DYNAMIC ENERGY MANAGEMENT USING REAL TIME OBJECT DETECTION

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Abstract - *The system mainly concentrates on the human detection using YOLO CV2 algorithm and sectoring the area into four parts. The hardware requirements used is Raspberry Pi4 and webcam. The software requirements include YOLO CV2 and VNC viewer to display the area detected by the camera. The sectored area in the software is merged with the area that has been chosen in real time in which camera identifies a human detection in a particular sector and the specified sector is alone turned on instead of using the electrical energy in the whole unused space. The project's primary goal is to minimize energy usage dynamically. Additionally, the project incorporated intrusion detection, automatic on & off of the system at specified timing, and to alert when unwanted movement is detected.*

Key Words: Machine Learning, Energy Management, Object Detection, Electrical Control, Intruder Detection

1.INTRODUCTION

The project's objective is to minimize energy consumption by managing electrical devices through human detection in a designated area. The observation area is divided into four sectors, and each sector's electrical devices are managed separately based on human presence in that sector. To detect and identify human presence, Machine Learning algorithms are employed. The Raspberry Pi serves as the central unit for the project, and a working prototype has been developed in a real-time environment. Overall, the project's innovative use of YOLO CV2 algorithm provides an efficient and cost-effective solution for energy management and security.

1.1 OBJECT DETECTION

Object detection plays a crucial role in video processing, allowing computers to automatically identify and track objects in real-time. Video object detection is used in a variety of applications, including security and surveillance, traffic monitoring, and autonomous vehicles. To perform object detection in video processing, algorithms typically analyze frames of video by identifying objects and tracking their movements over time. However, this process can be challenging due to factors such as changes in lighting, occlusion, and object deformation. To overcome these challenges, our project developed various techniques, including deep learning-based methods, to improve the accuracy and speed of object detection in videos. Additionally, advancements in computer hardware and GPU-accelerated computing have enabled real-time video object detection and tracking, making it an essential tool for a wide range of applications.

1.2 IMAGE SEGMENTATION

Image sectoring, also known as image segmentation, is the process of dividing an image into multiple segments or regions based on certain criteria, such as colour, texture, or shape. This technique is widely used in computer vision and image processing applications, including object detection, image recognition, and scene analysis. In the context of reducing electricity consumption, image sectoring can be used to identify the presence of humans in a particular area or sector, such as a classroom or office space. Image sectoring can be performed using various algorithms and techniques, such as thresholding, clustering, and edge detection. These algorithms can be tailored to specific applications and environments, allowing for accurate and reliable detection of human presence in different spaces. Additionally, advancements in computer vision and deep learning technologies have enabled more advanced image sectoring algorithms that can analyse images in real-time and detect more complex patterns and objects.

Object detection and sectoring images are two critical tasks that rely heavily on object detection technology. Object detection enables computers to recognize and locate objects in images or videos, while sectoring images involves dividing an image into smaller segments or regions. By combining these techniques, we effectively identify and analyse the contents of an image or video.

1.3 YOLO CV2 ALGORITHM

The YOLO CV2 (You Only Look Once, OpenCV 2) algorithm is a popular object detection algorithm that can be used for human detection in video. This algorithm uses a deep neural network to analyze video frames and detect objects, including humans, in real-time. YOLO CV2 is particularly effective for human detection because it can accurately identify individuals even in crowded scenes or low-light environments. This algorithm can also detect people in different poses and orientations, making it a versatile tool for human detection. Additionally, YOLO CV2 can be trained on custom datasets, allowing it to be tailored to specific use cases or environments. Overall, the YOLO CV2 algorithm has proven to be an effective tool for human detection in a wide range of applications, including security and surveillance, traffic monitoring, and sports analysis.

1.4 RASPBERRY PI 4

Dividing a room into four sectors using image sectoring algorithms can be an effective way to detect human presence and control lighting and fans in that area to reduce electricity consumption. To implement this approach using a Raspberry Pi 4, several hardware components and software tools are used.

The Raspberry Pi 4 is a small, single-board computer that can be used for a variety of applications, including image processing and machine learning. To detect human presence in each sector of the room, a camera module can be attached to the Raspberry Pi 4 and used to capture images of the room. The images can then be processed using image sectoring algorithms to identify the presence of humans in each sector.

To control the lighting and fans in each sector, the Raspberry Pi 4 can be connected to a relay module or a set of smart switches. The relay module can be used to turn the lights and fans on or off based on the human presence detected in each sector.

To implement this system, programming languages such as Python can be used to develop the software that runs on the Raspberry Pi 4. Libraries such as OpenCV can be used to perform image processing tasks, while the GPIO (General Purpose Input/Output) pins on the Raspberry Pi 4 can be used to control the relay module or smart switches.

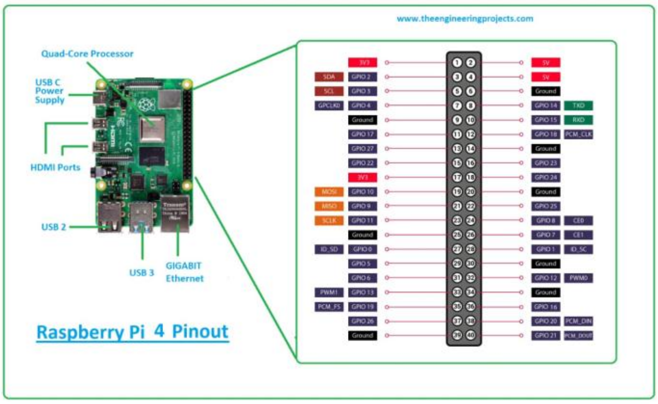

Fig -1: Raspberry Pi4 Pin Layout

2. PROPOSED METHODOLOGY

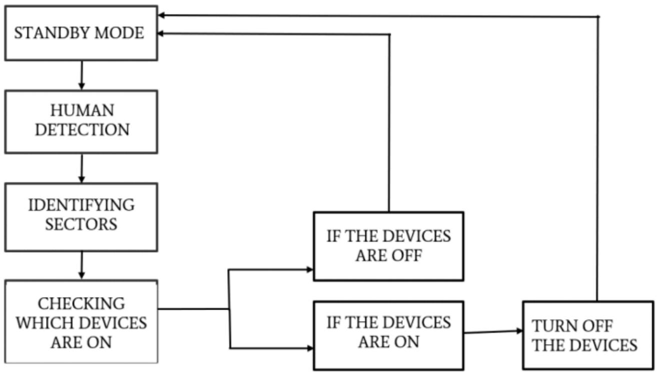

Fig-2: Methodology Flowchat

Figure-2 outlines the process flow of the methodology proposed. The detection of humans is implemented using YOLO CV2 algorithm. This is followed by Hardware implementation where sectorized control is done over electrical appliances.

2.1 YOLO CV2 ALGORITHM

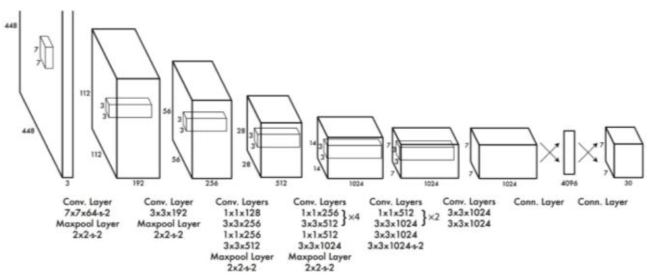

Fig-3: YOLO CV2 Algorithmic Architecture

YOLO stands for “You Only Look Once”. It is an algorithm which can detect several objects in a photo and recognize it instantly. Each object type is a separate class in YOLO algorithm and detection is done as a regression problem.

YOLO uses convolutional neural networks (CNN) to perform real-time object detection. The advantage of the algorithm is that it only needs one single forward propagation through the CNN to identify the object. Hence, a single algorithm run is sufficient to identify and predict objects in a whole image. The YOLO CNN can predict various class probabilities simultaneously along with the bounding boxes.

Figure-3 shows the architecture of the YOLO algorithm. The initial 20 layers are pre-trained using ImageNet. Since the convolutional and connected layers of a pretrained model is used, it improves performance. The final layers of YOLO are the fully connected layers which predict the class probability and the coordinates of bounding boxes.

For this application, the COCO (Common Object in Context) data set is used to train the YOLO algorithm. The COCO dataset consists of various objects encountered in daily life. Out of all those objects, the coco name "people" is compared with the recognized objects and if found a match, then it proceeds with the energy management flow.

2.2 SECTORING

A novel factor introduced in the proposed energy management system is sectoring. Sectoring refers to the division of an area into a fixed number of sectors. For the ease of implementation and testing, the number of sectors is fixed as four in the project.

Instead of controlling only individual devices at a time or an entire premises or area, sectoring allows controlling the electricity supply in smaller areas. This allows the energy saving to be more than the existing solutions. When the algorithm detects the presence of a human, the co-ordinates of the sector in which they are present is obtained. This allows only the fan and lights in that sector to be turned on while others remain switched off. Also, if multiple sectors can be on at the same time.

2.3 HARDWARE METHODOLOGY

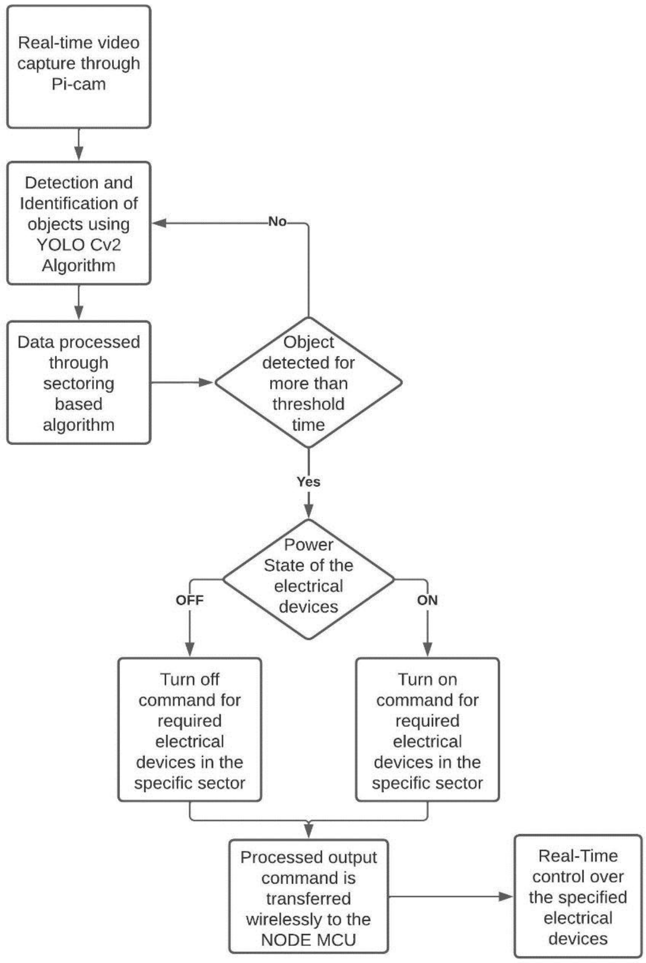

Fig-4: Flowchart of Proposed Hardware Implementation

In the implemented system, the Raspberry Pi and NodeMCU modules are both utilized as shown in Figure-4. Real-time object detection and identification are performed using the Raspberry Pi, with the assistance of a Pi-Cam. The Raspberry Pi also serves as the controlling module, which utilizes the processed data outputs to control the electrical devices. To connect the Raspberry Pi with the NodeMCU, a shared server is utilized. The NodeMCU is responsible for decentralizing the Raspberry Pi module and controlling the switch for the electrical devices. The approach used in this system involves first detecting objects through the camera feed provided by the Pi-Cam. Then, identification of the objects is carried out using algorithms programmed into the Raspberry Pi module. When an object is detected or not detected for a specific duration of time, a corresponding output is activated. This output is then wirelessly transmitted to the NodeMCU module, which is linked to the control switch for regulating the power supply to the electrical devices.

3. IMPLEMENTATION

3.1 INITIALIZING THE NECESSARY MODULES

In order to implement a Python program that captures and processes videos, controls the GPIO ports of a Raspberry Pi, and connects to an MQTT broker, it is necessary to import several modules. The first module required is CV2, which is used to capture and perform videos. The Time module is also essential, as it helps to represent time in the code. Additionally, the RPi.GPIO module is needed to allow the Python code to control the GPIO ports of a Raspberry Pi. Finally, the Paho.mqtt module provides a client class to connect with an MQTT broker, which is necessary for communicating with other devices or systems. Once these modules are imported, the Python program can begin implementing its functionality.

3.2 SECTORING

To accurately determine the location of a person or individual in a room, the image must be split into four coordinates or sectors, with each sector being 320x320 in size. This allows for precise calculations of the individual's position within the room.

Fig -5: Sectoring Image Feed

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sector1 = [0, 240, 320, 240]
sector2 = [0, 0, 320, 240]
sector3 = [320, 0, 320, 240]
sector4 = [320, 240, 320, 240]
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Fig -6: Co-Ordinates of individual sectors

As shown in Figure 6, the image displays the coordinates of each sector, enabling the system to identify the exact location of the person based on the coordinates. This method is effective in various applications, such as security systems or indoor navigation

In order to identify and locate an individual within a room, the YOLO algorithm is utilized, and a green bounding box is introduced around the identified person. This box allows for easy capture and scaling of the person or object, simplifying the process of marking and locating the individual within the room.

As shown in Figure-5, when a predefined object (in this case, an individual) is identified in the viewed area, the bounding boxes are initialized to surround the object. The position of the anchors within the box determines the location of the individual with respect to the sector. If the box is in the first sector, for example, the system can determine that the person is located within the first sector of the room. This system is effective in various applications, such as security monitoring or tracking individuals within a facility.

3.3 CONTROLLING LIGHTS

Upon detecting a person within a particular sector of the room, the devices (such as lights and fans) configured with that sector are activated. There are different cases that may occur when a person is detected. In the first case, if a person is detected in only one sector, the devices corresponding to that sector are turned on.

3.3.1 CASE-1-DETECTION IN ONE SECTOR

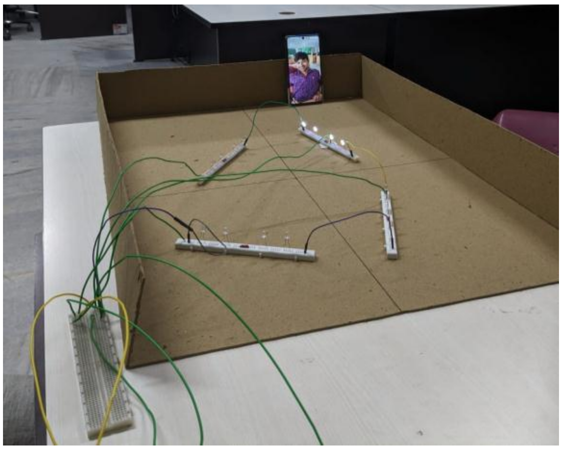

Fig-7: Person in one sector

3.3.2 CASE-2-DETECTION IN MULTIPLE SECTOR

If people are detected in one or more sectors, the sectors where the bounding boxes are present will have the corresponding devices turned on. This system ensures that energy is not wasted on powering devices in unoccupied sectors, making it more efficient and cost-effective. Additionally, it allows for greater customization and control over the devices within the room.

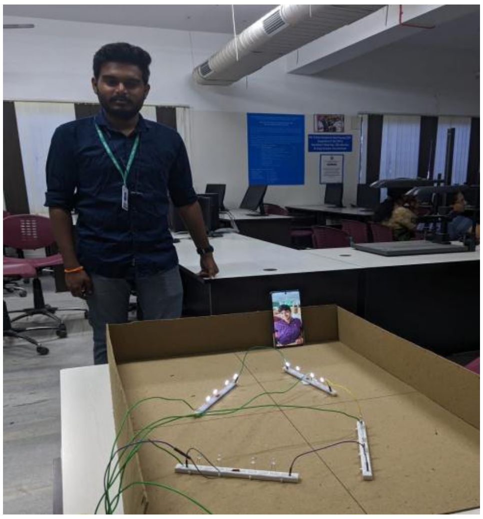

Fig-8: Multiple people identified in multiple sectors

3.4 WIRELESS DATA TRANSFER

To control the devices in the system, the input GPIO (General Purpose Input/Output) pins are initially set to low. When data is passed to these pins, the values are set to high, which triggers the corresponding devices to turn on. Similarly, if there is no detection of humans in the room, the pin values are set to low, which causes the devices to turn off automatically. This mechanism allows the system to respond dynamically to changes in the environment, turning on or off devices as needed based on the presence or absence of people in the room

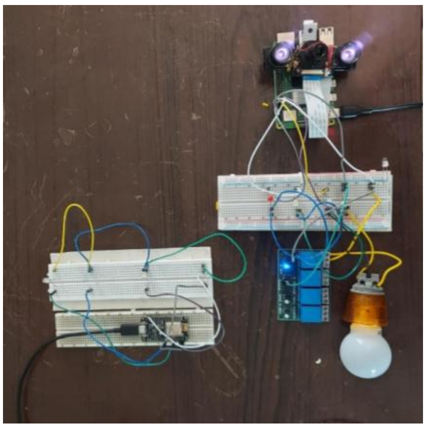

Fig-9: The setup of the final model using Node MCU

The setup consists of a central controlling element, which is a Raspberry Pi. It is connected to a Pi-Cam that captures real-time videos. Additionally, a NODE MCU is used to control the light bulbs by receiving commands from the Raspberry Pi. This setup allows for the decentralization of the Raspberry Pi and the electrical device controlling module. A relay is also included in the setup, which acts as a connecting node between the controlling modules and the electrical appliances. Its function is to control the circuit.

3.5 RESULT & ANALYSIS

The YOLO Cv2 Deep Learning Algorithm was adapted and utilized for detecting and recognizing human presence in a live video feed. The system was designed to cover the entire field of view by segmenting the video feed into four equal-sized sectors. The algorithm identified the position of objects in each sector, and based on the duration of their presence, the electrical appliances in the corresponding sector were controlled.

After several rounds of testing and training, the detection efficiency of the algorithm was significantly enhanced, and the system was implemented in real-time. The Node MCU served as a secondary control unit to manage the light bulbs on the commands received from the raspberry pi.

Fig-10: Person is identified in the sector and data is transferred to the NodeMCU

In a practical application, four 50W (3000 lumen) light bulbs were turned on for six hours. According to the theoretical calculation, each light bulb would consume 180 Joules of energy per hour, accumulating to a total energy consumption of 4320 Joules. However, in the real-time scenario, the system controlled the bulbs in such a way that each sector had an individual bulb, and the time period for which each bulb was powered was measured. As a result, the combined energy consumption was reduced to 2700 Joules. This indicates that the system is capable of reducing energy consumption in real-world scenarios.

4. CONCLUSIONS

The primary goal of the project is to enhance energy efficiency by reducing energy consumption. A cost-effective prototype has been developed that utilizes machine learning algorithms to capture and process real-time video feed, enabling it to operate effectively in real-world environments. The machine learning algorithm has been trained and tested for object detection and identification to improve its efficiency.

During a real-time inference, the system was able to reduce energy consumption by controlling the lights according to their needs. By powering the lights only when a human presence was detected, energy consumption was reduced by 20%. The theoretical energy consumption for four 50-watt light bulbs turned on for six hours was calculated to be 4320 Joules, but the actual energy consumption was reduced to approximately 2700 Joules, resulting in a 37.5% decrease in energy usage. Additionally, the system can function as an intrusion alert system by triggering an alarm when human presence is detected at unwanted times

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