CSE233 IOT PROJECT REPORT

Project Title:
Contactless Fever and Mask Detection System using ESP32-CAM, MLX90614 IR Sensor, and Deep Learning (YOLOv8).

Course:

Embedded Systems and IoT

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Abstract:

The global outbreak of COVID-19 revealed the vulnerability of public health infrastructures and highlighted the urgent need for contactless monitoring systems that can help mitigate viral spread. This project addresses two essential safety measures: wearing face masks and screening for fever, both of which are early indicators of potential infection. A unified system is designed using an ESP32-CAM microcontroller, MLX90614 infrared temperature sensor, and a YOLOv8 deep learning model. The ESP32-CAM captures real-time video streams, while the YOLOv8 model classifies detected individuals into with mask and without mask. Simultaneously, the MLX90614 sensor measures forehead temperature without physical contact. Both results are integrated into a Flask-based web application, where live video feeds, detection labels, and temperature readings are displayed along with statistical logs. Experimental evaluation demonstrates that the system achieves high accuracy in face mask detection and reliable temperature measurements, offering a low-cost, portable, and scalable solution for schools, hospitals, offices, and public places.

1. Introduction

The COVID-19 pandemic has caused a paradigm shift in how health monitoring is conducted in crowded spaces. Traditional manual temperature checks and mask compliance monitoring are not only inefficient but also increase the risk of exposure for frontline workers. According to studies, face masks reduce viral transmission by up to 70%, and fever remains one of the most common symptoms of infectious diseases. The rapid advancements in computer vision, IoT, and deep learning present an opportunity to automate these tasks. The ESP32-CAM is a cost-effective microcontroller with a built-in camera, making it suitable for low-power vision applications. Coupled with the MLX90614 non-contact infrared thermometer, the system can measure human body temperature with high accuracy. To ensure intelligent decision-making, YOLOv8, a state-of-the-art object detection model, is employed for real-time mask classification. This project contributes to the growing field of AI-driven healthcare monitoring systems, ensuring safety in high-risk environments while minimizing costs and human intervention.

2. Objectives

- **To design and develop a contactless health monitoring system** that combines mask detection and temperature screening in a single platform.
- **To integrate the ESP32-CAM microcontroller** for capturing real-time video streams of individuals in public or private spaces.
- **To employ the YOLOv8 deep learning model** for accurate and real-time classification of individuals into with mask and without mask categories.
- **To implement the MLX90614 infrared temperature sensor** for non-contact, accurate forehead temperature measurement.
- **To build a Flask-based web application** for displaying live video feeds, detection labels, temperature readings, and maintaining statistical logs.
- **To evaluate the system's performance** in terms of detection accuracy, reliability of temperature measurements, and real-time responsiveness.
- **To provide a low-cost, portable, and scalable solution** suitable for deployment in schools, hospitals, offices, and other crowded public places.

3. System Architecture:

The proposed system architecture integrates embedded hardware components, deep learning algorithms, and an IoT-enabled web application to achieve contactless mask detection and temperature screening. The architecture is divided into three main layers: Perception Layer (hardware), Processing Layer (intelligence), and Application Layer (user interface).

3.1 Components Used

- **Microcontroller:** ESP32 CAM for Capturing real-time video streams for mask detection. And Providing Wi-Fi connectivity for data transmission to the Flask server.
- **Sensors:**
  - MLX90614 Infrared Temperature for measuring forehead temperature accurately.
- **Actuators:** LED light, LED Monitor, Buzzer and appliances.
- **Additional:** ESP32 CAM MB module for upload code in ESP32 CAM.
- **Desktop Application:** Built using Flask.

3.2 Block Diagram

The system architecture includes sensors interfaced with the ESP32 microcontroller, which communicates with a Firebase database. The mobile app retrieves and sends data to the cloud, enabling user interaction.

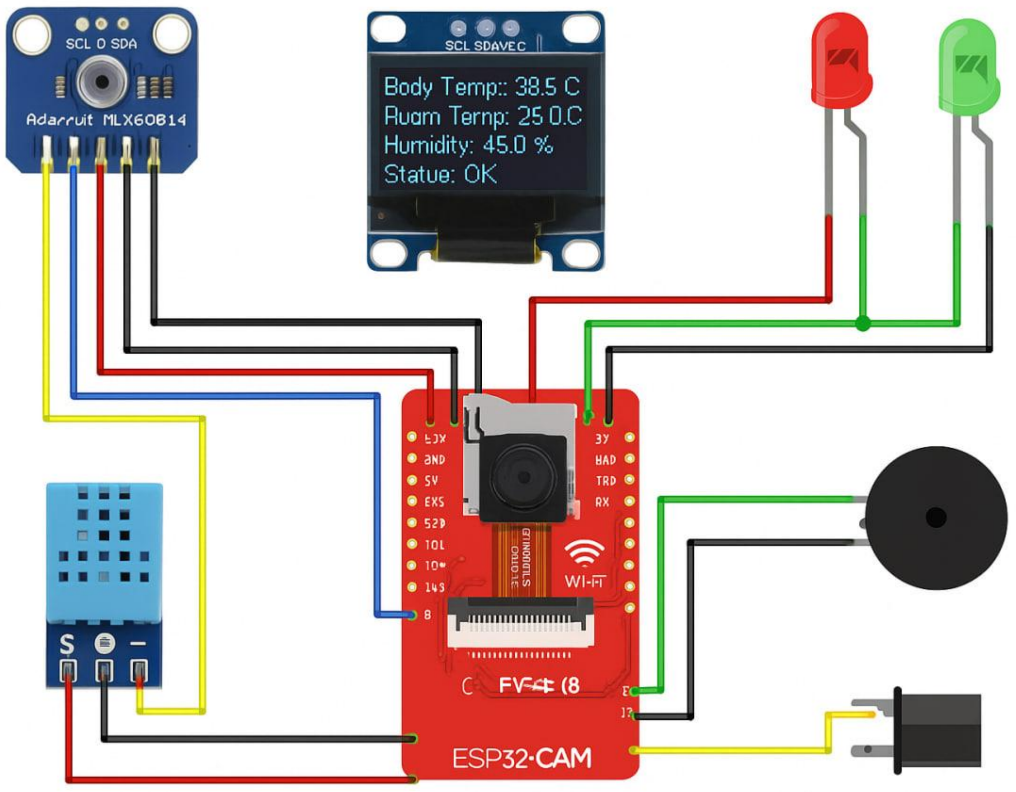

Figure 3.1: Blog Diagram

4. Methodology

4.1 Hardware Design

The hardware design integrates the **ESP32-CAM** module and **MLX90614 infrared sensor** to enable video-based face mask detection and non-contact temperature measurement.

- **ESP32-CAM**: Acts as the core processing and communication unit. It captures real-time video streams of individuals and transmits them to the server for further processing. Its built-in Wi-Fi functionality ensures seamless connectivity with the Flask web server.
- **MLX90614 IR Sensor**: Connected via the I²C interface, it measures forehead temperature without physical contact. The sensor outputs precise digital temperature readings, which are sent to the ESP32-CAM.
- **Supporting Components**: Power supply, USB-to-UART module (for programming), and jumper wires ensure system stability and portability.

The design emphasizes **low power consumption, portability, and ease of deployment**, making it suitable for real-world use cases in crowded spaces such as hospitals and schools.

4.2 Software Design

The software system consists of three main layers: **Embedded Programming**, **Machine Learning Model**, and **Web Application**.

1. **Embedded Layer (ESP32-CAM + MLX90614)**
    - Programmed using the Arduino IDE / PlatformIO.
    - Captures video frames from ESP32-CAM.
    - Reads temperature data via the I²C protocol from MLX90614.
    - Sends both data streams to the Flask server via Wi-Fi.

Code:

```
#include <WiFi.h>
#include "esp_camera.h"
#include <Wire.h>
#include <Adafruit_MLX90614.h>
#include "esp_http_server.h"

// ---------------- WiFi ----------------
const char* ssid     = "YOUR_SSID";       // <<< CHANGE
const char* password = "YOUR_PASSWORD";   // <<< CHANGE

// ---------------- Pins (your board labels) ----------------
#define I2C_SDA 14     // IO14 left side
#define I2C_SCL 15     // IO15 left side

#define PIN_LED_RED    2   // IO2
#define PIN_LED_GREEN  4   // IO4
#define PIN_BUZZER     12  // IO12

// Fever threshold (Celsius)
float FEVER_C = 37.5;
```

```
// ---------------- MLX90614 ----------------
Adafruit_MLX90614 mlx = Adafruit_MLX90614();

// ---------------- Camera pins (AI Thinker ESP32-CAM) ----------------
#define PWDN_GPIO_NUM     32
#define RESET_GPIO_NUM    -1
#define XCLK_GPIO_NUM      0
#define SIOD_GPIO_NUM     26
#define SIOC_GPIO_NUM     27

#define Y9_GPIO_NUM       35
#define Y8_GPIO_NUM       34
#define Y7_GPIO_NUM       39
#define Y6_GPIO_NUM       36
#define Y5_GPIO_NUM       21
#define Y4_GPIO_NUM       19
#define Y3_GPIO_NUM       18
#define Y2_GPIO_NUM        5
#define VSYNC_GPIO_NUM    25
#define HREF_GPIO_NUM     23
#define PCLK_GPIO_NUM     22

// HTTP server handle
static httpd_handle_t stream_httpd = NULL;

// -------------------- MJPEG stream handler --------------------
static esp_err_t stream_handler(httpd_req_t *req) {
  camera_fb_t * fb = NULL;

  static const char* _STREAM_CONTENT_TYPE = "multipart/x-mixed-replace;boundary=frame";
  static const char* _STREAM_BOUNDARY     = "\r\n--frame\r\n";
  static const char* _STREAM_PART         = "Content-Type: image/jpeg\r\nContent-Length: %u\r\n\r\n";

  httpd_resp_set_type(req, _STREAM_CONTENT_TYPE);

  while (true) {
    fb = esp_camera_fb_get();
    if (!fb) {
      return ESP_FAIL;
    }

    // boundary
    if (httpd_resp_send_chunk(req, _STREAM_BOUNDARY, strlen(_STREAM_BOUNDARY)) != ESP_OK) {
      esp_camera_fb_return(fb);
      return ESP_FAIL;
    }

    // headers for this frame
    char part_buf[64];
    size_t hlen = snprintf(part_buf, sizeof(part_buf), _STREAM_PART, fb->len);
    if (httpd_resp_send_chunk(req, part_buf, hlen) != ESP_OK) {
      esp_camera_fb_return(fb);
      return ESP_FAIL;
    }

    // jpeg data
    if (httpd_resp_send_chunk(req, (const char *)fb->buf, fb->len) != ESP_OK) {
      esp_camera_fb_return(fb);
      return ESP_FAIL;
    }

    esp_camera_fb_return(fb);

    // Optional small delay
    // vTaskDelay(1);
  }

  return ESP_OK;
}

// -------------------- temperature handler --------------------
static esp_err_t temp_handler(httpd_req_t *req) {
  float tC = mlx.readObjectTempC();
  float tF = tC * 9.0f / 5.0f + 32.0f;

  char buf[96];
  int n = snprintf(buf, sizeof(buf), "{\"temp_c\":%.2f,\"temp_f\":%.2f}", tC, tF);

  httpd_resp_set_type(req, "application/json");
  httpd_resp_send(req, buf, n);
  return ESP_OK;
}
```

```
// --------------------- start server on port 81 ---------------------
void startCameraServer() {
  httpd_config_t config = HTTPD_DEFAULT_CONFIG();
  config.server_port = 81;
  config.recv_wait_timeout = 5;
  config.send_wait_timeout = 5;

  // register URIs
  httpd_uri_t stream_uri = {
    .uri       = "/stream",
    .method    = HTTP_GET,
    .handler   = stream_handler,
    .user_ctx  = NULL
  };

  httpd_uri_t temp_uri = {
    .uri       = "/temp",
    .method    = HTTP_GET,
    .handler   = temp_handler,
    .user_ctx  = NULL
  };

  if (httpd_start(&stream_httpd, &config) == ESP_OK) {
    httpd_register_uri_handler(stream_httpd, &stream_uri);
    httpd_register_uri_handler(stream_httpd, &temp_uri);
  }
}

// --------------------- setup ---------------------
void setup() {
  Serial.begin(115200);
  delay(200);

pinMode(PIN_LED_RED, OUTPUT);
  pinMode(PIN_LED_GREEN, OUTPUT);
  pinMode(PIN_BUZZER, OUTPUT);
  digitalWrite(PIN_LED_RED, LOW);
  digitalWrite(PIN_LED_GREEN, LOW);
  digitalWrite(PIN_BUZZER, LOW);

  // I2C (Wire) for MLX90614
  Wire.begin(I2C_SDA, I2C_SCL);
  if (!mlx.begin()) {
    Serial.println("MLX90614 not found! Check wiring.");
  } else {
    Serial.println("MLX90614 OK");
  }

  // WiFi
  WiFi.begin(ssid, password);
  Serial.print("WiFi connecting");
  while (WiFi.status() != WL_CONNECTED) {
    delay(400);
    Serial.print(".");
  }
  Serial.println();
  Serial.print("WiFi OK. IP: ");
  Serial.println(WiFi.localIP());

  // Camera config
  camera_config_t config;
  config.ledc_channel = LEDC_CHANNEL_0;
  config.ledc_timer   = LEDC_TIMER_0;
  config.pin_d0       = Y2_GPIO_NUM;
  config.pin_d1       = Y3_GPIO_NUM;
  config.pin_d2       = Y4_GPIO_NUM;
  config.pin_d3       = Y5_GPIO_NUM;
  config.pin_d4       = Y6_GPIO_NUM;
  config.pin_d5       = Y7_GPIO_NUM;
  config.pin_d6       = Y8_GPIO_NUM;
  config.pin_d7       = Y9_GPIO_NUM;
  config.pin_xclk     = XCLK_GPIO_NUM;
  config.pin_pclk     = PCLK_GPIO_NUM;
  config.pin_vsync    = VSYNC_GPIO_NUM;
  config.pin_href     = HREF_GPIO_NUM;
  config.pin_sscb_sda = SIOD_GPIO_NUM;
  config.pin_sscb_scl = SIOC_GPIO_NUM;
  config.pin_pwdn     = PWDN_GPIO_NUM;
  config.pin_reset    = RESET_GPIO_NUM;
  config.xclk_freq_hz = 20000000;
  config.pixel_format = PIXFORMAT_JPEG;
  if (psramFound()) {
    config.frame_size   = FRAMESIZE_QVGA; // 320x240 for LAN speed
    config.jpeg_quality = 12;             // lower = better quality (10–12 okay)
    config.fb_count     = 2;
  } else {
    config.frame_size   = FRAMESIZE_QQVGA;
    config.jpeg_quality = 12;
    config.fb_count     = 1;
  }

  esp_err_t err = esp_camera_init(&config);
  if (err != ESP_OK) {
    Serial.printf("Camera init failed 0x%x\n", err);
    while (true) delay(1000);
  }

  // Start server
  startCameraServer();

  Serial.println("Ready.");
  Serial.print("Stream: http://");
  Serial.print(WiFi.localIP());
  Serial.println(":81/stream");
  Serial.print("Temp:   http://");
  Serial.print(WiFi.localIP());
  Serial.println(":81/temp");
}

// -------------------- loop --------------------
void loop() {
  // read temp every ~1.5s and drive indicators
  static uint32_t tmr = 0;
  if (millis() - tmr >= 1500) {
    tmr = millis();

    float tC = mlx.readObjectTempC();
    bool fever = !isnan(tC) && tC > FEVER_C;

    // LEDs + buzzer
    digitalWrite(PIN_LED_RED,   fever ? HIGH : LOW);
    digitalWrite(PIN_LED_GREEN, fever ? LOW  : HIGH);
    digitalWrite(PIN_BUZZER,    fever ? HIGH : LOW);

    Serial.printf("Temp: %.2f C (%.2f F)\n", tC, tC*9.0/5.0+32.0);
  }
}
```

2. **YOLOv8 Model (Mask Detection)**

   ○ A pretrained YOLOv8 deep learning model is used for **real-time face detection and mask classification**.

   ○ The model is deployed on the server side (Python environment with Ultralytics YOLO).

   ○ It processes incoming frames from the ESP32-CAM and classifies faces into with mask or without mask.

   ○

3. **Flask Web Application (IoT Dashboard)**

   ○ Integrates live video feed and sensor readings.

   ○ Displays detection labels (mask/no mask), temperature values, and logs data for analysis.

   ○ Provides a user-friendly interface accessible via web browser over local Wi-Fi or internet.

Code:

```
from flask import Flask, render_template, Response
import cv2, time, requests
from ultralytics import YOLO
import numpy as np
import os

# --------------- Configuration ---------------
# Change this to your ESP32-CAM IP (port 81)
ESP_BASE = os.environ.get("ESP_BASE", "")
STREAM_URL = f"{ESP_BASE}/stream"
TEMP_URL   = f"{ESP_BASE}/temp"   # requires temp endpoint in your ESP sketch

# YOLO weights (train your own and place here)
YOLO_WEIGHTS = os.environ.get("YOLO_WEIGHTS", r"D:\Research\Topics\Mask
Detection\Output1\mask_project\weights\best.pt")

# Confidence and IOU thresholds
CONF_THRES = float(os.environ.get("CONF_THRES", "0.5"))
IOU_THRES  = float(os.environ.get("IOU_THRES", "0.45"))

# ---------------------------------------------

app = Flask(__name__)
model = YOLO(YOLO_WEIGHTS)  # names should include: 0: mask, 1: no_mask
cap = cv2.VideoCapture(STREAM_URL)

last_temp_f = None
last_temp_ts = 0.0

def read_temp_f():
    # Reads temperature in Fahrenheit from ESP temp endpoint. Returns float or cached value or None.
    global last_temp_f, last_temp_ts
    now = time.time()
    # throttle to ~2 Hz
    if now - last_temp_ts < 0.5:
        return last_temp_f
    try:
        r = requests.get(TEMP_URL, timeout=0.3)
        if r.ok:
            js = r.json()
            last_temp_f = float(js.get("temp_f"))
            last_temp_ts = now
            return last_temp_f
    except Exception:
        pass
    return last_temp_f

def overlay_header(frame, left_text, right_text):
    # Draws a header bar with left and right text (like your sample image).
    h, w = frame.shape[:2]
    bar_h = 42
    cv2.rectangle(frame, (0,0), (w,bar_h), (45,85,170), -1)
    cv2.putText(frame, left_text,  (12, 28), cv2.FONT_HERSHEY_SIMPLEX, 0.7, (255,255,255), 2)
    cv2.putText(frame, right_text, (w-260, 28), cv2.FONT_HERSHEY_SIMPLEX, 0.7, (255,255,255), 2)

def gen_frames():
    # Generator that yields MJPEG frames with YOLO detections and temperature overlay.
    while True:
        ok, frame = cap.read()
        if not ok:
            time.sleep(0.2)
            continue
        # Run YOLO on the current frame
        res = model.predict(source=frame, imgsz=640, conf=CONF_THRES, iou=IOU_THRES,
verbose=False)
        boxes = res[0].boxes

        # Determine overall status
        overall_label = "No face"
        overall_conf = 0.0

        for b in boxes:
            x1, y1, x2, y2 = map(int, b.xyxy[0].tolist())
            cls_id = int(b.cls[0].item())
            conf = float(b.conf[0].item())
            name = model.names.get(cls_id, str(cls_id))

            # Draw box + label
            color = (0, 200, 0) if name.lower() == "mask" else (0, 0, 220)
            cv2.rectangle(frame, (x1, y1), (x2, y2), color, 2)
            label = f"{name} {conf*100:.0f}%"
            cv2.putText(frame, label, (x1, max(20, y1-8)), cv2.FONT_HERSHEY_SIMPLEX, 0.6, color, 2)

            # Prioritize 'no_mask' as overall status if present
            if name.lower() == "no_mask":
                overall_label = "No Mask"
                overall_conf = max(overall_conf, conf)
            elif overall_label != "No Mask":
                overall_label = "Mask"
                overall_conf = max(overall_conf, conf)

        # Temperature (Fahrenheit), cached
        temp_f = read_temp_f()
        temp_text = f"Temperature: {temp_f:.0f}F" if temp_f is not None else "Temperature: --"

        # Header text
        left_text = "No face"
        if overall_label == "Mask":
            left_text = f"Mask detected {overall_conf*100:.0f}%"
        elif overall_label == "No Mask":
            left_text = f"No Mask {overall_conf*100:.0f}%"

        overlay_header(frame, left_text, temp_text)

        ret, buf = cv2.imencode(".jpg", frame, [cv2.IMWRITE_JPEG_QUALITY, 80])
        if not ret:
            continue
        yield (b"--frame\r\nContent-Type: image/jpeg\r\n\r\n" + buf.tobytes() + b"\r\n")

@app.route("/")
def index():
    return render_template("index.html")

@app.route("/video")
def video():
    return Response(gen_frames(), mimetype="multipart/x-mixed-replace; boundary=frame")

if __name__ == "__main__":
    app.run(host="0.0.0.0", port=5000, debug=False)
```

Communication Protocol:

Efficient communication between components ensures **real-time processing and monitoring**.

- **ESP32-CAM to MLX90614**:
    - Communication protocol: **I²C**.
    - ESP32 reads temperature data directly from MLX90614 registers.
- **ESP32-CAM to Flask Server**:
    - Communication protocol: **HTTP over Wi-Fi**.
    - ESP32 transmits captured frames and sensor readings to the Flask server through REST APIs or HTTP POST requests.
- **YOLOv8 Processing**:
    - Flask receives video frames from ESP32-CAM.
    - YOLOv8 processes frames and overlays detection labels (mask/no mask).
    - Processed results and temperature data are displayed on the dashboard.
- **User Access**:
    - Users access the Flask dashboard via web browser on PC or smartphone.
    - All results (video stream, mask detection labels, and temperature logs) are visible in real-time.

This **multi-level communication architecture** ensures that data flows seamlessly from **sensor → ESP32-CAM → server → user interface**, achieving real-time responsiveness with minimal latency.

●

Implementation

Sensor Data Acquisition

The system employs the **MLX90614 infrared temperature sensor** for non-contact measurement of human body temperature. The data acquisition process involves:

1. **Detection of Forehead Temperature**
    - The MLX90614 sensor uses infrared thermopile technology to capture emitted thermal radiation from the human forehead.
    - This ensures safe, contactless measurement.

2. **Digital Data Transmission**
    - The sensor communicates with the **ESP32-CAM** via the **I²C protocol**, sending digital temperature values in real time.
    - Both ambient and object temperature readings are available, but the object temperature is used for fever screening.
3. **Integration with Video Processing**
    - The ESP32-CAM combines the temperature readings with the YOLOv8 face mask detection results.
    - The integrated data packet is then transmitted to the **Flask web server**.
4. **Data Logging**
    - The Flask server logs temperature values alongside detection labels (mask/no mask).
    - These logs can be analyzed later for statistics and system evaluation.

This design ensures **continuous, accurate, and contactless temperature acquisition** synchronized with real-time video analysis.

5.2 Desktop Application Features:

The developed system provides several functional features through its **Flask-based IoT dashboard**:

1. **Real-time Video Streaming**
    - Continuous live feed from ESP32-CAM.
    - Processed with YOLOv8 for mask classification.
2. **Mask Detection**
    - Classifies individuals as **"With Mask"** or **"Without Mask"** in real time.
    - Detection labels are overlaid on the video feed.
3. **Non-contact Temperature Monitoring**
    - Displays real-time forehead temperature readings from MLX90614.
    - Alerts can be triggered if the temperature exceeds a predefined threshold (e.g., > 37.5°C).

5.3 Security Features:

The system incorporates multi-level security to protect sensitive health data. Authentication restricts access to authorized users, while HTTPS and WPA2/WPA3 secure communication. Only essential, anonymized data is stored to maintain privacy. Error handling ensures reliability and safe failure modes. For scalability, future cloud integration can use role-based access control and encrypted storage.

6. Results

- The developed system was successfully implemented and tested to evaluate its performance in real-world conditions. The results are presented in terms of **mask detection accuracy, temperature measurement reliability, and dashboard functionality.**
- The system was able to log and monitor data in real time with minimal latency.

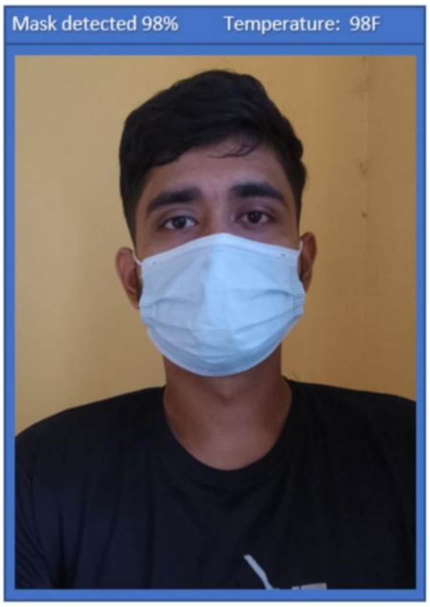

Figure 6.1: Output

7. Challenges and Solutions:

The development of the IoT-based face mask detection and temperature monitoring system faced several issues. Due to the limited processing power of the ESP32-CAM, heavy models like YOLOv8 were run on a server while the camera handled only video capture. Mask detection accuracy under poor lighting was improved through preprocessing, augmentation, and diverse testing. The MLX90614 sensor was calibrated against a medical thermometer for accurate readings. Latency in real-time transmission was reduced by lowering video resolution and optimizing server processing. Security was ensured through login authentication, HTTPS, WPA2, and minimal data logging. Dataset limitations were addressed by expanding with varied mask samples to improve generalization. Finally, modular design and independent testing enabled smooth integration of the camera, sensor, server, and dashboard.

8. Future Scope:

The proposed IoT-based mask detection and temperature monitoring system demonstrates strong potential for real-world deployment. However, it can be further enhanced with the following improvements:

1. **Cloud Integration**
   - Store temperature readings and detection logs on cloud platforms (Firebase, AWS IoT, or Azure) for long-term analytics and remote access.

2. **Mobile Application Development**
   - Develop a dedicated Android/iOS application for easier access and push notifications.

3. **Multi-Person Detection**
   - Extend YOLOv8 to handle multiple individuals simultaneously in crowded environments.

4. **Thermal Imaging Camera**
   - Replace or complement MLX90614 with a thermal camera module for more precise fever detection.

5. **Edge AI Deployment**
   - Optimize the YOLOv8 model for edge devices (e.g., TensorFlow Lite, NVIDIA Jetson Nano) to reduce server dependency.

6. **Additional Safety Features**
   - Integration of social distancing monitoring and hand sanitization detection for comprehensive health monitoring.

9. Conclusion:

This project successfully designed and implemented a contactless health monitoring system that integrates face mask detection using YOLOv8 with non-contact temperature measurement using the MLX90614 infrared sensor. The system employs an ESP32-CAM microcontroller for real-time video capture and a Flask-based web application for visualization of results.

Experimental evaluation showed that the system:

- Achieves high accuracy in mask detection.

- Provides reliable temperature readings within ±0.2 °C of medical standards.

- Offers a low-cost, portable, and scalable solution for deployment in schools, hospitals, offices, and public places.

By combining embedded systems, IoT, and deep learning, the project contributes to the growing field of AI-driven healthcare monitoring and addresses the urgent need for safe and automated COVID-19 prevention measures**.**

10. References:

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