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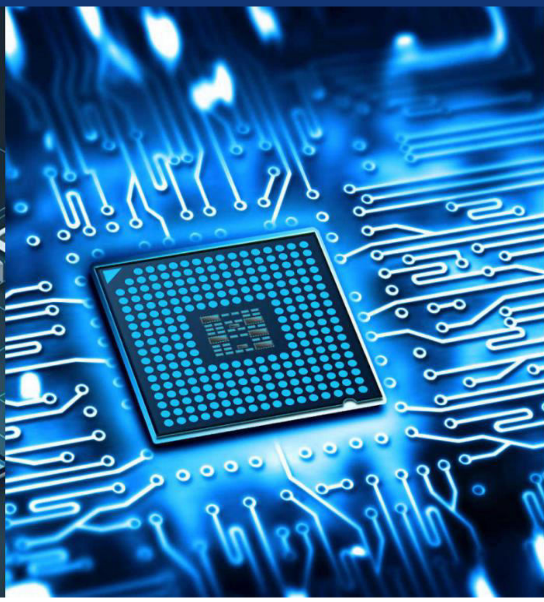


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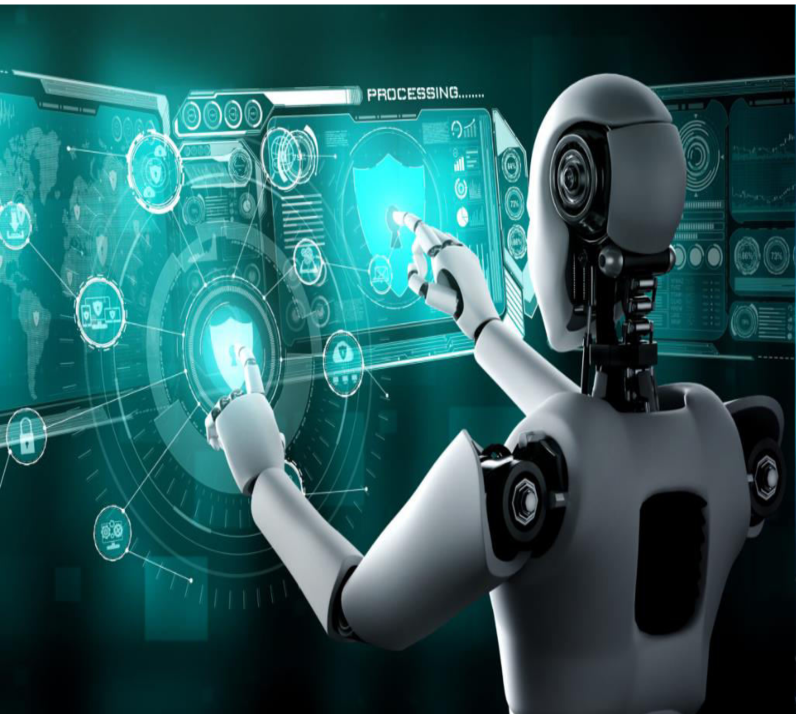

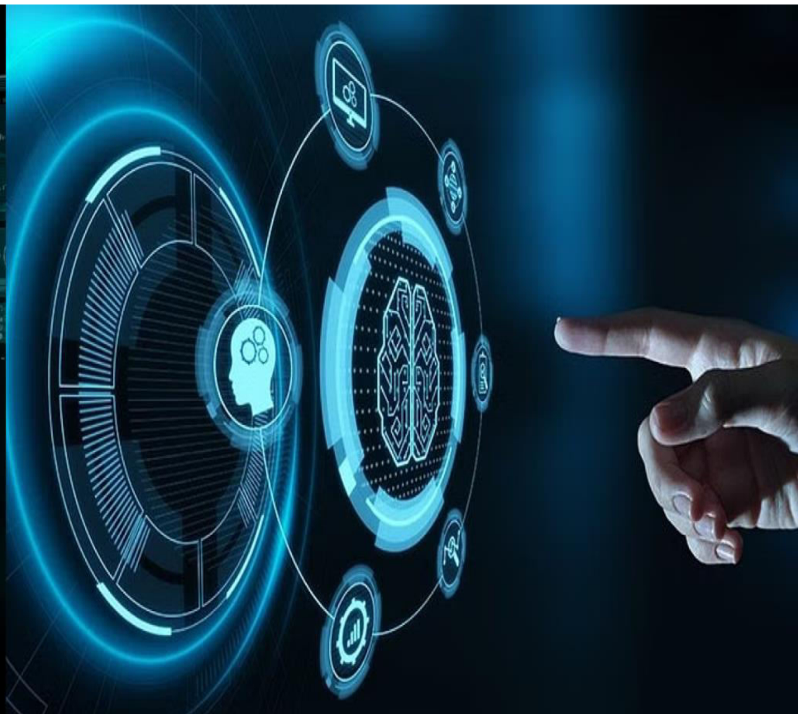

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Crowd Density Estimation and Security Risk Monitoring in Real Time Using YOLOv8

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ABSTRACT: In recent years, public safety and crowd management have become critical concerns, particularly in large gatherings such as concerts, sports events, and public demonstrations. This project, "Crowd Density Estimation and Security Risk Monitoring in Real Time using YOLOv8, Raspberry Pi Pico, and ESP32-CAM," presents an intelligent surveillance system designed to enhance security monitoring and crowd control. The system employs YOLOv8 (You Only Look Once, Version 8), a state-of-the-art deep learning model for object detection, to analyze real-time video feeds from the ESP32- CAM module. The model processes crowd density levels and detects anomalies such as overcrowding or unusual movements that may indicate potential security risks. The Raspberry Pi Pico acts as a microcontroller to manage sensor inputs and communication, ensuring efficient processing and low-latency alerts. The ESP32-CAM captures live video and transmits it to a monitoring system, where YOLOv8 processes the frames to detect human presence and estimate crowd density. If predefined thresholds are exceeded, alerts are sent via an IoT-based notification system, enabling real-time response from security personnel. A monitor (LCD or external display) provides a graphical representation of the crowd data, helping authorities make informed decisions. This project aims to enhance public safety by integrating real-time AI-based surveillance with IoT-enabled monitoring, ensuring an efficient and proactive approach to crowd management. It is particularly useful for law enforcement agencies, event organizers, and smart city applications where crowd control and risk assessment are essential.

KEYWORDS: Crowd Management, Public Safety, YOLOv8, ESP32-CAM, Raspberry Pi Pico, Real-Time Monitoring, Object Detection, IoT Notification System, Security Risk Monitoring

I. INTRODUCTION

With the rise of large-scale public events such as concerts, sports matches, religious gatherings, and political rallies, effective crowd management has become vital for ensuring public safety and responding to security threats in real time. Traditional surveillance methods, relying on manual oversight and CCTV monitoring, often fall short due to inefficiency, human error, and the lack of real-time, automated analysis. To address these limitations, this project—*"Crowd Density Estimation and Security Risk Monitoring in Real-Time using YOLOv8, Raspberry Pi Pico, and ESP32-CAM"*—proposes an AI-driven, IoT-based monitoring system that utilizes YOLOv8 for real-time crowd detection and analysis. Integrated with low-cost microcontrollers like Raspberry Pi Pico and ESP32-CAM, the system is designed to identify crowd density levels and flag security risks such as overcrowding, unauthorized access, and abnormal movement, offering a scalable, intelligent solution for modern surveillance challenges..

II. PROPOSEDSYSTEM

The proposed system presents a real-time crowd monitoring and security risk detection framework utilizing YOLOv8, Raspberry Pi Pico, and ESP32-CAM, aimed at enhancing public safety during large-scale gatherings. This intelligent surveillance solution detects crowd density and identifies potential threats by analyzing unusual movement patterns. The ESP32-CAM module captures live video streams and transmits them for real-time processing. YOLOv8, a state-of-the-art object detection algorithm, processes these frames to accurately detect individuals and estimate crowd density. Upon identifying abnormal crowd behavior or density exceeding predefined thresholds, the system triggers instant alerts.The Raspberry Pi Pico serves as a lightweight microcontroller, managing sensor inputs and coordinating

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communication among system components. An IoT-based alert mechanism ensures immediate notification to relevant authorities or event organizers, facilitating rapid response. Furthermore, the system features a display interface (e.g., LCD or Monitor) to visualize crowd metrics and real-time system status.
By integrating AI-based detection with low-power, cost-effective hardware, the proposed system offers a scalable and efficient solution for real-time crowd surveillance. Its compact and modular design makes it particularly well-suited for deployment in smart cities, event venues, and public spaces requiring continuous crowd monitoring and risk management.

III.METHODOLOGY

The methodology for the proposed real-time crowd density estimation and security risk monitoring system is structured around the integration of YOLOv8, Raspberry Pi Pico, and ESP32-CAM to deliver efficient, AI-powered surveillance.
Video Capture and Preprocessing: The process begins with the ESP32-CAM, which captures live video feeds from the monitored area. These video streams are transmitted to the Raspberry Pi Pico, which handles the initial processing and manages the communication between all system components.

Crowd Detection and Density Estimation: The core of the system lies in the use of YOLOv8 for object detection. YOLOv8 processes the video frames in real-time, identifying individual humans and estimating the crowd density based on the number of detected people in each frame. YOLOv8, a state-of-the-art deep learning model, has been trained to detect human presence with high accuracy and efficiency.

Anomaly Detection:Once crowd density is determined, the system continuously monitors for anomalies, such as overcrowding, where density exceeds predefined thresholds, or unusual movement patterns that may signal potential security risks. YOLOv8's high accuracy allows it to track people and their movement within the crowd, further helping to detect any abnormal behaviors.

Alert Mechanism: Upon detecting anomalies or security threats, the system triggers an IoT-based notification mechanism to alert event organizers, security personnel, or authorities in real-time. The Raspberry Pi Pico ensures that alerts are sent quickly and efficiently, providing key information on the detected risk or overcrowding scenario.
Data Visualization: For enhanced decision-making, the system includes a visual display interface (such as an LCD screen or external monitor) that presents real-time crowd data, including the number of people detected, estimated crowd density, and system status. This allows authorities to monitor the situation at a glance and respond proactively.

Hardware and Software Integration: The system combines efficient hardware and software integration, where the Raspberry Pi Pico functions as the central microcontroller, managing sensor data and communication between components. The use of low-power hardware and AI-driven detection enables the system to operate in real-time with minimal latency, making it ideal for large public gatherings and continuous surveillance.This methodology ensures that the system can effectively monitor crowd behavior, estimate crowd density, and detect security risks in real-time, offering a comprehensive solution for modern crowd management.

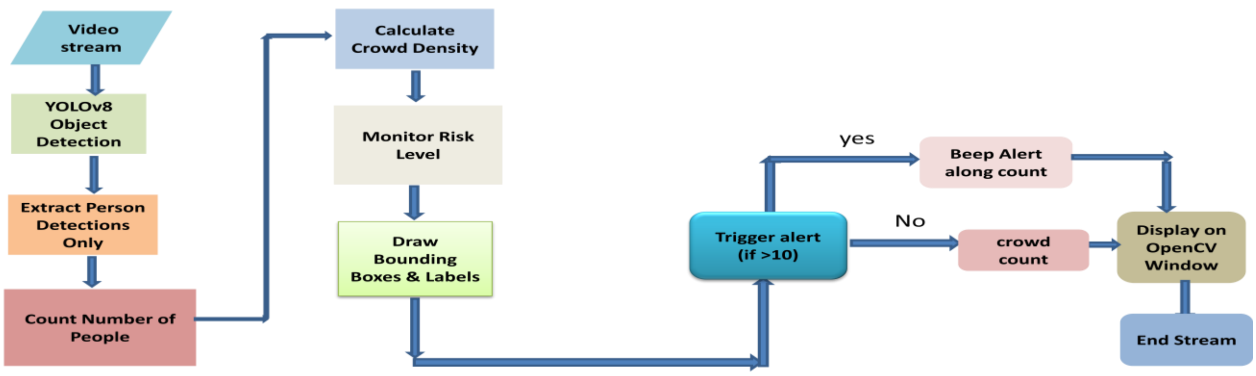

FIG: The proposed approach's model state diagram

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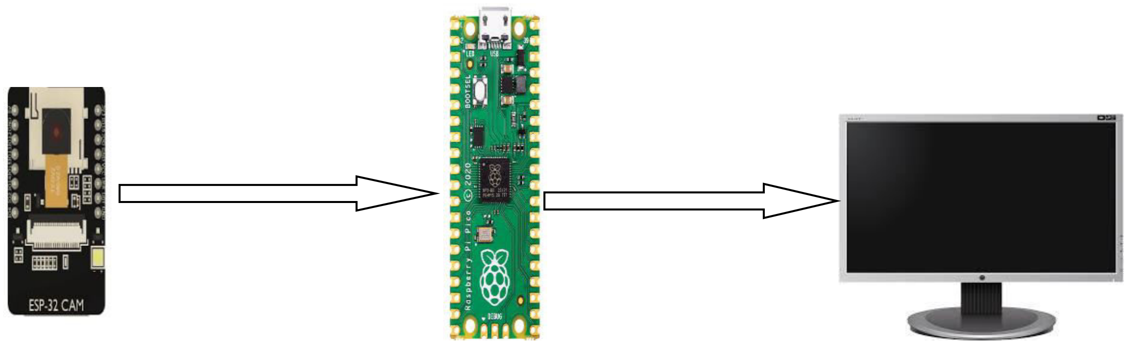
BLOCK DIAGRAM:



The block diagram represents a real-time crowd monitoring and density estimation system. An ESP32 Camera captures live images of the crowd and sends them to the Raspberry Pi Pico, which processes the image data to estimate crowd density. The processed information is then displayed on a monitor for visualization and analysis. This setup enables efficient and low-cost crowd monitoring in real-time.

IV.YOLOV8 ARCHITECTURE

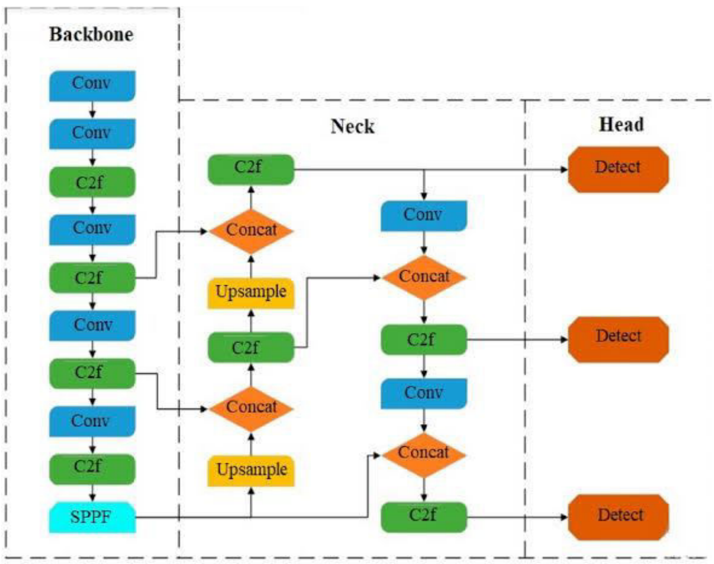


FIG: YOLOv8 Architecture

This architecture is divided into three main components—Backbone, Neck, and Head—each playing a critical role in the object detection pipeline.

Backbone (Feature Extraction)

The Backbone is responsible for extracting rich and meaningful features from the input image. These features include edges, textures, and patterns that are essential for understanding the visual content.

• Conv (Convolutional Layers): Capture low-level features such as edges, corners, and textures.

• C2f (CSP Bottleneck with Fusion): Enhances feature representation while optimizing computational efficiency through cross-stage partial connections.

• SPPF (Spatial Pyramid Pooling - Fast): Aggregates features at multiple scales, enabling robust detection of objects with varying sizes.

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Neck (Feature Refinement and Fusion)

The Neck processes and refines the features extracted by the Backbone. It fuses information from different scales to strengthen the network's ability to detect objects of different sizes.

• Concat (Concatenation): Merges feature maps from multiple layers to preserve both spatial and contextual information.

• Upsample: Increases the spatial resolution of feature maps, facilitating better detection of small objects.

• C2f: Further processes and enhances features before passing them to the detection layer.

Head (Object Detection and Prediction)

The Head is responsible for the final stage of detection, where it predicts the class, location, and confidence score for each detected object.

• Conv: Applies final transformations to the refined features to prepare for prediction.

 Detect: Outputs the bounding boxes, object categories, and confidence scores based on the processed features.

V.EXPERIMENTAL RESULTS

FIG 1:.Random Video Output

FIG 2:Live Video Output

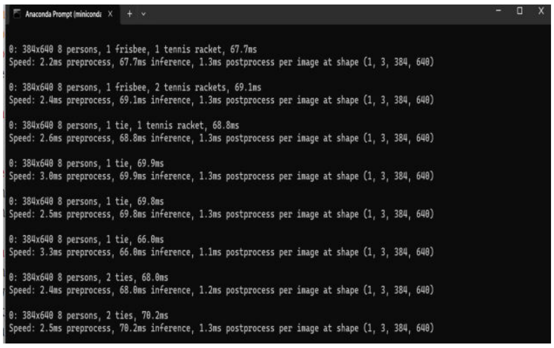

FIG 3:Output on ANACONDA Prompt

FIG[1] shows the result in which crowd density is estimated for random input video,FIG[2] Shows the output in which the crowd is estimated in live which means in Real-Time and FIG[3]The output is observed on Anaconda Prompt.

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VI. CONLUSION

This project presents an efficient, real-time crowd density estimation and security monitoring system using YOLOv8. By integrating ESP32-CAM for image capture, Raspberry Pi Pico for control, and IoT for remote alerts, the system accurately detects crowd levels from both live and recorded video. An automated buzzer alert is triggered when crowd density exceeds a threshold, enhancing public safety. Despite challenges, the system shows strong potential for applications in smart cities, healthcare, disaster management, and public event monitoring.

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