collect data from different areas and estimate crowd density.

The system performs reliably, and its use allows for remote monitoring and control, making it applicable in smart cities.

However, security risks, dependency on communication networks, and increased complexity are associated with its use.

D. Machine Learning-Based Crowd Detection

Redmon et al. [4] presented a crowd detection algorithm called YOLO, or You Only Look Once, which has been used successfully in crowd detection applications. The algorithm processes images in one pass and detects multiple objects efficiently.

The algorithm performs reliably, and its use results in accurate detection and fast detection time, making it applicable in real-time applications. However, its use requires a large amount of memory and processing, restricting its use in smaller devices.

E. Infrared Sensor-Based Detection

Zhang et al. [5] proposed an IR sensor-based people counting approach, which uses beam interruption technology to detect the movement of people. IR sensors are fixed at the entry and exit points of the crowd.
The approach is highly accurate for counting the crowd in real time. Also, it is cost-effective. However, the technique is prone to errors when people move in groups. Moreover, the range of the sensor is less.

F. Hybrid Crowd Detection Systems

Alahi et al. [6] proposed a hybrid crowd monitoring approach, which uses different sensors like wireless sensors and computer vision techniques. Sensor fusion is used in the proposed technique to improve the accuracy of the crowd estimation.
Hybrid techniques have overcome the limitations of individual techniques. This is because the proposed technique uses a combination of different approaches. This makes the proposed technique highly accurate.

G. Raspberry Pi-Based Monitoring Systems

Upton and Halfacree [7] proposed the use of Raspberry Pi, which is a low-cost platform for computing. It is used in embedded systems and IoT applications.
The system is compact and energy-efficient, making it suitable for crowd monitoring systems. However, due to the low processing capabilities, optimization techniques have to be implemented while executing complex algorithms.

H. OpenCV-Based Human Detection

Bradski [8] developed the OpenCV library, which is useful for various image processing and object detection techniques.
Techniques like HOG and Haar Cascade Object Detection are commonly used to detect humans in images.
The OpenCV library is useful to process images in real-time and is easily integrated with the Raspberry Pi. However, the detection accuracy is reduced while handling large crowds and low lighting conditions.

I. Entry and Exit Monitoring System

Kim et al. [9] proposed a system to detect the entry and exit of crowds by using IR sensors. These sensors are useful to detect the movement of crowds. Individuals are counted based on the detection of their direction while entering the area.

The system is useful to improve accuracy by keeping a real-time count of the number of people in a specific area. However, the sensors have to be correctly positioned to ensure accurate detection. Errors occur while handling large crowds where multiple people are crossing the area.

J. Limitations of Existing Systems

Li et al. [10] analyzed the limitations of existing crowd detection systems. They identified issues like dependency on the environment while implementing vision-based detection and accuracy problems while implementing wireless detection.

III. COMPARISON ANALYSIS

The approaches discussed and reviewed show that camera-based systems are best for direct human detection, though these are highly affected by different environmental factors such as lighting and occlusions. The use of wireless signals is cost-effective and non-visual, though these are not highly accurate because of different usage scenarios. The use of machine learning is also seen to improve the performance of the system, though this is highly computation-intensive and hence not preferred for such scenarios.

The use of sensor-based approaches such as IR detection is highly efficient for real-time counting, though this is highly affected by errors while dealing with dense crowds. The use of IoT-based approaches is highly efficient for improving the capabilities of the system, though this is highly affected by network and security issues.

Overall, the Hybrid approach is highly efficient for improving the performance and accuracy of the system. The use of wireless detection, computer vision, and sensor-based approaches is highly efficient for improving the performance and accuracy of the system.

Table I
Comparative Analysis Of Existing Crowd Detection Techniques And The Proposed Hybrid System

Parameter	Camera-Based Methods	Wireless-Based Methods	IOT-Based Systems	ML-Based Methods	Proposed Hybrid System
Detection Principle	Image/Video analysis	Wi-Fi/Bluetooth signals	Sensor networks	CNN, YOLO, SSD	Wireless + Vision + IR
Accuracy	Moderate	Moderate	Moderate	High	High
Cost	High	Low	Medium-High	High	Low
Scalability	Limited	High	Moderate	Limited	High

IV. CONCLUSION

This paper aims to present a study on various techniques for crowd detection and emphasize the effectiveness of a hybrid crowd detection system based on Raspberry Pi. Various techniques, such as camera-based detection, wireless scanning, and sensor-based detection, have limitations in terms of accuracy and environmental conditions. The hybrid approach of combining all techniques can be more effective in terms of accuracy. The proposed approach can be an effective solution for real-time crowd detection in public areas.

V. FUTURE SCOPE

Future work can be done to further improve the accuracy of the proposed system. Various deep learning techniques can be implemented to improve accuracy. Moreover, integration with cloud and edge computing can be done to further enhance its accuracy. Other possible improvements can be done to further enhance sensor-based detection, energy harvesting, and data security. These improvements can further enhance the practicality of hybrid crowd detection systems in smart cities.

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