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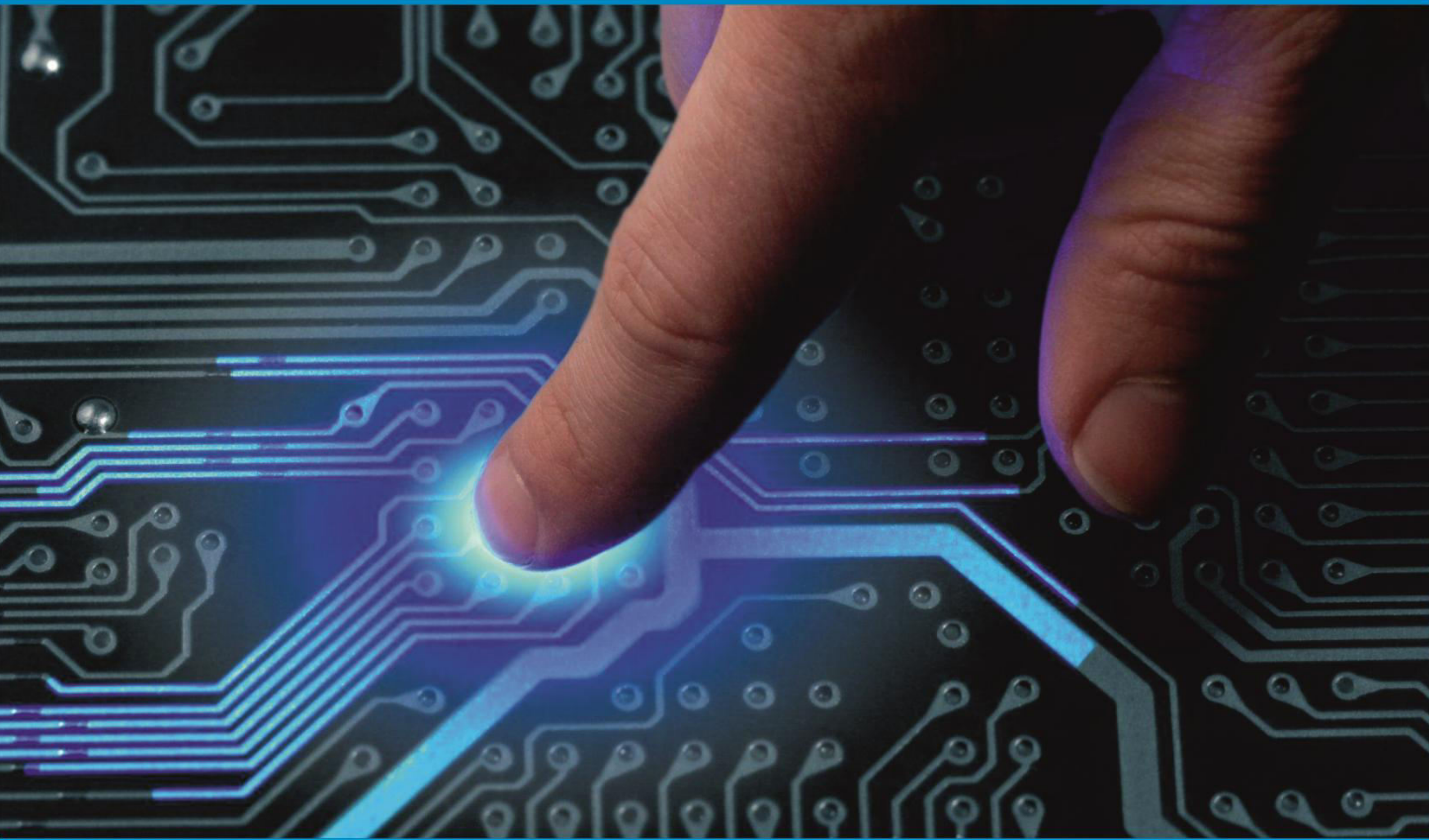

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IoT Based Intelligent Sensor Nodes to Predict the Optimal Set-Points of HVAC Systems

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ABSTRACT : HVAC systems consume considerable energy in buildings that exists without monitoring the parameters resulting in compromising energy efficiency and user comfort. A sensor node-based architecture is proposed for the prediction of optimal set-points of HVAC system. The system is built on the top of IoT(Internet of Things) framework where parameters are sensed. The system includes sensing of Internal room temperature, humidity, pressure, carbon dioxide and number of occupants. The sensing, control and actuating subsystems are connected through an I2C interface. The indoor temperature and number of occupants determine the efficiency of system. The level of pollution has increased with time due to increased vehicular motion, urbanization and deforestation resulting in adverse health effects for human beings. Determining the CO_2 levels in the room/space can help in maintaining the IAQ (Indoor Air Quality).IAQ is an important parameter that refers to the nature of conditioned air present inside the room. The sensed parameters are stored in the cloud for Data visualization and processing. ThingSpeak platform is used for cloud storage and visualization of Data. The effectiveness of the HVAC system is assessed in real time environment by evaluating the user ease

Keyword Image classification, YOLO, Predicted Mean Vote, HVAC, Object detection

I. INTRODUCTION

In recent times, one of the most important consideration designing a room is the extent it provides comfort to the user. Thermal comfort is one among them refers to a condition occupant are not feeling either too hot or too cold. People are dissatisfied with their thermal surroundings not only is it a potential health hazard, it also impacts on their ability to function effectively. One of the effects of this is heat stress, a person experiences extreme heat through body unable to lose heat through evaporisation of sweat causing elevated deep-body temperature and increased heart rate.

A solution for effective control of HVAC system to optimize the setpoints to condition the room temperature, humidity, pressure and number of occupants in the room. The HVAC system can work in different modes such as Heating, Cooling and Auto. The "Auto" mode means according to the indoor temperature the HVAC system can automatically switch between cooling and heating. In order to achieve thermal comfort two modules can be utilized one to sense and another for control and actuate. Sensing involves 4 sensor modules one each for temperature and humidity, pressure and number of occupants. Through accurate estimation of occupants and room temperature the energy can be conserved by 10%.

Air pollution is a point of major concern for everyone with rapid industrialization and urbanization difficult to control and reduce the pollution levels. Air pollution creates drastic impact on the characteristics and irritates the well-being of human beings. Every year many people pass away due to air pollution because of widespread air toxins causing intense lower respiratory diseases, ischemic coronary illness, lung malignant growth and cancer. Human beings exhale CO_2 and therefore the concentration increases when the number of occupants increases in a room. Humans cognitive function decreases by 21% with 400ppm increase in CO_2. Moderate to high concentration of CO_2 can cause headache and fatigue. Thus, monitoring CO_2 is essential.

II. RELATED WORK

Smart Random Neural Network Controller for HVAC Using Cloud Computing Technology A model for the intelligent controller by integrating internet of things (IoT) with cloud computing and web services is proposed. The wireless sensor nodes for monitoring the indoor environment and HVAC inlet air, and wireless base station for controlling the actuators of HVAC have been developed. The sensor nodes and base station communicate through RF transceivers at

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915 MHz. Random neural network (RNN) models are used for estimating the number of occupants, and for estimating the predicted-mean-vote-based setpoints for controlling the heating, ventilation, and cooling of the building. Three test cases are studied (Case 1-Data storage and implementation of RNN models on the cloud, Case 2-RNN models implementation on base station, Case 3-Distributed implementation of RNN models on sensor nodes and base stations) for determining the best architecture in terms of power consumption. The results have shown that by embedding the intelligence in the base station and sensor nodes (i.e., Case 3), the power consumption of the intelligent controller was 4.4% less than Case 1 and 19.23% less than Case 2.

Karami et al examined Temperature, CO2, VOC (CO, CH4, alcohols, ketones, organic, acids, amines, aliphatic hydrocarbons and aromatic hydrocarbons and PM2.5 in the environment and analyzed using Voltron software [1]. They evaluated thermal comfort using two parameters namely Predicted Mean Value (PMV) & Predicted Percentage Dissatisfied (PPD). They experimented that PMV and PPD indexes are well below threshold limit leads to user dissatisfaction and energy consumption. Their results revealed that Particle concentration, CO2 and VOC are in acceptable limit. The proposed work enhances good extensibility and due to robustness of toolbox for long term applications no missing data was notified

Choi et al examined Temperature, Humidity, CO, CO2, Dust, PM, VOC and Methane in air.The proposed work comprises of IoT based HVAC system which contains HVAC system and middleware. The HVAC system comprises of Ventilation system & AC system and the middleware comprises of IoT based HVACD, IoT managing gateway and Intelligent control manager. The Power consumption is reduced by a factor of 13.7% compared with the existing system. It is worth noting that the HVAC system is focused on the perspective of IoT paradigm and the user-oriented preferences.

III. METHODOLOGY

The primary sensor data collected are temperature, pressure and humidity of the room and number of occupants in the room. The temperature and humidity data are collected from DHT11 sensor since it's an analog data its converted to digital to send to the NodeMCU board through I2C interface. NodeMCU is an open-source platform, its hardware design is open for edit/modify/build. The number of occupants is determined by the PC camera it is passed to NodeMCU through serial communication process.Serial communication enables to easily communicate between NODEMCU and PC. Serial communication is a communication process wherein data transfer occurs by transmitting data one bit at a time in sequential order over a computer bus or a communication channel. It is the most widely used approach to transfer information between data processing equipment and peripherals. Binary One represents a logic HIGH or 5 Volts, and zero represents a logic LOW or 0 Volts, used for communicating between the Arduino board and a computer or other devices. All Arduino boards have at least one serial port which is also known as a UART or USART. It communicates on digital pins 0 (RX) and 1 (TX) as well as with the computer via USB. Serial communication on pins TX/RX uses TTL logic levels (5V or 3.3V depending on the board). The sensor data get stored in cloud through a platform known as THINGSPEAK. ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams.

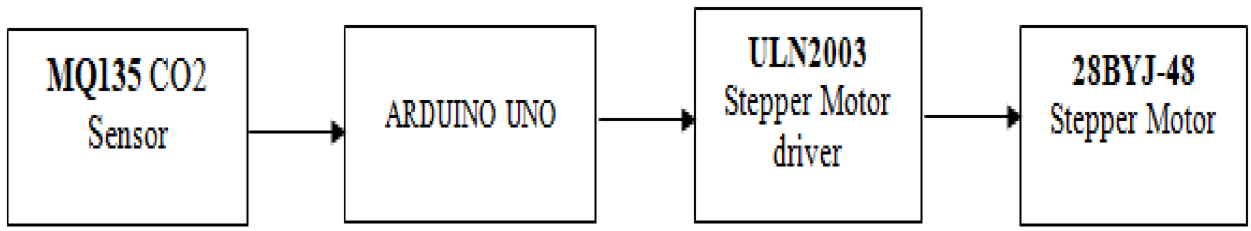

FIG 1 CO_2 LEVEL MONITOR

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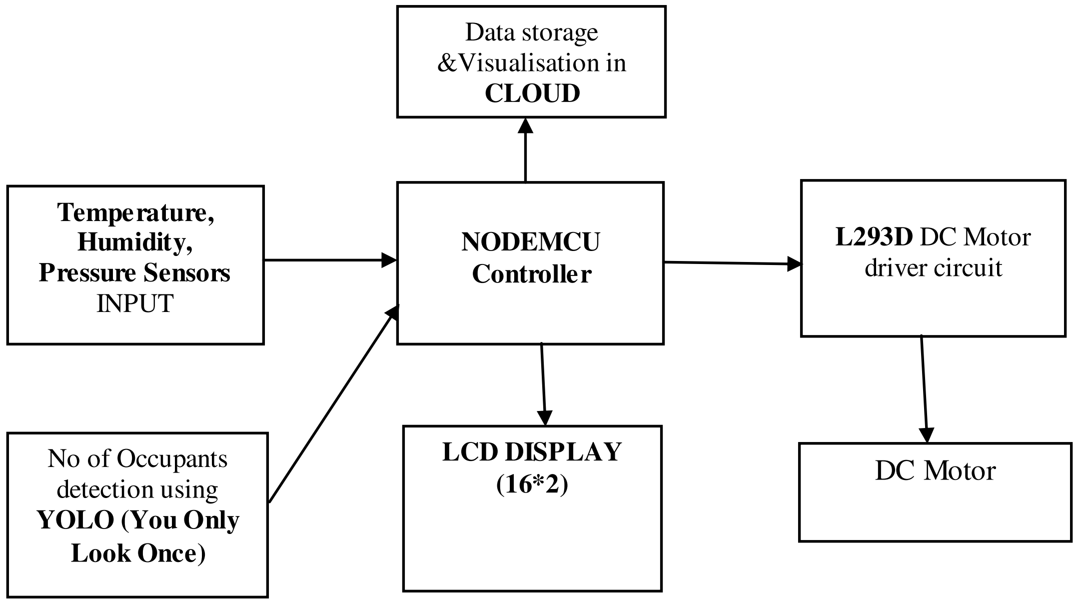

FIG 2: HVAC SYSTEM CONTROLLER

Once data to ThingSpeak from your devices, one can create instant visualizations of live data without having to write any code. With MATLAB analytics inside ThingSpeak,one can write and execute MATLAB code to perform more advanced preprocessing, visualizations, and analyses. Get started with building IoT systems without setting up servers or developing web software. The data corresponding to Temperature, Pressure and Humidity gets stored in the Thingspeak platform which can be accessed using a MathWorks account. The Temperature and humidity is got using DHT11 sensor and pressure data is also got to be uploaded to the cloud. The data is visualized using ThingSpeak. The dashboard can be viewed through any electronic devices like mobile phones, laptops and tablets. The Dashboard can have additional features like average of values and various charts to depict and visualize the values got from these sensors. The feature of visualizing the data can be of greater use to the consumer who could set the temperature according to their convenience. Data can be exported from ThingSpeak platform for further processing. The export functions help for processing from Matlab enabling better use of all features and future processing. Thingspeak has various integrations and plugins for further action. The platform provides various Data visualization tools to help visualize the data perfect.

Implementing complex person detection and consequently counting number of occupants in a room is one of the modules. The algorithm used here is YOLO (You Look Only Once). YOLO is better algorithm for real-time usage with high fps (frames per second) and based a regression, instead of selecting the interesting part of image. YOLO algorithm gives a much better performance on all the parameters we discussed along with a high fps for real-time usage. YOLO algorithm is an algorithm based on regression, instead of selecting the interesting part of an Image.

Image classification: aims at assigning an image to one of a number of different categories (e.g., car, dog, cat, human, etc.).
Object localization: then allows us to locate object.In a real real-life scenario, need to go beyond locating just one object but rather multiple objects in one image.
Object detection: Provides the tools for doing just that – finding all the objects in an image and drawing the so-called bounding boxes around them.
Intersection over Union and Non-Max Suppression:
Here's some food for thought – how can we decide whether the predicted bounding box is giving us a good outcome (or a bad one)? This is where Intersection over Union comes into the picture. It calculates the intersection over union of the actual bounding box and the predicted bonding box.
IoU = Area of the intersection / Area of the union, i.e.

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IoU = Area of yellow box / Area of green box
If IoU is greater than 0.5, we can say that the prediction is good enough. 0.5 is an arbitrary threshold we have taken here, but it can be changed according to your specific problem. Intuitively, the more you increase the threshold, the better the predictions become. This technique is used to find the number of occupants in a particular room and set the temperature value appropriately. The technique is of much use to enhance the overall understanding of the system because of the inter-relationship between number of occupants and current room temperature.

The parameters such as Temperature, Pressure, Humidity are recorded for use by user for computation. These data play a pivotal role in the determination of optimal set-points for user comfort and thus ensuring proper utilization of HVAC system. Higher humidity is an indication of more moisture and thus an identification point for a greater number of occupants. Temperature and humidity maintain a correlation which helps in determination of set-points.

The primary aim of project is to save energy and control the HVAC system while ensuring the user comfort with the help of sensors, cloud and IoT.The system avoids the energy wastage by switching to "Standby Mode" after 15 minutes and an energy efficient system to better the constraints specified by the Government to reduce the energy. The system is built using automation of energy usage and sensing the right parameters.

IV. RESULTS

Different graphs are shown below to depict the setup and thus ensuring proper utilization of the model proposed. Temperature vs Time is depicted to show the variation it observes with respect to time and Humidy is also mentioned to ascertain its changes and interrelation with Time and Temperature.Finally Real temperature and corrected temperature is depicted.

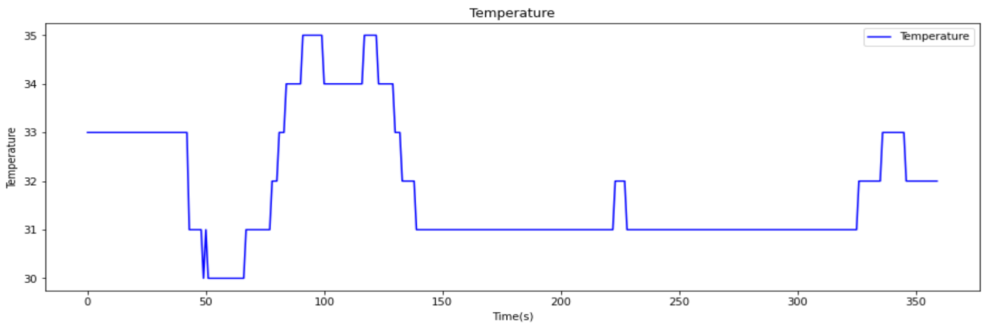

FIG 3:TEMPERATURE VS TIME

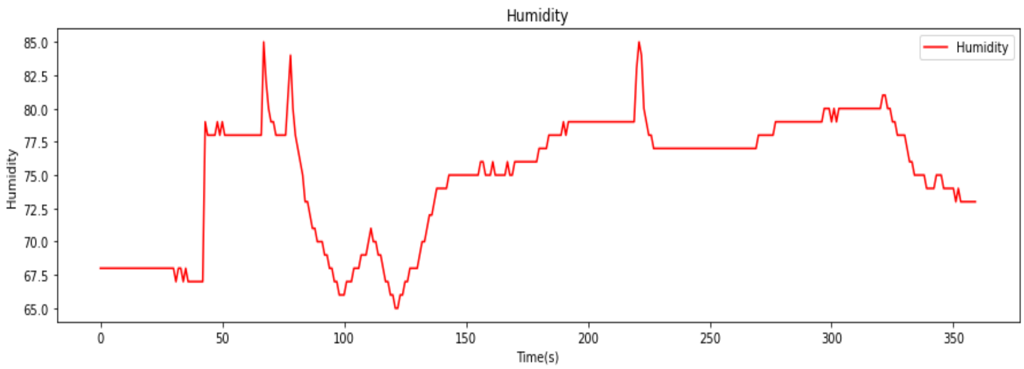

FIG 4:HUMIDITY VS TIME

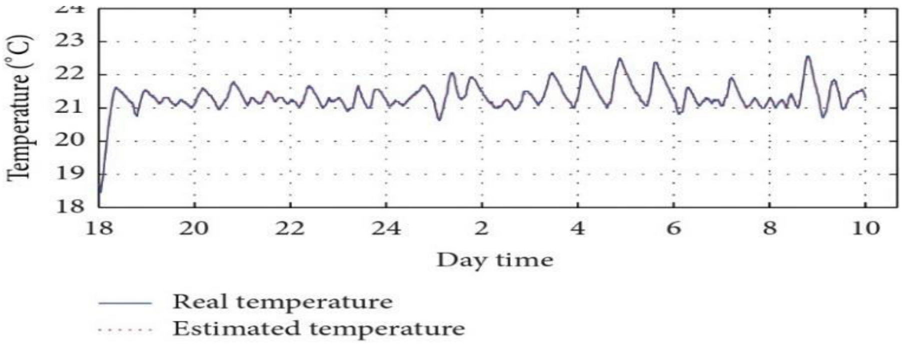

FIG 5:REAL TEMPERATURE VS ESTIMATED TEMPERATURE

V. CONCLUSION

Ensuring the effective usage of HVAC systems is one of the most predominant requirements to maintain better efficiency and thermal comfort to the user. By applying YOLO algorithm on sensor node data like the number of occupants to process an output to regulate and optimize the set-points of the HVAC system to enable better utilization of energy and also provide thermal comfort to the user. The energy efficiency is increased by using the proposed system. Occupancy data adds to the efficiency of the system data is sensed to actuate better and offer higher level of optimization to the set-points of HVAC systems.

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