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Image Processing Based Controller for Indoor Cooling Unit

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Abstract

For interior cooling systems, efficient energy management is crucial to reducing power consumption and running expenses. In this work, an image-processing-based controller that uses real-time occupancy identification and tracking to optimize air conditioning utilization is presented. To precisely count the number of people in an area, the system analyzes CCTV camera footage using YOLOv5 for object detection and Deep SORT for multi object tracking. To increase efficiency, the monitored area is separated into many areas, each of which is managed by a separate air conditioner. The system allows for automated control using the MQTT protocol, guaranteeing that cooling units only run when a designated area is occupied and dynamically modifying the temperature in response to occupancy density. According to experimental data, the suggested method greatly reduces energy loss while achieving excellent occupancy detection accuracy. By providing a scalable and economical smart building management solution, this approach promotes sustainable operations and energy reduction.

Keywords: Occupancy detection, YOLOv5, Deep SORT, MQTT, energy efficiency, air conditioning optimization.

I. Introduction

Reducing Meeting halls frequently have varying occupancy levels, which results in wasteful energy use when cooling systems run constantly regardless of usage. Conventional air conditioning systems operate according to predetermined settings, which frequently leads to needless electricity usage while the hall is empty. The efficacy of current technologies, like motion sensors or planned cooling, is limited since they are unable to dynamically modify cooling based on occupancy in real time. An image processing-based controller is suggested to automate cooling unit operation based on real-time occupancy detection to address this inefficiency [1], [2]. The number of people present is determined by processing the CCTV footage of the meeting room using YOLOv5 for object detection and Deep SORT for multi-object tracking [3]. The ideal temperature is determined using the occupancy data, and the MQTT protocol is used to send the result to the ESP32 microcontroller [4]. The system sends an "OFF" instruction to the ESP32 to make sure the cooling unit is turned off if no occupancy is detected [5]. This technology greatly reduces energy use while improving thermal comfort by making sure that cooling is only delivered when people are present [6]. This study offers a clever and affordable way to maximize meeting room air conditioner performance while maintaining energy efficiency and user comfort [7]. This paper's methodology, implementation,findings, and conclusions are covered in detail in the sections that follow. These sections also show how well the suggested solution works to reduce energy wastage and enhance operationalefficiency.

II. Methodology

Continuous video footage of the monitored area is captured by an IP camera and sent as a video feed to the computational unit, where Deep SORT is utilized for multi-object tracking and YOLOv5 is used for object detection [7], [5]. Based on occupancy density, this unit determines the proper temperature setting and processes the video to determine the number of people present (Fig. 1) [2], [6]. An ESP32 microcontroller receives the calculated data once it has been wirelessly transferred using the MQTT protocol [4]. If occupancy is detected, the ESP32 receives the corresponding temperature and sends an IR control signal to adjust the cooling unit accordingly [9]. In the absence of occupancy, the ESP32 receives an "OFF" command to deactivate the cooling unit, ensuring efficient energy management [1], [5]. By dynamically adjusting the cooling system based on real-time occupancy levels, this approach optimizes power consumption while maintaining a comfortable indoor environment [10], [3]. (Table. 1) Processing the real-time video stream from the IP camera is done by the Computational Unit, which has a 2.4 GHz processor and at least 6GB of RAM [6]. It uses Deep SORT to track individuals within the observed area and YOLOv5 to detect objects [2]. Furthermore, it uses the MQTT protocol to interact with the ESP32 board in order to regulate the cooling unit [4]. With a minimum resolution of 4MP, the IP Camera records real-time video and wirelessly sends it to the computational unit for additional processing [3]. By enabling steady wireless connectivity between the IP camera and the computational unit, the router, which runs at 2.4 GHz, guarantees low-latency and seamless video transmission [9]? The interface between the cooling unit and the computational unit is the ESP32 Board [5]. It gets control signals through MQTT and instructs the cooling unit to activate or deactivate based on occupancy detection [1]. By protecting the ESP32 from direct exposure to greater currents that could harm it, the BC547 transistor ensures that the control signals are handled properly [8].

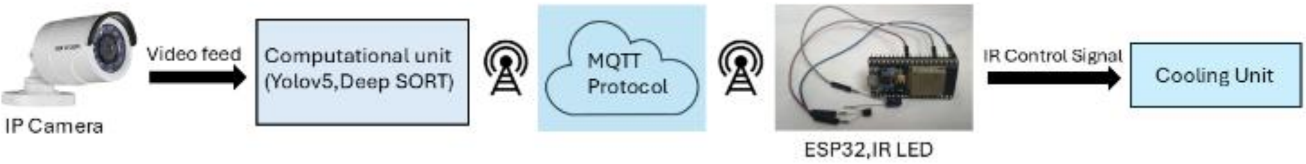

Fig. 1 overall flow diagram

S NO	COMPONENT NAME	SPECIFICATION
1.	Computational unit	Min 6GB Ram,2.4GHZ
2.	IP Camera	4MP
3.	Router	2.4 GHz
4.	Espressif Board	ESP32
5.	Transistor	BC547
6.	IR LED	1.2V – 3.4V

TABLE1. Name of the components with specification

An IR LED that runs between 1.2V and 3.4V is also attached to the ESP32 and serves as a signaling element [4]. In accordance with the analyzed occupancy data, it transmits a control signal to the cooling unit, causing it to either activate or deactivate[10].

A. Yolov5 With Deep Sort Real-Time Video Processing

Real-time video footage of the seminar hall is recorded by a CCTV camera and sent wirelessly to the processing unit via a router. For object detection—more specifically, recognizing and categorizing individuals in the observed area—YOLOv5 deep learning model is employed. Deep SORT (Simple Online and Real-time Tracker) is used to guarantee ongoing tracking of persons. By giving each observed person a unique ID, Deep

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SORT enables thesystem to keep accurate occupancy counts even when users relocate between various regions. This tracking system guarantees accurate occupancy monitoring and gets rid of duplicate detections.

B. Message Queuing Telemetry Transport (MQTT) for Communication

A lightweight messaging protocol called MQTT is utilized in Internet of Things applications for real-time communication. It uses a publish-subscribe approach in which the ESP32 subscribes to control signals that are published by the computational unit based on occupancy detection. The ESP32 uses the IR LED to activate or deactivate the cooling unit in response to a message. MQTT is perfect for automatic climate control since it guarantees quick, dependable, and effective data transfer.

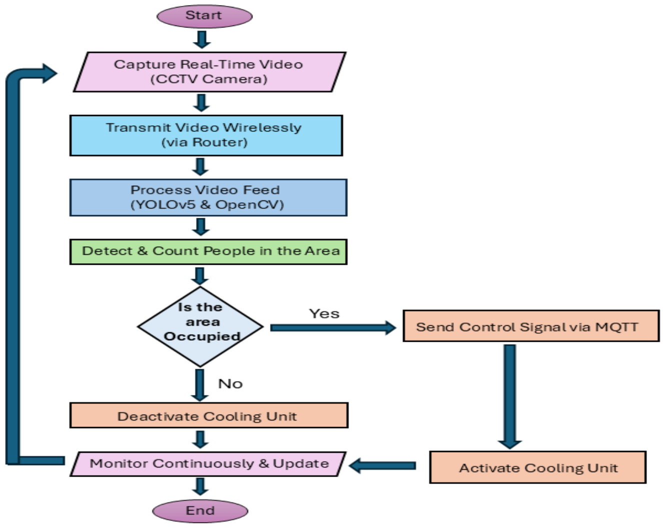

Fig. 2. Functional flow chart

C. System Automation and Energy Efficiency

The ESP32 microcontroller, equipped with an IR LED, receives temperature control signals via MQTT and transmits infrared commands to the air conditioners. This ensures seamless automation without requiring manual intervention. By activating only the necessary cooling units and adjusting temperatures dynamically, the system achieves energy savings while maintaining optimal cooling efficiency.The automated cooling system's operation is depicted in the flowchart (Fig. 2). The computational unit uses YOLOv5 and Deep SORT to process the real-time video that the IP camera records to identify occupancy. The system determines the necessary temperature based on the number of people in the monitored area and communicates this information to the ESP32 via MQTT. The ESP32 receives the temperaturereading and modifies the cooling unit if the space is occupied. The cooling unit is deactivated by sending an OFF signal over MQTT if no occupancy is detected.

Based on occupancy data in real time, this procedure guarantees effective energy use.

Fig.3 Seminar hall with three Air conditioner

III. Result And Discussion

Three air conditioners were strategically placed in a seminar hall, each designated to cool a specific region, to evaluate the performance of the proposed image-processing-based controller for indoor cooling units. The system's effectivenesswas assessed based on its ability to accurately detect occupancy, facilitate real-time communication via MQTT, and optimize energy consumption. The seminar hall was divided into three specific regions, with each air conditioner assigned to a particular section to ensure efficient cooling distribution. This division enabled a more precise analysis of energy efficiency and occupancy-based cooling adjustments. Figure 3 illustrates the monitored area, highlighting the three air conditioners assigned to different sections of the hall.

A CCTV camera continuously captured real-time video footage, which was wirelessly transmitted through a router to the computational unit. The router, operating at a frequency of 2.4 GHz, ensured a stable and low-latency connection between the IP camera and the processing unit, enabling seamless video transmission. The controlling unit employed YOLOv5 and Deep SORT to process this video feed, effectively detecting and tracking individuals within the monitored space.YOLOv5, a deep learning-based object detection model, was responsible for recognizing and classifying individuals in real-time, while Deep SORT facilitated continuous tracking by assigning unique IDs to each detected person. This dual approach eliminated duplicate detections and maintained accurate occupancy counts even when individuals moved between different regions of the seminar hall.

In order to avoid wasting energy, the system was correctly detected when no one was in the seminar hall and made sure that all air conditioners were turned off.Because it allowed real-time communication between the ESP32 microcontroller and the computational unit, the MQTT protocol was essential to this operation. The system made sure the air conditioners stayed off by sending an "OFF" signal to the ESP32 via MQTT if no occupancy was detected. On the other hand, when occupancy was identified, the system dynamically modified the cooling parameters according to the number of people in each area, maximizing power efficiency without sacrificing thermal comfort.

This technology showed the potential for intelligent climate control in big indoor areas and greatly increased energy efficiency by combining cutting-edge computer vision techniques with IoT-based automation.

Once occupancy was successfully identified, the system used YOLOv5's object identification capabilities to count the number of individuals in the hall and establish their distribution across different sections.A cutting-

edge deep learning model called YOLOv5 effectively identified people in the observed region, allowing for real-time and extremely precise person detection. After the attendees were identified, each one was given a unique ID using Deep SORT, a multi-object tracking technique, which allowed for ongoing tracking even when people walked about the lecture hall.Through the avoidance of missing or duplicate identifications, this

Fig.4 Seminar Hall with Processed Output

detection and tracking combination reduced errors in occupancy counting. The seminar hall was divided into three distinct areas, as illustrated in (Fig. 4), allowing the system to count the number of attendees in each section independently. This regional segmentation helped in precise energy management by ensuring that cooling was applied only where it was needed. The processed output displayed an occupancy count of 10:22:13, indicating that 10 individuals were present in Region 1,22 in Region 2, and 13 in Region 3.This information was crucial for dynamically adjusting the cooling system, as each region's cooling requirement varied based on the density of occupants. The controlling unit processed this occupancy data and generated an output signal that selectively activated only the air conditioners in the occupied zones. This method ensured that air conditioners in unoccupied areas remained switched off, significantly reducing unnecessary power consumption while maintaining comfort in occupied spaces.According to the real-time occupancy distribution across various regions, the MQTT server dynamically modified cooling settings to further improve thermal comfort and maximize energy efficiency (Fig. 5).By receiving the computed temperature values from the MQTT server and sending the appropriate infrared signals to the air conditioners, the ESP32-based IR remote control unit served as a bridge between the computational unit and the air conditioners, as shown in (Fig. 4).

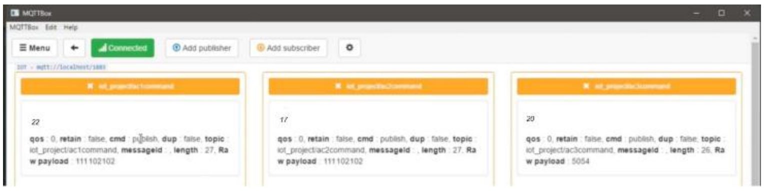

Fig.5 MQTT Server Sending Temperature to Esp32

Real-time responsiveness was guaranteed by this communication method, which enabled the air conditioners to modify their function without human assistance.The system assigned distinct temperature settings to each region in order to deliver the best cooling possible based on occupancy levels in real time. The air conditioner was adjusted to 22°C by the system for Region 1, which had 10 persons, Region 2, which had the highest occupancy rate at 22 people, needed a lower temperature setting of 17°C to remain comfortable,13 persons in Region 3 were given a temperature setting of 20°C (Fig.5).Thermal comfort considerations guided the selection of these temperature values, which prevented excessive energy use in lightly populated sections while guaranteeing that heavily occupied regions received greater cooling.

Energy waste was greatly reduced by this region-based cooling method, which also showed the system's effectiveness under practical circumstances. The potential for intelligent energy management solutions, where cooling operations are constantly modified based on real-time occupancy data, is highlighted by the smooth integration of computer vision and IoT-based automation. This method guarantees accurate control over cooling units, improved resource use, and enhanced sustainability in large interior spaces by using MQTT for communication and YOLOv5 for human detection.

IV. CONCLUSION

Through dynamic operation adjustments based on real-time occupancy recognition and tracking, the suggested image-processing-based controller for indoor cooling units effectively optimizes air conditioning usage. The system precisely detects and counts the number of people in various areas of a monitored environment by utilizing YOLOv5 for object detection and Deep SORT for multi-object tracking. The detection system and air conditioners can communicate seamlessly thanks to the MQTT protocol, which enables automated activation and temperature adjustment based on occupancy levels. According to experimental data, the technology efficiently reduces energy waste because air conditioners are only turned on in areas that are inhabited and cooling settings are modified appropriately. Large indoor spaces like conference rooms, offices, and lecture halls can benefit from this smart building management strategy since it lowers operating costs while simultaneously improving energy efficiency. By integrating computer vision and IoT-based automation, this system provides a scalable, cost-effective, and sustainable solution for intelligent climate control.Future enhancements could include expanding the system to Support multiple camera inputs, improving tracking accuracy in complex environments, and integrating additional sensor-based validation for enhanced robustness. The findings of this research contribute to the advancement of energy-efficient smart building technologies,paving the way for more sustainable and intelligent energy management solutions.

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