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Conservation of Energy using Object Detection Model

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Abstract: ***Energy conservation has become a vital responsibility for every citizen. Considering classroom environment, electric appliances like fans and lights are usually unmonitored while students leave. It leads to the wastage of electricity. To save electricity, conventionally, sensors can be deployed to detect the presence / absence of person in the classroom and control electric appliances based on its trigger. Since (low-cost) sensors have reliability issues with shorter life span, it can't be used effectively. On the other hand, if costly (high precision and reliability) sensors were used to detect persons, deploying it in each and every classroom is not practicable due to very high initial investment. Here, this paper's approach is to use a medium quality, low cost night vision web-camera to detect persons inside classroom using YOLOv3 Object detection model built on top on TensorFlow framework. Computational capabilities for processing webcam footage is provided by PCs inside each and every classroom. (Assumption: Each and every classroom has a dedicated PC for sharing power-point slides) Switch board is configured with relays, which are connected in parallel to normal switches to allow manual intervention. Relays are controlled by Wi-Fi enabled micro-controllers like NodeMCU. Communication is made possible between NodeMCU and PC via LAN. By this means, a huge amount of electricity can be saved with least deployment cost.***

Keywords—YOLOv3, NodeMCU, Relay, Common Objects in Context (COCO), Switch Board, DC Power supply.

I. INTRODUCTION

In an attempt to make efficient use of energy, many public and private sector units have innovated a lot to minimize power consumptions. To get a better perspective, let's dive into 80's where electronic components were huge in size and dissipated a huge amount of heat. Batteries were larger in size and stored very less energy. Now-a-days, a microcontroller with a size of a nail-tip has got a lot of processing in it and batteries got thin and sleek inside our mobiles which can stand up to a couple of days without charge. Even though, we are using energy in a more precise manner compared to earlier days, usage of electronic and electric appliances has skyrocketed compared to earlier days and this made us to think of non-renewable resources becoming more and more scarce in upcoming future. So, here comes need to think of saving resources in every possible aspect.

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Considering classroom scenario, [2], a context-aware architecture is proposed where it uses temperature, luminance sensors to predict the ambience and LSTM (Long Short-Term Memory), 3D-CNN (Convolutional Neural Network) to predict student's activity and based on its outcome, electric appliances are effectively used to save energy.

In [3], an algorithm is proposed where the change in Wi-Fi's Received Signal Strength Indicator (RSSI), with and without person inside classroom is used as an inference to save energy efficiently.

In [4], a unique M-Learning (Mobile-based Learning) model is proposed where students can able to access contents related to their studies via mobile platform, while creating awareness on the importance of energy savings.

In [5], PIR (Passive Infra-Red) sensor is used to sense the presence of person inside classroom and based on the sensor output, a microcontroller with a relay is used to control electric appliances.

In [6], a card-based authentication system is proposed, which is placed at the entrance of every single classroom and the data is collected, stored in a centralized database. Based on the information from database, electric appliances inside classroom are controlled more efficiently.

In [7], a study is made regarding our eye's perception at different colour temperatures. Here, temperature of light sources is controlled based on the ambient light inside classroom. Since, lower temperature light source consumes less energy compared to higher temperature light source. It is a novel way of saving energy.

II. PROPOSED SYSTEM

This paper proposes usage of state-of-the-art object detection model aka YOLO version 3 for detecting person inside classroom.

Here, classroom is divided into 4 quadrants for adaptive processing of the environment. A night-vision web camera is used to take classroom footage and then the footage is given as input to the YOLOv3 neural network.

This neural network is realized by using TensorFlow, which is an open source machine learning framework developed and maintained by Google.

The realization of YOLOv3 is very complex and is beyond the scope of our project. So, we used an existing implementation.

GitHub Source:

https://github.com/YunYang1994/TensorFlow2.0-Examples/tree/master/4-Object_Detection/YOLOV3

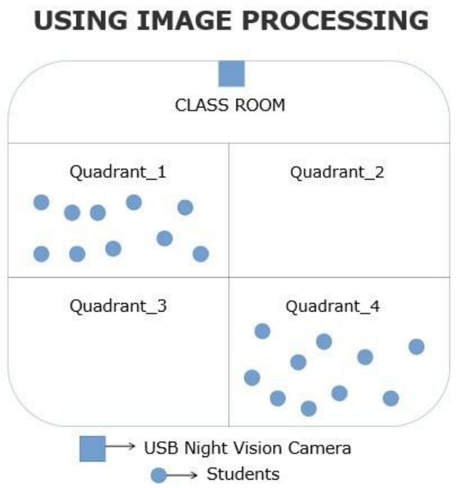

Fig. 1 High level view of the implementation

Fig. 2 Power saving strategy

A. Why YOLO?

YOLO - You Only Look Once is the state-of-the art model designed specifically for object detection. This means that this model won't be suitable for applications like iris and fingerprint authentication which requires resource heavy neural networks like ResNet (Residual Neural Network) and R-CNN (Region based Convolutional Neural Network) for extraction of very minute details (or) features. Whereas YOLO focuses on extraction and clustering of more common features available in the dataset. YOLO is the fastest light-weight model ever seen with accuracy (mAP - mean average precision) higher or comparable to other models like SSD (Single Shot Detector), MobileNet and ResNet. Even Though, more accuracy can be obtained from other models like ResNet, it requires a hell lot of computation power, requires costly hardware and consumes more energy. Higher energy consumption will break our whole idea of energy conservation. So, we stuck on to YOLO version 3 for person detection inside the classroom.

B. Controlling Electric appliances:

For controlling the switching operation of electric appliances, we need a microcontroller along with Wireless communication capability like Bluetooth or Wi-Fi. The most popular hobbyist board called Arduino UNO which has ATMEGA328P microcontroller can be used along ESP8266 Wi-Fi module or HC-05 Bluetooth module. But It is not cost effective, because Arduino UNO costs around 350 INR, HC-05 Bluetooth module costs around 230 INR and ESP8266 Wi-Fi module costs around 150 INR Therefore, for a single classroom, it would cost around 500 to 580 INR. On the other hand, NodeMCU costs around 250 INR and It has both microcontroller and Wi-Fi (ESP8266) embedded in it. So, it is more cost effective than previous options.

Table-I: SPECIFICATIONS OF NODEMCU

DESCRIPTION	SPECIFICATION
Microcontroller	ESP-8266 32-bit
Clock Speed	80 MHz
USB to Serial	CP2102
USB Connector	Micro USB
Operating Voltage	3.3V
Input Voltage	4.5V-10V
Flash/SRAM	4 MB / 64 KB
Digital I/O Pins	11
Analog In Pins	1
ADC Range	0-3.3V
UART/SPI/I2C	1/1/1
Wi-Fi Built-In	802.11 b/g/n
Temperature Range	-40C – 125C

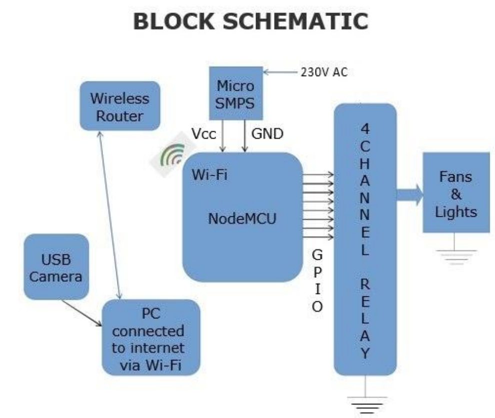

Fig. 3 Block Schematic of overall implementation

III. IMPLEMENTATION [HARDWARE]

Switch Board consists of NodeMCU, micro-SMPS (230V AC to 5V DC) converter and a 4-channel relay. NO (Normally Open) and COMMON terminal of relay are connected in parallel to switches. This makes the mechanical switch to override the relay controls. (i.e., Relay control only works when the mechanical switch is in OFF state). The COIL (CONTROL) Terminals are connected to GPIO pins of NodeMCU.

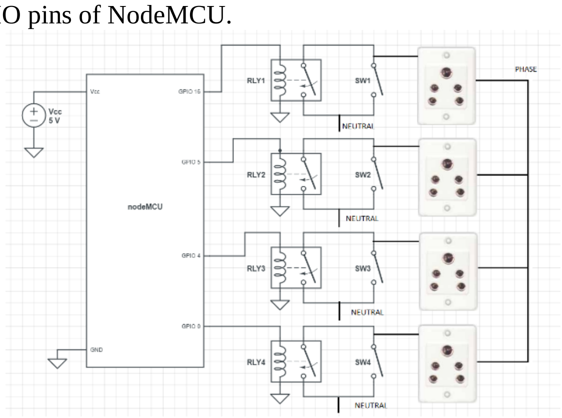

Fig. 4 Switch board internal block circuitry

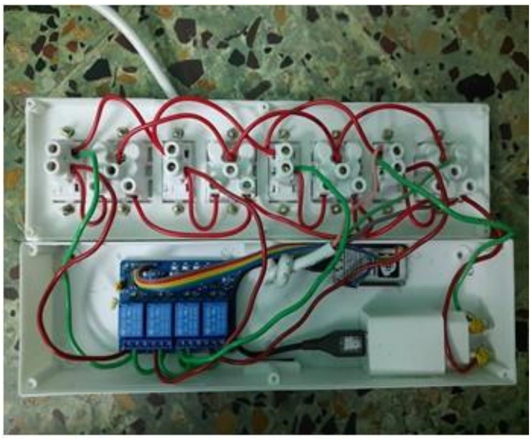

Fig. 5 IoT switchboard realization

IV. IMPLEMENTATION [SOFTWARE]

A. PC Hardware specs:

- CPU: Intel i5 8300H
- RAM: 16 GB
- GPU: nVIDIA GTX 1050 4GB VRAM (Optional)

B. Pre-requisites:

- Python 3.x
- OpenCV
- OpenSSL
- TensorFlow 2
- CUDA Toolkit and cuDNN required for GPU support. (Optional)
- Arduino IDE
- ESP8266 WIFI Manager library

C. Working:

At client side (PC):

List of functions used and their functionalities:

checkServer():

Periodically checks whether NodeMCU is online (connected over LAN) or not.

resetCounter():

Counter is initially set to a non-zero value and It gets decremented if person is not detected. And if a person is detected, then the counter is reset to initial value. (Note: counter won't be decremented below zero)

appControl():

It sends request to the server based on the value of the counter. Electric appliances will be switched on if the counter has non-zero value and are switched off if counter reaches zero.

Algorithm:

Step 1: IP address of server (NodeMCU) is found using its host name. (E.g. esp8266.local)
Step 2: Using OpenCV library, try to connect to webcam using its video path. It usually starts from zero and if only one camera is present then the video path should be zero.
Step 3: Once the camera and the server is identified, TensorFlow and YOLO libraries are loaded.
Step 4: Using OpenCV, Night vision camera's output is read frame by frame.
Step 5: All functions stated above are executed as sub-threads asynchronously. *resetCounter()* is spawned 4 times for distinguished control of electric appliance in each quadrant.
Step 6: Webcam frame is given to YOLO model one by one and the output is retrieved back from the model.
Step 7: Person detected in a quadrant is identified by ((x1, y1), (x2, y2)) values of rectangular box generated by YOLO.
Step 8: Based on the counter values from each quadrant *appControl()* makes appropriate HTTPS request to NodeMCU.

At server side (NodeMCU):

Self-signed CA certificate:

Self-signed CA certificates were generated using OpenSSL binary. It is used to establish HTTPS connection between client (PC) and server (NodeMCU).

Steps to generate CA certificate:

Step 1: Run OpenSSL binary to enter into OpenSSL CLI (Command Line Interface).

Step 2: Run the following command in OpenSSL CLI to generate certificate, key pair.

OpenSSL> *req -x509 -newkey rsa:1024 -sha256 -keyout esp8266.key -out esp8266.crt -days 365 -nodes -subj "/C=country_name/ST=state_name/L=locality/O=organization [RO]/OU=organizational_unit/CN=esp8266.local" -addext subjectAltName=DNS:esp8266.local*

WIFI Manager library:

WIFI Manager library is used to update / configure SSID and password of nearby WLAN it needs to connect via OTA (Over-The-Air).

During initialization, ESP8266 acts as (AP) Access Point and the username and password is configured via its default gateway.
After completing the configuration, it tries to connect to specified AP, if the connection gets established, it stays in that state or else it will fall back to AP mode.

GPIO trigger latency (HTTP vs HTTPS):

Wi-Fi signal strength: -67 dBm

Table-II: HTTP vs HTTPS connection latency

Trials	HTTP (ms)	HTTPS (ms)
1	230	1570
2	190	1440
3	260	1630
4	210	1510
Average:	222.5	1537.5

From the table, it is evident that HTTPS connection latency is 7 times higher compared to HTTP connection latency. This is a trade-off between security (encryption) and performance. In real world scenario, around 1.5 seconds response time for switching electric appliance is acceptable and for security reasons, HTTPS connection is preferred over HTTP.

Algorithm:

Step 1: Initialize required GPIO pins as output.

Step 2: Initiate Wi-Fi connection to router using SSID and password stored in flash memory.

Step 3: If connection fails, enable AP mode for re-configuration of Wi-Fi credentials.

Step 4: If connection succeeds, start HTTPS server in its default port number (443).

Step 5: Periodically check for the request from client.

Step 6: Based on the request, appropriate GPIO pin status is modified. (i.e., HIGH / LOW state)

GPIO pin's outputs are given as input to channel of relays. These relays allow client to control electric appliances wirelessly. Moreover, these relays are connected in parallel to mechanical switches to facilitate manual intervention, in case something goes out of order.

D. Source code:

- Visit my GitHub (private) repo: https://github.com/Santhosh360/classroom_yolov3

E. YOLOv3 object detection:

Case 1: Classroom with students

Fig. 6 Sample classroom with students

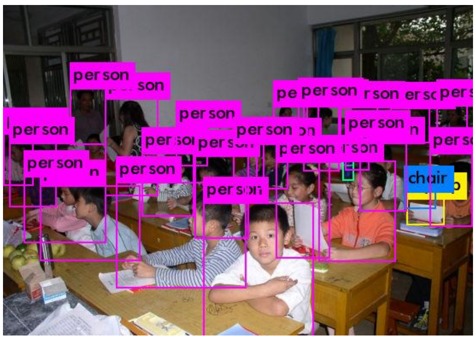

Fig. 7 Sample classroom with students processed by YOLOv3

Case 2: Empty classroom

Fig. 8 Sample classroom without students

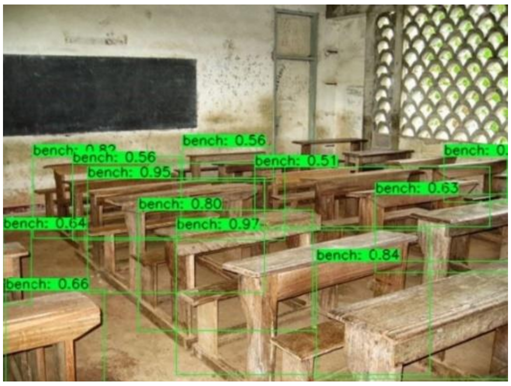

Fig. 8 Sample classroom without students processed by YOLOv3

From the images shown, it is evident that YOLOv3 is a viable option to detect persons in classroom.

V. CONCLUSION

In this paper, only pre-trained weight is used for YOLOv3 model, and is trained using COCO dataset by default. COCO dataset has around 80 distinct classes and this paper's scope is only on one class named person. So, if we reduce the number of classes and do custom training, even higher performance can be achieved with less computational power which leads to lower power consumption.

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