Adaptive Cooling Management for Dynamic Occupancy in Classrooms

Group member names:

- **Vedika Lundia**
- **Harshit Kumar**
- **Vivek Kumar Yadav**
- **Indra Narayan Dhami**
- **Ritika Chaudhary**

Mentor:

Akash Pundir

Introduction

- The project aims to optimize cooling and lighting in classrooms based on real-time occupancy detection.

- Uses CCTV cameras to monitor occupancy and control AC, fans, and lights dynamically.

- Reduces energy consumption while maintaining thermal comfort.

Problem Statement

01

- TRADITIONAL COOLING AND LIGHTING SYSTEMS OPERATE INEFFICIENTLY.

02

- CLASSROOMS OFTEN HAVE UNEVEN OCCUPANCY, LEADING TO ENERGY WASTAGE.

03

- THE NEED FOR A SMART SYSTEM TO ADJUST COOLING AND LIGHTING BASED ON REAL-TIME OCCUPANCY.

Objectives of the Project

To develop a real-time occupancy detection system for classrooms using computer vision.

To implement zone-based control logic for fans, lights, and AC units.

To reduce energy consumption by dynamically adjusting cooling based on people count and temperature.

To integrate a user-friendly interface for monitoring and controlling the environment.

Review of Existing Studies

Most current HVAC systems are based on fixed schedules or manual control, leading to energy waste.

Studies have shown that zone-based cooling systems can save up to 30% energy in large spaces like classrooms.

Prior works primarily focus on temperature control, lacking real-time occupancy-based automation.

Methodology

- **Occupancy Detection**: Real-time person detection using computer vision algorithms (YOLO, OpenCV).
- **Zone Mapping**: Classrooms divided into zones; occupancy data mapped to these zones.
- **Device Control**:
  - Fans scaled according to people count per zone.
  - Lights triggered based on presence.
  - AC controlled by temperature thresholds and future integration with occupancy.
- **Data Collection**: DHT22 sensor collects temperature and humidity.
- **Interface**: GUI dashboard for monitoring and control.

Project Overview

Uses YOLOv8 for person detection.

Classroom divided into 6 zones (2x3).

Controls 6 fans, 6 lights, and 2 ACs.

Supports camera switching and real-time video display.

System Architecture (Software Prototype)

The system consists of the following components:

- Camera (Webcam, DroidCam, External Webcam): Used for occupancy detection.
- Cooling and lighting control logic: Based on detected occupancy.
- Cooling and lighting control logic: Based on detected occupancy.
- Temperature and humidity sensor simulation: To adjust cooling based on environment.

Person Detection and Zone Mapping

- Real-time frame capture and YOLOv8 person detection
- Detection bounding boxes mapped into classroom zones
- Count people per zone and total count
- Example: If person detected in zone (row 1, col 2), activate Fan 2 and Light 2

Fan and Light Control Logic

- **People-based scaling**:
  - 1–4 people → 1 fan
  - 5–8 people → 2 fans
  - … up to 6 fans
- Fan priority given to currently occupied zones.
- Empty zones: Fan runs 60s before turning off.
- Vertical arrangement of fans matches zone layout
- Lights: ON/OFF based on presence in each zone.

AC Control Logic

- Based on Temperature thresholds
    - Temp > 28°C → AC1 & AC2 ON (set to 20°C)
    - 25°C < Temp ≤ 28°C → AC1 ON, AC2 OFF (set to 22°C)
    - Temp ≤ 25°C → Both OFF
- Uses DHT22 sensor for live temp/humidity data.
- Planned future enhancement: Integrate people count into AC control

Camera Management

Supports multiple camera sources: laptop webcam, DroidCam, USB camera

User can switch camera sources dynamically via GUI

Helps ensure reliable video feed for occupancy detection

User Interface & Visualization

- Real-time video with detection boxes and zone grid overlay
- Status indicators for fans, lights, and AC per zone
- Temperature and humidity readings displayed
- Camera selection dropdown

Planned Hardware Integration

- ESP32 Microcontroller
- Relays (6 fans, 6 lights, 2 ACs)
- MQTT or HTTP communication
- Commands sent via Wi-Fi from Python
- Real-time feedback/status display
- DHT22 sensor for live temperature/humidity input

Challenges & Optimizations

LAG DUE TO FRAME PROCESSING → OPTIMIZATION NEEDED

HANDLING FALSE POSITIVES IN DETECTION

REAL-TIME COMMUNICATION WITH ESP32

POWER HANDLING FOR MULTIPLE RELAYS

WEB GUI INTEGRATION (FLASK)

Future Work

- Hardware integration: ESP32/relay modules for real device control
- Real sensor integration for temperature and humidity
- Incorporate people count into AC dynamic control logic
- Optimize video processing for smoother real-time performance
- Patent filing for the adaptive cooling management method

Live Demonstration Plan

Start

- • Step 1: Start the system with the laptop webcam.

Display

- • Step 2: Display real-time people detection and zone assignment.

Show

- • Step 3: Show how fans/lights turn on in occupied zones.

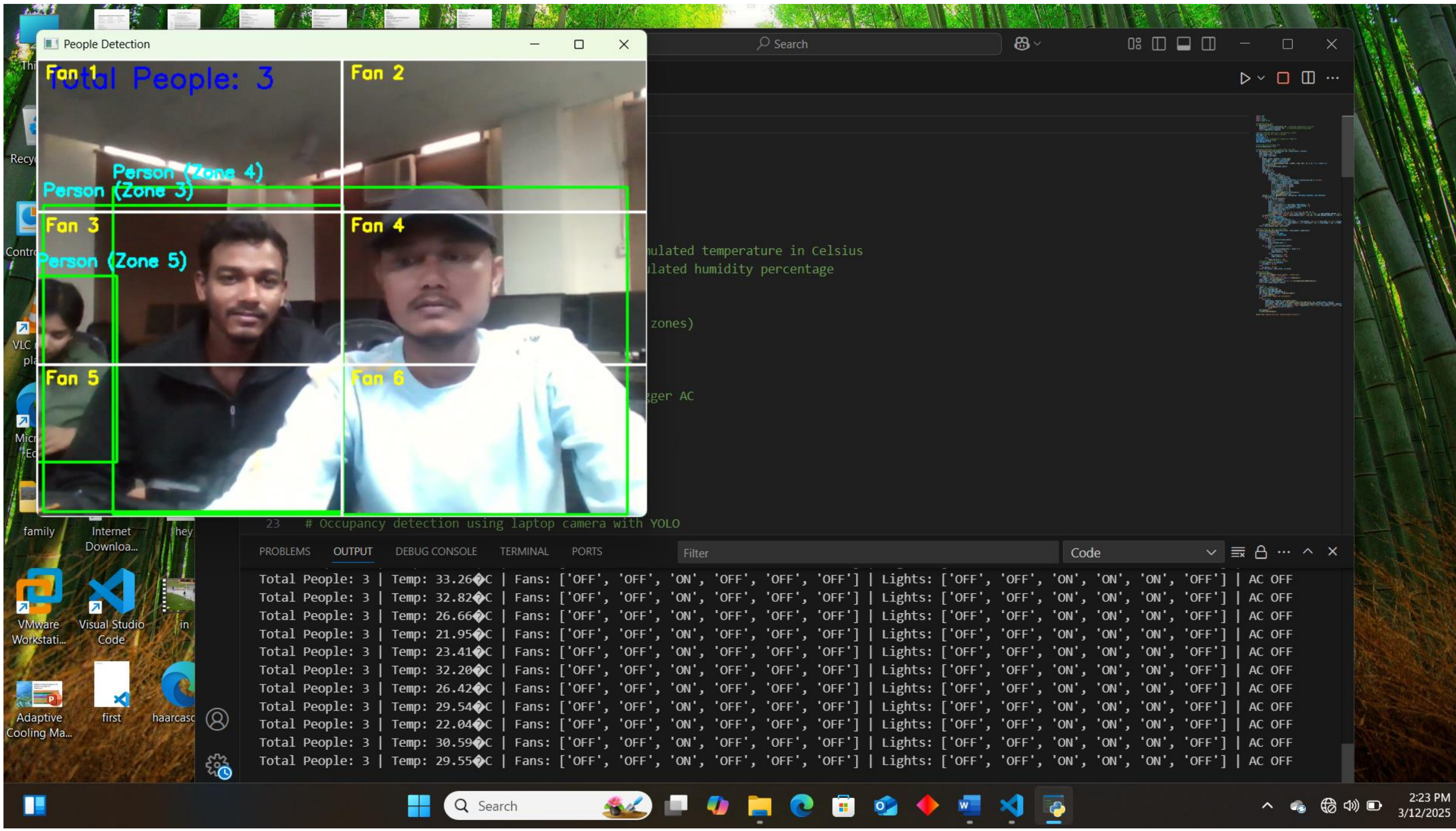
Demonstrate

- • Step 4: Demonstrate camera switching feature (DroidCam, External Webcam).

Explain

- • Step 5: Explain AC control based on occupancy & temperature.

Output



People Detection
Total People: 3
Fan 1
Fan 2
Fan 3
Fan 4
Fan 5
Fan 6
Person (Zone 4)
Person (Zone 3)
Person (Zone 5)
Occupancy detection using laptop camera with YOLO
PROBLEMS
OUTPUT
DEBUG CONSOLE
TERMINAL
PORTS
Total People: 3 | Temp: 33.26�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 32.82�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 26.66�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 21.95�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 23.41�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 32.20�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 26.42�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 29.54�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 22.04�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 30.59�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
Total People: 3 | Temp: 29.55�C | Fans: ['OFF', 'OFF', 'ON', 'OFF', 'OFF', 'OFF'] | Lights: ['OFF', 'OFF', 'ON', 'ON', 'ON', 'OFF'] | AC OFF
2:23 PM
3/12/2025

Conclusion

- Adaptive cooling management helps save energy by cooling only occupied zones
- Real-time person detection enables dynamic device control
- Prototype demonstrates feasibility of zone-based cooling and lighting control
- The system supports multi-camera sources and switching
- Ready for next steps toward full hardware implementation and deployment

Thank You.