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AI-Based Crowd Density Estimation and Prediction Using Raspberry pi-5

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Abstract **- Ensuring public safety at large gatherings requires real-time crowd density estimation and risk monitoring. This project leverages artificial intelligence (AI) and sensor-based technologies to estimate crowd density and assess security risks during public events. Using datasets, cameras, infrared (IR) sensors, ultrasonic sensors, and Raspberry Pi 5, the system provides accurate and real-time monitoring.**

The system processes live video footage from cameras and combines it with sensor data to estimate crowd density dynamically. AI algorithms analyze the data, detecting anomalies such as overcrowding or unusual movement patterns that may indicate security threats. Infrared and ultrasonic sensors enhance accuracy by measuring crowd proximity and density variations in low-visibility conditions.

A desktop-based interface visualizes real-time data, alerting event organizers and security personnel to potential risks. A servo motor controls mechanical responses, such as automated barriers or alarms, triggered by predefined security thresholds. The SD card stores recorded data for post-event analysis and improving future security protocols.

The buzzer provides instant audible alerts when security thresholds are exceeded, ensuring rapid response to critical situations. Raspberry Pi 5, acting as the central processing unit, integrates all components and runs AI-based algorithms efficiently. This system enhances public safety by providing intelligent, automated crowd monitoring and risk assessment, ensuring well-coordinated security measures for large-scale events.

Keywords: Datasets, IR sensor, Ultrasonic sensor, SD card, Buzzer, desktop, servomotor, rasberry pi5.

I. INTRODUCTION

Large public gatherings, such as concerts, festivals, and sporting events, pose significant security challenges due to uncontrolled crowd movement, congestion, and potential security threats. Traditional crowd management methods rely on manual surveillance, which is often inefficient and prone to human error.The need for an automated, real-time crowd density estimation and security monitoring system has become crucial for ensuring public safety.

This paper presents an AI-based crowd density estimation and security risk monitoring system that integrates multiple sensors and computing technologies to enhance event security. Using Raspberry Pi 5 as the central processing unit, the system collects real-time data from cameras, infrared (IR) sensors, and ultrasonic sensors to estimate crowd density accurately. AI-driven algorithms analyze the collected data to detect overcrowding, unusual movement patterns, and potential security threats.

The system features a desktop-based interface for real-time visualization and alerts. Security personnel receive notifications through an integrated buzzer when crowd density surpasses a critical threshold, allowing for immediate intervention. Additionally, a servomotor mechanism can trigger automated security responses, such as opening or closing gates based on crowd movement. An SD card is used for data storage, enabling post-event analysis and improving future security strategies.

By leveraging AI and IoT-based technologies, this system offers a scalable and efficient solution for crowd monitoring, reducing the risks associated with large gatherings. The proposed approach aims to improve situational awareness, enhance response times, and ensure a safer environment for event attendees.

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II. EXISTING SYSTEM

1. Camera-Based Crowd Density Estimation

Advanced computer vision techniques, particularly Convolutional Neural Networks (CNNs), are widely used for analyzing video feeds to estimate crowd density. A notable approach is the lightweight crowd density estimation model (LCDnet), designed specifically for real-time video surveillance. This model strikes a balance between accuracy and computational efficiency, making it ideal for deployment on edge devices with limited processing power.[Source: dl.acm.org]

2. Raspberry Pi and OpenCV Implementations

The Raspberry Pi, combined with OpenCV, has been effectively utilized to create cost-efficient crowd monitoring systems. One such implementation detects and counts individuals in a crowd by analyzing head movements. The system captures video, processes it to identify heads, and keeps track of people entering or exiting a specific area.[Source: link.springer.com]

3. Sensor-Based Approaches

Integrating infrared (IR) and ultrasonic sensors enhances crowd density estimation, especially in situations where visual data alone may not be sufficient. While AI-based crowd monitoring using these sensors is still emerging, the general approach involves using ultrasonic sensors to measure distances and detect obstacles, indirectly estimating crowd presence and density. Meanwhile, IR sensors detect heat signatures, helping to identify individuals in low-visibility conditions. These sensors can be integrated with microcomputers like the Raspberry Pi for data collection and processing.

4. Combined Sensor and AI Approaches

A more robust system combines camera data processed by AI models with additional insights from IR and ultrasonic sensors. This multimodal approach improves accuracy in crowd density estimation and security monitoring. Cameras provide detailed information on crowd size and movement patterns, IR sensors detect individuals in low-light conditions, and ultrasonic sensors measure proximity to identify obstacles. The Raspberry Pi 5 serves as the central processing hub, collecting data from these sensors, executing AI algorithms, and triggering alerts via buzzers or other actuators when security risks are detected.

For effective deployment, such a system requires strategic sensor placement, optimized data fusion techniques, and real-time processing capabilities to ensure accurate crowd monitoring and prompt response to potential threats.

III. PROPOSED SYSTEM

The proposed AI-based crowd density estimation and event security system utilizes real-time data acquisition, image processing, and sensor-based analysis to ensure safety at large public gatherings. At its core, the system employs a Raspberry Pi 5 as the central processing unit, interfacing with a camera, IR sensor, ultrasonic sensor, and other essential components. By integrating computer vision, deep learning, and IoT-based sensor fusion, the system delivers precise and real-time insights into crowd movement and potential security threats.

The system functions by capturing live video footage through a camera module, which is then processed using pre-trained deep learning models to estimate crowd density. The AI model, trained on diverse datasets, performs crowd counting by analyzing key features such as head detection, body segmentation, and movement patterns. To enhance accuracy, IR and ultrasonic sensors work alongside the camera to detect obstacles, unusual movement, or unauthorized access in restricted areas. These sensors provide continuous real-time data to the Raspberry Pi, enabling immediate analysis and response.

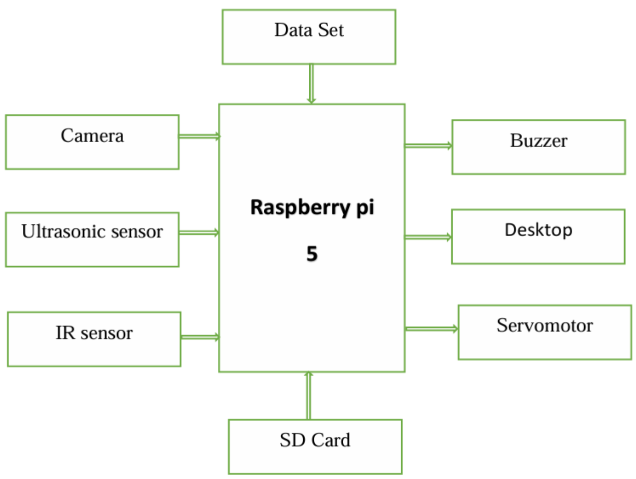

Figure 1: Block Diagram

For proactive security management, the system incorporates an SD card for data storage and logging, while an integrated buzzer triggers alerts when potential threats arise, such as overcrowding, stampede risks, or suspicious behaviour. A servo motor may also be implemented to adjust the camera's position dynamically, ensuring broader coverage of the event area. The entire setup is monitored via a desktop interface, where security personnel can access live crowd

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analytics, receive real-time alerts, and take necessary actions to mitigate risks effectively.

By combining AI-driven crowd density estimation with multi-sensor integration, this system significantly enhances situational awareness and facilitates a swift response to security concerns. Its automated approach not only strengthens event safety measures but also optimizes resource allocation for efficient crowd management, making it a vital tool for ensuring public safety at large-scale events.

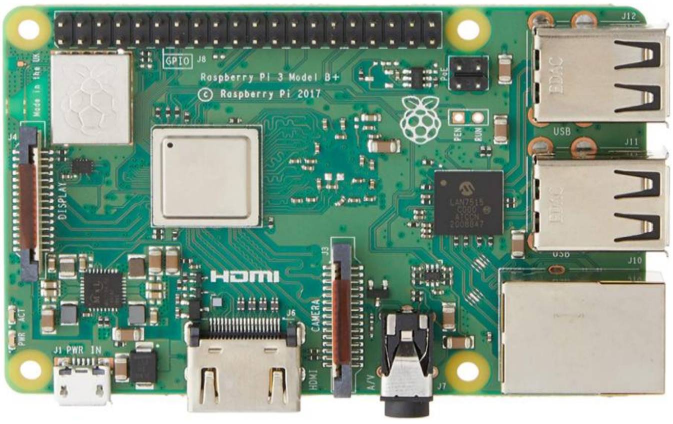

Figure 2: Raspberry pi-5

Raspberry Pi is a small single-board Computer developed in UK by Raspberry Pi foundation to promote the teaching of computer science in schools and in developing acountries.

Original model become far more popular than anticipated sealing outside of its target market, for uses such as robots.

Features

The heart of the Raspberry Pi is a Broadcom System on Chip (SOC) which includes ARM compatible CPU and on-chip graphic processing unit and Videocore IV.

The key feature from First generation to the Third generation includes:

- CPU speed ranges from 700 MHz to 1.2 GHz.
- On board Memory (RAM) ranges from 256 MB to 1 GB.
- USB slot differs from 1 slot to USB slots.
- HDMI, composite video output and 3.5mm phone jack.
- Low level output is provided by GPIO pins which support common protocols like I2C (inter-integrated circuit).
- Ethernet 8 Position 8 Contact (8P8C).

Processor

The processor at the heart of the Raspberry Pi is a Broadcom BCM28XX.

This is the Broadcom System on Chip (SOC) chip use in the Raspberry Pi. The processor from first to third generations include:

- Raspberry Pi 1: Broadcom BCM2835 SOC with 700MHz CPU speed, L2 cache of 128kb with ARM compatibility AR1176JZF-S (ARMv6) 32-bit RISC ARM.
- Raspberry Pi 2: Broadcom BCM 2836 SOC with 900MHz CPU speed, L2 cache of 256kb with 32-bit quad-core ARM cortex-A7 (ARMv7).
- Raspberry Pi 3: Broadcom BCM2837 SOC with 1.2GHz 64-bit quad-core –A53 with 512 kb shared L2 cache (64-bit instruction set ARMv8).

1) Raspberry Pi Configuration

Setting up Raspberry Pi

As said earlier Raspberry Pi comes without any peripheral devices. The first thing to do is to unpack RasPi and protect it with an enclosure (Figure 3). Raspberry Pi can be installed to the protective enclosure without using any tools. The enclosure has plastic clips which are holding the Raspberry Pi in its place.

After Raspberry Pi has been installed to enclosure and well protected, all the neccessary peripherals can be attached to it. Just like any other computer, Raspberry Pi needs some basic devices such as display which is connected via the HDMI cable, the mouse and the keyboard, and the internet connection cable.

Before plugging the power cable, MicroSD-card should be checked if it is flashed and prepared with an operating system. Also it is recommendable to create a backup folder of the MicroSD-card just in case of complications.

The MicroSD-card can be checked with a card-reader. The card-reader can be found from most of the laptops and desktop computers. Insert the MicroSD-card into the card-reader and check that there is something stored in the MicroSD-card. If everything looks good, take the MicroSD-card and plug it into the Raspberry Pi. Now the power cable can be connected.

Raspberry Pi does not have any kind of power switch so it will start up immediately when the power cable is connected to it. At the start up text starts to flow on the monitor and shortly after that there appears a configuration menu. The configuration menu is called Raspi-config (Figure 4). In Raspi-config it is possible to change some of the settings on Raspberry.

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Figure 3: Raspberry pi software configuration Tool

The most important settings that should be checked in Raspi-config are:

- Expand File system, where it is necessary to check that Raspi can use the whole memory capacity of the MicroSD-card. Otherwise the memory can run out fast.
- Internationalisation Options, where it is possible to choose between different languages and the time zones.
- Advanced Options, if the internet cable has been plugged in, it is possible to update RasPi to the latest version available. (McManus, S. & Cook, M. 2013, 38.)

It is recommendable that users who do not have so much experience with Linux operating systems should choose the English language because then help and advice can be found more easily from the internet.

It is possible to get back to the Raspi-config and change the settings also after the first setup by typing the following command into the terminal:

Sudoraspi-config

After making the changes on the Raspberry Pi's settings, the settings can be accepted by choosing the Finish option. Now the terminal view should appear and it might be asking for the username and the password. The username in Raspian Wheezy is by default pi and the password should be raspberry. Notice that these are written in small letters. The Linux is letter case sensitive and it will recognize the difference between small and capital letters.

The next step is logging in to Raspberry and instead of the graphical environment there will be a command console flashing. However, the graphical environment, or so called desktop view, can be started by entering the command:

Startx

Now Raspberry will be loading for a while and a few seconds later there will ap-pear a more user friendly desktop view. It is recommended to learn how to use the command console as it makes some of the actions faster than doing them in the desktop view.

So far the basic configurations are made for the Raspberry. There might still be some things that are not working correctly. For instance, the keyboard layout might be defined to be in UK style which is the default keyboard layout setting on Rasp-berry Pi. This can be frustrating and annoying. The layout can be changed easily by opening the LXTerminal which opens the command console. Open the key-board file in the command console with the nano text editor by typing the following command:

sudo nano /etc/default/keyboard

The keyboard configuration file (Figure 5) will appear and it can be modified. The keyboard layout can be changed by replacing the XKBLAYOUT value as shown in Figure 5. After the file is edited it can be saved by pressing CTRL + O key combi-nation.

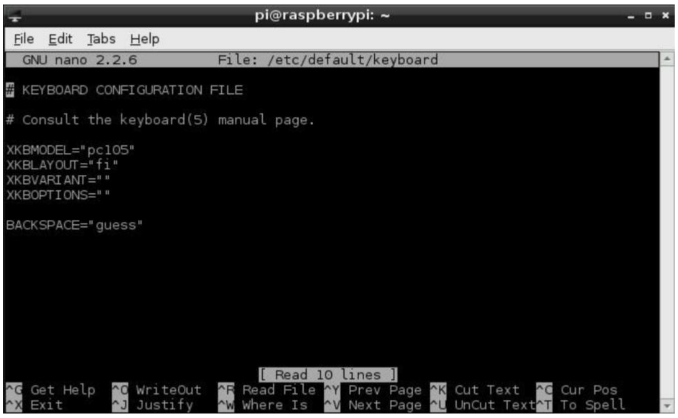

Figure 4: Keyboard configuration file

The keyboard configuration, setting the layout to the Finnish "fi"

Controlling the GPIO pins with Python

This chapter discovers the GPIO connector and how it can be used in controlling. The first experiments with the GPIO were to light up a LED (light-emitting diode) through the Python Shell.

The second experiment is little bit more complex and it demonstrates the control-ling loop of an heating element. The heating element will start to heat the room when room's temperature is getting below the pre-defined lower limit and stops heating when the temperature in the room reaches the second pre-defined upper limit.

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Controlling the LED with the GPIO

This is the first experiment with the GPIO connector and it demonstrates how to use it in controlling. This experiment requires a LED and a resistor. The resistor's resistance can be calculated from the Ohm's law which is shown in Formula 1.

Defining the resistance from the Ohm's law:

$$U = R * I \qquad (1)$$

$$R = \frac{U}{I} = \frac{3.3V_{GPIO\ voltage} - 1.18V_{LED\ voltage\ drop}}{10mA_{LED\ current}} = 212\ \Omega \qquad (2)$$

Where

· U is voltage
· R is resistance
· I is current

The resistors above 212 Ω are suitable and can be used for lightning the LED directly from the GPIO.

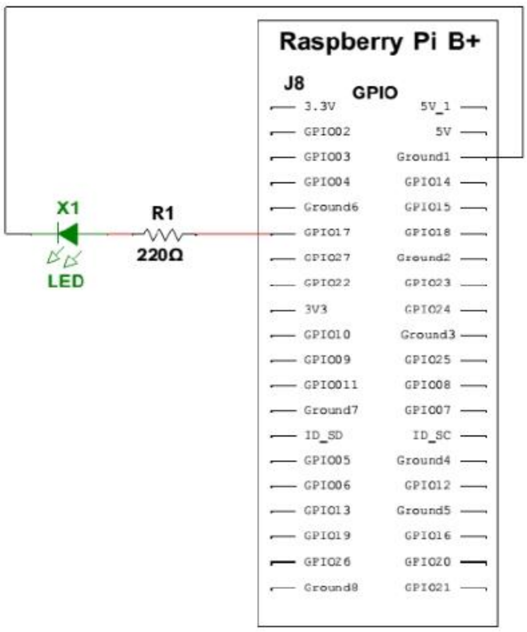

Figure 5: Raspberry pi B+

After the wirings are done the Python library called python-rpi.gpio needs to be installed. This library allows controlling the GPIO pins. It can be installed with the following command:

sudo apt-get install python-rpi.gpio

When the installation is finished, open up a Python Shell from the terminal as root user and import the RPi.GPIO library.

import RPi.GPIO as GPIO

Next thing to do is to set the mode to use the pin numbers from the ribbon cable board and define one of the GPIO pins to be an output. For instance the GPIO 17:

GPIO.setmode(GPIO.BCM) # Ribbon cable board

GPIO.setup(17, GPIO.OUT) # Defines the GPIO17 to be output

Now it is possible to control the GPIO17 pin to high and low. The LED will light up when the pin 17 is set to high and when it is set to low the LED will turn off.

GPIO.output(17, GPIO.HIGH) # Turns the GPIO17 to high

GPIO.output(17, GPIO.LOW) # Turns the GPIO17 to low

Taking advantage of Raspberry Pi's camera module

This chapter is about the Pi NoIR camera module's installation to the Raspberry Pi, and observing the built in functions which are made for it. At the end of this chapter a Python script is created to take resized pictures. The pictures are named with current timestamp and saved to an own directory.

Installing the Pi NoIR camera module

The Raspberry Pi's NoIR camera module board comes in anti-static plastic bag. It is fast and easy to install. The camera module can be mounted to the protective case's cover, where is reserved slot for the camera. (Figure 12) It is screwed with two small screws, and the ribbon cable is connected to the Raspberry Pi's camera connection port. The connection port is located between the 3.5mm audio jack and the HDMI socket. The connection port's clip has to be pulled up before plugging the camera module's ribbon cable on its place After mounting the camera module, it is required to enable the camera module from the Raspi-config configuration tool and then Raspberry Pi has to be rebooted so that the changes will take effect.

Taking the first pictures and videos with the Pi NoIR camera

In Raspbian there are built in functions for the camera module. With these built in functions it is possible to take pictures and record videos, just to try out proper function of the camera module. One of these built in functions or commands is called “raspistill”.

Raspistill -v -o first_image.jpg

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After typing the command above into terminal a preview window is started up. The preview window is running for 5 seconds, and then Raspberry takes the picture, and saves it to the file called first_image.jpg. Parameters -v stands for verbose information during the run and with the -o parameter it is possible to give filename for the output file.

Other simple and useful parameters which can be added into raspistill command are:

– image width **-w**
– image height **-h**
– image quality **-q**
– flip the image vertically **-vf**
– flip the image horizontally **-hf**
– image rotation **-rot**

A complete parameter list can be found from the RaspiCam documentation. (RaspiCam Documentation. 2013. 5-18.)

Creating a Python script for taking pictures

First things to consider before creating the script which takes the picture and stores it automatically are: where the picture is stored, finding the right parameters for the picture so that the image quality and size does not suffer too much. After a while, some limitations for the pictures are found. The size and quality are reduced to minimize the picture size on the hard drive. The Quality of 75% and the resolution of 1280x720 pixels are sufficient. With these parameters the picture size on the hard drive is around 500KB. That is good starting point, and trade-off be-tween picture quality and available space for picture saving. All the pictures which are taken by the Python script will be saved to the own folder with current timestamp filename. The folder is located at /var/www/camera/. Apache2 is hosting the folder so that the pictures are available on the website.

Creating the script starts with placing the shebang information and importing the necessary libraries. These libraries are datetime, picamera and time.

```
#!/usr/bin/env/ python
import datetime
import picamera
import time
```

On the second step a function called takePicture should be defined. It does not take any input variables. The function consists of three parts. The first part is the general settings, where the location to the saved pictures and the filename are defined.

```
def takePicture():
location="/var/www/camera/" #Location to the files
date=datetime.datetime.now() #Get current date
file_ name=date.Strftime("%Y-%m-%d %H%M") #Format the string
```

The second part of the function is defining the settings for the picture size and it starts also the preview mode.

```
#configuration for the pictures
camera = picamera.PiCamera()
camera.resolution = (1280,720)
camera.Startpreview()
```

In the last part of the function, the preview mode is kept on for a certain time to warm up the camera. After the warm up time, the function captures the picture and saves it to the predefined location. The picture is named with current timestamp. At the end of the script the preview mode is stopped and the camera is closed.

```
time.sleep(2) #Camera warm up time
# Capture the picture and saved it with the current date
camera.capture("%s%s.jpg" % (location,file_name), quality=75)
camera.stop_preview()
camera.close()
```

2) Ultrasonic Sensor

Ultrasonic sensors measure distance by using ultrasonic waves. The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. Ultrasonic Sensors measure the distance to the target by measuring the time between the emission and reception.

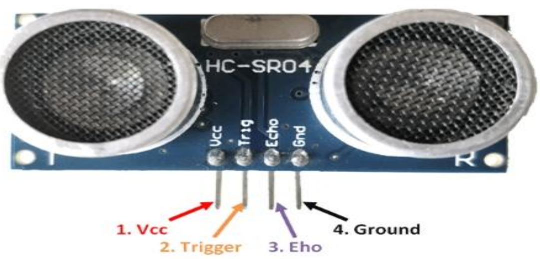

Figure 6: Ultrasonic sensor

An optical sensor has a transmitter and receiver, whereas an ultrasonic sensor uses a single ultrasonic element for both emission and reception. In a reflective model ultrasonic

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sensor, a single oscillator emits and receives ultrasonic waves alternately. This enables miniaturization of the sensor head.

As shown above the HC-SR04 Ultrasonic (US) sensor is a 4 pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eyes like projects in the front which forms the Ultrasonic transmitter and Receiver. The sensor works with the simple high school formula that

Distance = Speed × Time

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets objected by any material it gets reflected back toward the sensor this reflected wave is observed by the Ultrasonic receiver module as shown in the picture below.

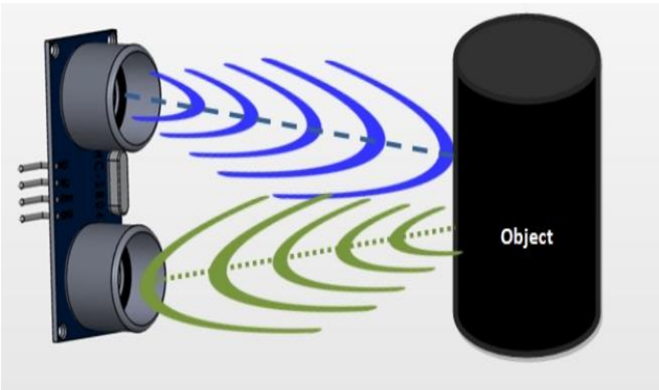

Figure 7: Ultrasonic sensor

Now, to calculate the distance using the above formulae, we should know the Speed and time. Since we are using the Ultrasonic wave we know the universal speed of US wave at room conditions which is 330m/s. The circuitry inbuilt on the module will calculate the time taken for the US wave to come back and turns on the echo pin high for that same particular amount of time, this way we can also know the time taken. Now simply calculate the distance using a microcontroller or microprocessor.

Power the Sensor using a regulated +5V through the Vcc ad Ground pins of the sensor. The current consumed by the sensor is less than 15mA and hence can be directly powered by the on board 5V pins (If available). The Trigger and the Echo pins are both I/O pins and hence they can be connected to I/O pins of the microcontroller. To start the measurement, the trigger pin has to be made high for 10uS and then turned off. This action will trigger an ultrasonic wave at frequency of 40Hz from the transmitter and the receiver will wait for the wave to return. Once the wave is returned after it getting reflected by any object the Echo pin goes high for a particular amount of time which will be equal to the time taken for the wave to return back to the sensor.

The amount of time during which the Echo pin stays high is measured by the MCU/MPU as it gives the information about the time taken for the wave to return back to the Sensor. Using this information the distance is measured as explained in the above heading.

3) IR (Infrared Sensor)

IR sensor is a simple electronic device which emits and detects IR radiation in order to find out certain objects/obstacles in its range. Some of its features are heat and motion sensing.

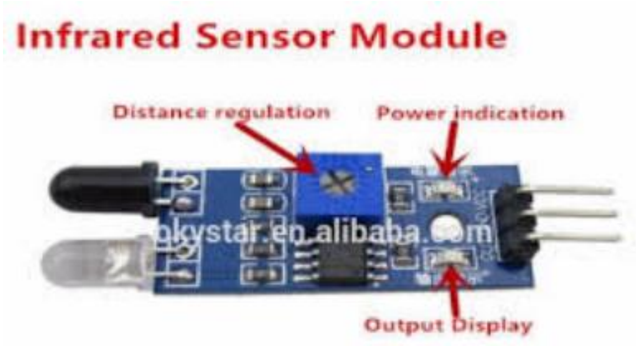

Figure 8: Infrared sensor

IR sensors use infrared radiation of wavelength between 0.75 to 1000µm which falls between visible and microwave regions of electromagnetic spectrum. IR region is not visible to human eyes. Infrared spectrum is categorized into three regions based on its wavelength i.e. Near Infrared, Mid Infrared, Far Infrared.

Wavelength Regions of Infrared Spectrum:

- Near IR – 0.75µm to 3 µm
- Mid IR – 3 µm to 6 µm
- Far IR – > 6 µm

Working Principle of Infrared Sensor

Infrared Sensors works on three fundamental Physics laws:

IR Transmitter

IR Transmitter acts as source for IR radiation. According to Plank's Radiation Law, every object is a source of IR radiation at temp T above 0 Kelvin. In most cases black body radiators, tungsten lamps, silicon carbide, infrared lasers, LEDs of infrared wavelength are used as sources.

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Transmission Medium

As the name suggests, Transmission Medium provides passage for the radiation to reach from IR Transmitter to IR Receiver. Vacuum, atmosphere and optical fibers are used as medium.

IR receiver

Generally IR receivers are photo diode and photo transistors. They are capable of detecting infrared radiation. Hence IR receiver is also called as IR detector. Variety of receivers are available based on wavelength, voltage and package.IR Transmitter and Receivers are selected with matching parameters. Some of deciding specifications of receivers are photosensitivity or responsivity, noise equivalent power and detectivity.

An Infrared Sensor works in the following sequence:

- IR source (transmitter) is used to emit radiation of required wavelength.
- This radiation reaches the object and is reflected back.
- The reflected radiation is detected by the IR receiver.
- The IR Receiver detected radiation is then further processed based on its intensity. Generally, IR Receiver output is small and amplifiers are used to amplify the detected signal.

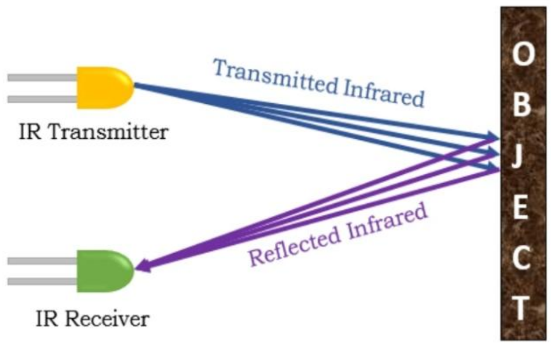

Figure 9: Infrared sensor

Incidence in an IR Detection System may be direct or indirect. In case of Direct Incidence, there is no hindrance in between transmitter and receiver. Whereas, in Indirect Incidence IR Transmitter and Receiver are kept side by side and the object is in front of them.

4) Buzzer

A buzzer or beeper is an audio signalling device, which may be mechanical, electromechanical, or piezoelectric (piezo for short). Typical uses of buzzers and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystro.

Figure 10: Buzzer

A buzzeris a small yet efficient component to add sound features to our project/system. It is very small and compact 2-pin structure hence can be easily used on breadboard, Perf Board and even on PCBs which makes this a widely used component in most electronic applications.

There are two types are buzzers that are commonly available. The one shown here is a simple buzzer which when powered will make a Continuous Beeeeeeppp.... sound, the other type is called a readymade buzzer which will look bulkier than this and will produce a Beep. Beep. Beep. Sound due to the internal oscillating circuit present inside it. But, the one shown here is most widely used because it can be customised with help of other circuits to fit easily in our application.

This buzzer can be used by simply powering it using a DC power supply ranging from 4V to 9V. A simple 9V battery can also be used, but it is recommended to use a regulated +5V or +6V DC supply. The buzzer is normally associated with a switching circuit to turn ON or turn OFF the buzzer at required time and require interval.

5) Camera

A webcam is a video camera that feeds or streams an image or video in real time to or through a computer to a computer network, such as the Internet. Webcams are typically small cameras that sit on a desk, attach to a user's monitor, or are built into the hardware. Webcams can be used during a video chat session involving two or more people, with conversations that include live audio and video. For example, Apple's iSight camera, which is built into Apple laptops, iMacs and a number of iPhones, can be used for video chat sessions, using the iChat instant messaging program (now called Messages). Webcam software enables users to record a video or stream the video on the Internet. As video streaming over the Internet requires a lot of bandwidth, such streams usually use compressed formats. The maximum resolution of a webcam is also lower than most handheld video cameras, as higher resolutions would be reduced during transmission. The

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lower resolution enables webcams to be relatively inexpensive compared to most video cameras, but the effect is adequate for video chat sessions.

Figure 10: Camera

Optics

Various lenses are available, the most common in consumer-grade webcams being a plastic lens that can be manually moved in and out to focus the camera. Fixed-focus lenses, which have no provision for adjustment, are also available. As a camera system's depth of field is greater for small image formats and is greater for lenses with a large f-number (small aperture), the systems used in webcams have a sufficiently large depth of field that the use of a fixed-focus lens does not impact image sharpness to a great extent.

Most models use simple, focal-free optics (fixed focus, factory-set for the usual distance from the monitor to which it is fastened to the user) or manual focus.

Compression

Digital video streams are represented by huge amounts of data, burdening its transmission (from the image sensor, where the data is continuously created) and storage alike.Most if not all cheap webcams come with built-it ASIC to do video compression in real-time.

Support electronics read the image from the sensor and transmit it to the host computer. The camera pictured to the right, for example, uses a Sonix SN9C101 to transmit its image over USB. Typically, each frame is transmitted uncompressed in RGB or YUV or compressed as JPEG. Some cameras, such as mobile-phone cameras, use a CMOS sensor with supporting electronics "on die", i.e. the sensor and the support electronics are built on a single silicon chip to save space and manufacturing costs. Most webcams feature built-in microphones to make video calling and videoconferencing more convenient

Interface

Typical interfaces used by articles marketed as a "webcam" are USB, Ethernet and IEEE (denominated as IP camera). Further interfaces such as e.g. Composite video or S-Video are also available

The USB video device class (UVC) specification allows inter-connectivity of webcams to computers without the need for proprietary device drivers.

Software

Various proprietary as well as free and open-source software is available to handle the UVC stream. One could use Guvcview or GStreamer and GStreamer-based software to handle the UVC stream.

6) Servo motor

A servo motor is a rotary actuator or a motor that allows for a precise control in terms of the angular position, acceleration, and velocity. Basically it has certain capabilities that a regular motor does not have. Consequently it makes use of a regular motor and pairs it with a sensor for position feedback.

Figure 11: Servo motor

Servo motor works on the PWM (Pulse Width Modulation) principle, which means its angle of rotation, is controlled by the duration of pulse applied to its control PIN. Basically servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears.

Servo motors control position and speed very precisely. Now a potentiometer can sense the mechanical position of the shaft. Hence it couples with the motor shaft through gears. The current position of the shaft is converted into electrical signal by potentiometer, and is compared with the command input signal. In modern servo motors, electronic encoders or sensors sense the position of the shaft

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We give command input according to the position of shaft. If the feedback signal differs from the given input, an error signal alerts the user. We amplify this error signal and apply as the input to the motor, hence the motor rotates. And when the shaft reaches to the require position error signal become zero, and hence the motor stays standstill holding the position.

The command input is in form of electrical pulses as the actual input to the motor is the difference between feedback signal (current position) and required signal, hence speed of the motor is proportional to the difference between the current position and required position. The amount of power require by the motor is proportional to the distance it needs to travel.

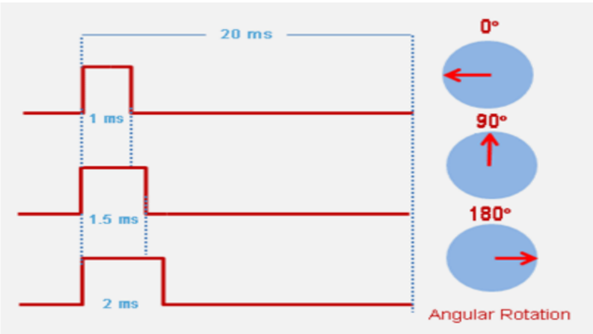

Figure 12: Working of Servo motor

Servo motor can be rotated from 0 to 180 degree, but it can go up to 210 degree, depending on the manufacturing. This degree of rotation can be controlled by applying the Electrical Pulse of proper width, to its Control pin. Servo checks the pulse in every 20 milliseconds. Pulse of 1ms (1 millisecond) width can rotate servo to 0 degree, 1.5ms can rotate to 90 degree (neutral position) and 2ms pulse can rotate it to 180 degree.

All servo motors work directly with your +5V supply rails but we have to be careful on the amount of current the motor would consume, if you are planning to use more than two servo motors a proper servo shield should be designed.

IV. ADVANTAGES

- **Instant Threat Detection** – AI processes live data from cameras and sensors, enabling swift responses to security threats.
- **Optimized Crowd Flow** – Assists organizers in managing crowd movement, reducing congestion, and ensuring a smooth experience.
- **Enhanced Safety Measures** – Identifies anomalies, potential stampedes, and suspicious activities to mitigate risks effectively.
- **Automated Warnings** – Sends alerts or notifications to security teams when crowd density reaches critical levels.
- **Smart Resource Allocation** – Uses AI-driven insights to strategically deploy security personnel, improving efficiency.
- **Adaptable to Various Events** – Scales easily for different event sizes, from small gatherings to large-scale public functions.
- **Data-driven Decision Making** – Records and analyzes crowd patterns to enhance future event security and management.
- **Long-term Cost Efficiency** – Minimizes dependency on manual surveillance, ultimately reducing operational expenses.

V. DISADVANTAGES

- **Expensive Implementation** – Requires significant investment in hardware (cameras, sensors, Raspberry Pi 5) and AI development.
- **Privacy & Ethical Concerns** – Continuous surveillance may raise legal issues regarding personal data collection and usage.
- **Technical Complexity** – Installation, calibration, and maintenance demand specialized knowledge and expertise.
- **Reliance on Power & Connectivity** – System performance may be impacted by network.
- **Risk of Inaccuracies** – AI may generate false alarms or fail to detect real threats, affecting reliability.
- **Environmental Constraints** – Factors like poor lighting, sensor obstructions, or adverse weather conditions may reduce system accuracy.
- **Cybersecurity Vulnerabilities** – AI-powered security systems are susceptible to hacking, posing potential data and operational risks

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VI. RESULT

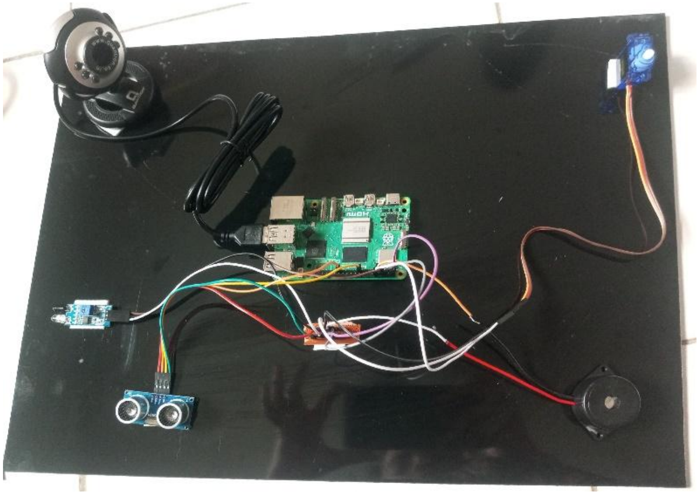

Figure 13: Implementation

The project's primary idea is to detect and identify it by looking at the image. Additionally, the vehicle will start if the driver's recognized image matches the image in the database; if not, it won't. Python is used to code the facial detection application. The Raspberry Pi is used to run this program. The USB camera instantly takes a picture of the individual. The face is then obtained by cropping this The graphic below illustrates this face detection process by cropping the face using the square produced by the Haar- Cascade Classifier. The Journal of Analytical and Experimental Modal Analysis International The owner's predefined photos that are kept in the database are then compared with this discovered image.

Figure 14: Crowd Counting

An MMS and SMS are sent to the owner's mobile device if the minimum Euclidean distance over the threshold "th." The owner responds to the MMS with an SMS, which is used to stop the ignition valve. Access is permitted if the Euclidean distance is smaller than the threshold, indicating authorization.

VII. FUTURE SCOPE

The use of AI in vehicle security is rapidly advancing, offering promising a venues for enhanced theft prevention. Leveraging facial recognition and GPS tracking technology can significantly improve security by reducing the chances of unauthorized access and increasing the efficiency of recovery if a vehicle is stolen. Here are some potential advancements and future applications of AI driven car theft prevention systems that integrate face ID and GPS:

- Advanced Biometric Security with Face ID: Facial recognition, powered by machine learning algorithms, offers a sophisticated way to control access to vehicles. Future AI systems could use 3D face mapping or facial micro-expression analysis to verify a user's identity with higher accuracy and prevent unauthorized access even if someone tries to spoof the system. Biometric data can be further enhanced by incorporating multimodal authentication, such as combining face ID with voice or gesture recognition for a multi-layered security approach.
- Behavioral Analysis for Real-Time Threat Detection: AI systems could learn typical behavior patterns of the owner, such as usual routes, driving style, and frequently used features. By combining facial recognition with this behavioral analysis, AI could detect irregularities or potential threats .For instance, if an unauthorized person tries to start the car, the system could automatically trigger lockdown procedures, alerting the owner and the authorities in real-time.
- Integration with GPS for Proactive Theft Prevention: GPS systems, when integrated with AI, can do more than just track the car's location. AI can analyze the vehicle's movement patterns to detect unusual or erratic driving behaviors that might indicate theft. For instance, if the car suddenly leaves a predetermined geo fenced area, AI can trigger alarms and provide real- time location updates to the owner or law enforcement, ensuring swift action.
- Remote Vehicle Control and Shutdown: AI-powered systems could offer remote control features allowing the owner to disable the vehicle remotely if a theft is suspected. Upon detecting unauthorized access, the AI could send alerts to the owner's smart phone, enabling them to lock or immobilize the car. This remote

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shutdown capability, combined with GPS tracking, could be a game-changer in preventing car thefts.

- Augmented Real it in Recovery Operations: In case of theft, AR overlays on smart phone apps could help owners or law enforcement locate and retrieve stolen vehicles with real-time GPS data. This overlay could provide directions, obstacles, or other useful information for the most effective recovery, increasing the chance of prompt retrieval and minimizing potential damage to car.
- Data Driven Insights and Predictive Analysis: Future systems could use AI to analyze broader patterns in theft attempts, identifying high-risk locations or times when thefts are more likely to occur. Using these insights, car manufacturers and owners can make data-driven decisions to improve security measures and minimize risks. Furthermore, predictive models could enable AI to anticipate potential thefts and activate preemptive security protocols.
- Privacy and Security Enhancements: As these system evolve, addressing privacy concerns will be critical. Future AI-driven solutions may use edge computing, which processes data locally on the car rather than in the cloud, to maintain data privacy and security. Implementing encrypted biometric storage and anonymizing GPS data can ensure users' personal data remains protected.
- Interconnected Vehicle Networks for Collaborative Theft Prevention: In the future, cars could be part of a networked system that shares real-time security information. Vehicles within a specific area could communicate with each other, using face ID recognition data and GPS insights to alert each other of potential threats or suspicious activities. This vehicle-to-vehicle (V2V) communication could lead to a community- wide approach to theft prevention.
- Adaptive and Continual Learning AI Models: AI systems can adapt and improve over time, learning from each attempted breach or unusual activity. This capability could enable the system to become progressively smarter, making it increasingly difficult for thieves to bypass security. As the system learns, it could continually update its threat detection parameters to stay ahead of emerging tactics used by car thieves.

VIII. CONCLUSION

The AI-based crowd density estimation and event security system leverages advanced machine learning techniques and IoT-based sensors to ensure real-time monitoring and risk assessment during large public events. By integrating a camera, IR sensor, ultrasonic sensor, and Raspberry Pi 5, the system accurately detects crowd density, identifying potential congestion points and security threats. The buzzer and servo motor allow for immediate response mechanisms, while the SD card enables data storage for further analysis. This solution enhances public safety by proactively mitigating risks, improving event management efficiency, and supporting security personnel with AI-driven insights.

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