SCHOOL OF COMPUTER SCIENCE ENGINEERING

SMART FIREFIGHTING HELMET

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Project report
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Abstract

Fire-fighting has been a problem since the medieval ages. Even with the advent of modern technology, we haven't been able to reduce fire accidents significantly. Our proposed project aims to use all relevant data, to remedy any fire accident. The project uses a variety of sensors and the collected data is processed and utilized to alert authorities and display meaningful results. All our sensors are integrated with one central microcontroller. The microcontroller is responsible for relaying the data to a shared database, from where the processed data is retrieved. Location data is broadcasted from the server to all clients in the nearby area.

The main idea of this project is to monitor the physical parameters around the fire-fighter in hazardous situations, the whole project is supposed to be mounted on the helmet of the individual. The parameters needed to be monitored are temperature, humidity, air condition i.e. levels of toxic and inflammable gases in the atmosphere nearby including the atmospheric pressure of the area.

There will be two interfaces of the project: a mobile application and a web interface. The mobile application which will report any abrupt change and will be used to send SoS messages to call for help and the web interface will be monitored by someone from outside so just in case if anything goes wrong or in case of abrupt parameter change, one can send help from outside.

Aim

Fire-fighting has been a problem since the medieval ages. Even with the advent of modern technology, we haven't been able to reduce fire accidents significantly. Our proposed project aims to use all relevant data, to remedy any fire accident. The project uses a variety of sensors and the collected data is processed and utilized to alert authorities and display meaningful results. All our sensors are integrated with one central microcontroller. The microcontroller is responsible for relaying the data to a shared database, from where the processed data is retrieved. Location data is broadcasted from the server to all clients in the nearby area.

Introduction

Firefighting is one of the toughest jobs in today's world,each and every day hundreds and thousands of firefighters put their life on stake for helping both nature and humanity. According to NFPA statistics over 100 casualties were recorded in 2019.

We have a novel helmet designed to advance current firefighting methods. By attaching various crucial sensors on the helmet, we will be able to gather important vitals about the environment such as temperature, CO_2 levels, atmospheric pressure, volume of total organic compounds, and much more while simultaneously sending this data in real-time over the Internet of Things platform to a remote database. We will then retrieve this information and create a unique app user interface that responds to the real-time changes in data to relay information across all individuals over watching the situation.

The firefighter helmet sends and retrieves information by using three sensors connected to a central microcontroller capable of connecting to nearby WiFi networks. When information from the environment is extracted, we are capable of sending this information using WiFi following the IOT protocol to a remote real-time database where it is stored and processed. When this information is retrieved, it is used to create an app user interface that displays the information in a real-time framework to show changes as they happen. This interface allows all subscribers to the web app to monitor the situation different firefighters are in and provide assistance when needed.

The microcontroller we used for this project is the NodeMCU board which is an Internet of Things enabled board built on top of the Arduino framework. We then attached several sensors to the board (DHT11 Temperature and Humidity Sensor, BMP180 Atmospheric and Pressure Sensor, and MQ3 –Flammable gas sensor) following the I2C (Inter-Integrated Circuit) protocol where we used a multi-master/multi-slave architecture to allow sensors to publish and receive data to the bus system. When the data is received by the NodeMCU microcontroller, the data is sent over WiFi to a real-time Google Firebase database where it is categorized by sensor and type of data. This information is then retrieved and displayed on an app user interface updated in real-time.

Literature review

[1]Compared with the traditional techniques of forest fire detection, a wireless sensor network paradigm based on a ZigBee technique was proposed. The proposed technique is in real time, given the exigencies of forest fires. The architecture of a wireless sensor network for forest fire detection is described. The hardware circuitry of the network node is designed based on a CC2430 chip. The process of data transmission is discussed in detail. Environmental parameters such as temperature and humidity in the forest region can be monitored in real time. From the information collected by the system, decisions for fire fighting or fire prevention can be made more quickly by the relevant government departments. This the abstract stated in [1]Forest fire detection system based on a ZigBee wireless sensor network by Junguo ZHANG, Wenbin LI, Ning HAN, Jiangming KAN E Higher Education Press and Springer-Verlag 2019

[2]The Navy program, Damage Control-Automation for Reduced Manning is focused on enhancing automation of ship functions and damage control systems. A key element to this objective is the improvement of current fire detection systems. As in many applications, it is desired to increase detection sensitivity and,more importantly increase the reliability of the detection system through improved nuisance alarm immunity. Improved reliability is needed, such that fire detection systems can automatically control fire suppression systems. The use of multi-criteria based detection technology continues to offer the most promising means to achieve both improved sensitivity to real fires,and reduced susceptibility to nuisance alarm sources. A multi-criteria early warning fire detection system, has been developed to provide reliable warning of actual fire conditions, in less time, with fewer nuisance alarms,than can be achieved with commercially available smoke detection systems. In this study a four-sensor array and a Probabilistic Neural Network have been used to produce an early warning fire detection system. A prototype early warning fire detector was built and tested in a shipboard environment. The current alarm algorithm resulted in better overall performance than the commercial smoke detectors, by providing both improved nuisance source immunity with generally equivalent or faster response times. This is the abstract stated in [2]Early Warning Fire Detection System Using a Probabilistic Neural Network by Susan L. Rose-Pehrsson, Sean J. Hart, Thomas T. Street, Frederick W. Williams, and Mark H. Hammond, Naval Research Laboratory, Chemistry Division, Washington, D.C. 20375-5342 Daniel T. Gottuk, Mark T. Wright, and Jennifer T. Wong, Hughes Associates, Inc., Baltimore, Maryland 21227-1652, © Springer Nature Singapore Pte Ltd. 2019

[3]A novel video smoke detection method using both color and motion features is presented. The result of optical flow is assumed to be an approximation of motion field. Background estimation and color-based decision rule are used to determine candidate smoke regions. The Lucas Kanade optical flow algorithm is proposed to calculate the optical flow of candidate regions. And the motion features are calculated from the optical flow results and use to differentiate smoke from some other moving objects. Finally, a back-propagation neural network is used to classify the smoke features from non-fire smoke features. Experiments show that the algorithm is significant for improving the accuracy of video smoke detection and reducing false alarms. This is the abstract stated in [3]Video Fire Smoke Detection Using Motion and Color Features by Yu Chunyu, Fang Jun, Wang Jinjun and Zhang Yongming*, State Key Laboratory of Fire Science, USTC, Number 96 Jin Zhai Road, Hefei, Anhui, China 2019 Springer Science+Business Media, LLC. Manufactured in The United States

[4] The possibility of detecting small forest fires with the help of a simple and cheap lidar operating at 0.532-μm wavelength up to distances of about 6.5 km is demonstrated. The values of the signal-to-noise ratio (SNR) achieved in the experiments are consistent with theoretical estimations obtained by computational

modeling of the lidar detection process, including simulation of the smoke-plume shape and of the laser beam–plume interaction. This model was used to assess the potential of the lidar technique for fire surveillance in large forest areas. In particular, the upper limiting range for effective detection (SNR>5) of small localized fires in dry- and clear-weather conditions is estimated at 7–15 km depending on operation mode, burning rate, and observation geometry. This is the abstract stated in [4]Detection of small forest fires by lidar by Utkin, A., Lavrov, A., Costa, L. et al. Detection of small forest fires by lidar. ApplPhys B 74, 77–83 29 November 2019 • © Springer-Verlag 2019

[5]Forest fire (wildfire) is one of the common hazards that is accrued in the forest. Fire monitoring has three phases: pre-fire (take appropriate action for fire control), during fire (detection of fire and planning to control fire), post-fire (damage assessment and mitigation planning). In older days, manually fire detection approach is used. In current days, satellite- based surveillance system is used to detect forest fire but this works when fire is spread in the large area. So these techniques are not efficient. According to a survey, approximately 80% losses are accrued in the forest due to the late detection of fire. So to overcome this problem, we use the Internet of things technology. In this paper, early fire detection model has been proposed with the help of the Raspberry Pi microcontroller and required sensors. Centralized server is used for storing the data and analyzing that data. Feed-forward fully connected neural network is used for prediction purpose. Then, an alert message is sent to the admin and to the people within the proximity. This is the abstract stated in [5]Forest Fire Detection System Using IoT and Artificial Neural Network by VinayDubey, Prashant Kumar and Naveen Chauhan Department of Computer Science and Engineering, National Institute of Technology Hamirpur, Hamirpur, Himachal Pradesh, India © Springer Nature Singapore Pte Ltd. 2019

[6] An integrated system based on video surveillance is presented for automatic fire detection and suppression. The system is composed of two modules, including fire detection and fire suppression. The fire detection module makes full use of traditional CCD cameras for fire recognition. Some spatio-temporal features, such as color and motion, are extracted to detect fire in real time by utilizing sequential image processing techniques. Once a fire is detected, the system will control the fire suppression module to extinguish the fire automatically. It mainly consists of control device, mobile device, and water gun. Experiments performed in a large space hall show that the integrated system can detect a fire about a few seconds after ignition and automatically suppress the fire quickly. This is the abstract stated in [6]An integrated fire detection and suppression system based on widely available video surveillance by Feiniu Yuan © Springer-Verlag 2019

[7] In this paper, we have proposed and designed a hybrid system that is able to detect fire breakout, gas leakage and noise pollution as well as providing location of the affected area and opening fire extinguish system. Raspberry Pi is integrated with

MQ-5 sensor, humidity sensor, flame sensor, sound sensor and camera module. A 360° servo motor is accumulated with a camera module to capture affected locations even at any angle. To increase the reliability of this system, an authorized person is assigned to assess the real situation. If fire is detected, the camera module takes a snapshot of the affected region and sends it to the admin's email through 802.11n LAN wireless module. Different sensors' value also transmits to the server through that module in one-minute intervals. Moreover, a buzzer is activated in the control room when data and pictures are sent to the admin. If the admin confirms the incident, the system will raise the alarm in the whole workplace, uncover the water valve of the affected region and send a message to the owner and nearby fire brigade. Thus, a garment can secure the workplace for its workers. This the the abstract stated in [7] IoT-Based Smart Monitoring System to Ensure Worksite Safety—A Context of Garment Industry in Bangladesh by Masum A.K.M., ShanA-Alahi A., Al Noman A., Uddin M.N., Azam K.I., Rakib M.G.S. (2020) Lecture Notes in Networks and Systems, vol 89. Springer 2020, Singapore

[8] Using efficiently the wireless sensor networks based on IEEE 802.15.4/zigbee remains a real challenge for the forest fire detection and monitoring applications. The most relevant question is how we can maintain a long lifetime for the network with the need of fast and active sensor devices for the fire detection. In this paper, we propose a new approach Auto Organization, Adaptive frame Periods for forest Fire detection for multi-level optimization based on the network topology reorganization, and the frame activity period optimization according to the energy preservation and also the fire detection timing constraints. The reorganization is made locally according to the node states with regard to the fire detection events. It is made by a new association/re-association procedure that creates links and paths between nodes with respect to the two constraints. According to the network topology, an adaptive frame periods adjustment procedure is executed to select the suitable timing periods that reduce the sensor node activities without exceeding the timing constraints. The simulation results show superiority and efficiency of the proposed approach for the energy preservation, even if we consider a large network size. This abstract is stated in [8]Auto Organization approach with adaptive frame periods for IEEE 802.15.4/zigbee forest fire detection system by Ouni, S., TrabelsiAyoub, Z. & Kamoun, F. Auto-organization approach with adaptive frame periods for IEEE 802.15.4/zigbee forest fire detection system , SpringerVerlag 2019

[9] The term IoT: Internet of Things paradigm provides an environment which facilitates the implementation of new technology in all social environments. Forests are one of the important aspects in our social life, which provides vegetation, place to wild animals, and ecosystem services that are critical to human welfare. But every year, they are attacked by wildfire; due to this, we lose huge vegetation, animal life and create air pollution. In this paper, we proposed an IoT-based model to provide a solution to the wildfire. The paper describes an approach to detect and reduce the effect of wildfire. We place smoke and temperature sensor poles in specific locations

in the forest and allow the collection of data from these sensors continuously to the cloud. In the cloud, we define an API to analyze the data and if any suspicious data is found, the API automatically sends necessary orders to drones, which can be deployed in that suspicious location and spread fire suppression gas to reduce the effect of wildfire, and also an instruction is sent to Central Monitoring System of Wildfire. This abstract is stated in [9]Monitor and Abolish the Wildfire Using Internet of Things and Cloud Computing By Ramesh P.A., Siva Prasad Y.A., Chidananda G. (2020) Monitor and Abolish the Wildfire Using Internet of Things and Cloud Computing. In: Venkata Krishna P., Obaidat M. (eds) Emerging Research in Data Engineering Systems and Computer Communications. Advances in Intelligent Systems and Computing, vol 1054. Springer (2020), Singapore

[10] IOT is one of the dominant positions all over the world in technological development. It is another information industry following computer, Internet and mobile communication. In Internet of Things technology the fire-fighting, fire monitoring and safety management system are an important applications. It discusses the IOT system framework for fire-fighting, planning, and monitoring. It gives development points for providing research and development of IOT in fire-fighting, monitoring and safety management. Intelligent fire monitoring systems need a key of accurate and effective firefighting software design. This paper also discusses the requirements of users and key main issues of wireless sensor network hardware and software for monitoring fire. It discusses in detail the function of each module and implementation of that module in a detailed way. It also discusses application features of IOT technology and Wireless Sensor Network technology for fire-fighting requirements. [10]Development and Application of the Smart Helmet for Disaster and Safety", MingiJeongIoT Research Division Electronics and Telecommunications Research Institute Daejeon, Republic of Korea, Hyesun Lee IoT Research Division Electronics and Telecommunications Research Institute Daejeon, Republic of Korea,MyungnamBaeIoT Research Division Electronics and Telecommunications Research Institute Daejeon, Republic of Korea, Dong-Beom Shin IoT Research Division Electronics and Telecommunications Research Institute Daejeon, Republic of Korea SunHwa Lim IoT Research Division Electronics and Telecommunications Research Institute Daejeon, Republic of Korea, Kang Bok Lee IoT Research Division Electronics and Telecommunications Research Institute Daejeon, Republic of Korea, 978-1-5386-5041- 7/18/$31.00 ©2019 IEEE

[11] In this study, a ContikiOS based Library Fire Detection System proposed to provide coverage for a large physical area and to increase throughput by using a multi-hop wireless sensor network. Moreover, the system has the cloud feature of Google's Firebase for online data storing and Android application to notify the users in case of emergency. Furthermore, the network can be expanded without adding extra sink nodes to collect data. Benefiting from a multi-hop network, additional source nodes can send temperature values via relay nodes in case of low transmission power with sink nodes. According to the test results, the system has

responded to the changes in temperature and prompted a warning/alarm message in approximately 4 seconds using a multi-hop network. Additionally, the system can notify the users in case of emergency. [11] A Cloud and Contiki based Fire Detection System using Multi-Hop Wireless Sensor Networks, ICEMIS '18: Proceedings of the Fourth International Conference on Engineering & MIS 2018June 2018 Article No.: 66 Pages 1–5

[12] Most of the cities in Latin America must face the phenomenon of settlements occupied by people displaced by violence or poverty. These communities build their homes in unstable terrains or use inadequate materials (wood, cardboard). In Colombia, these settlements have suffered great tragedies due to uncontrollable wildfires. Traditionally, fire alarm systems are not oriented to solve the problems of marginalized people. This paper describes the design and implementation of a low-cost fire alarm system for two settlements in Popayán - Colombia. The system uses Internet of things technologies and sends alarms to the fire station. [12] Aguirre J., Ordóñez A., Ordóñez H. (2017) Low-Cost Fire Alarm System Supported on the Internet of Things. In: Solano A., Ordoñez H. (eds) Advances in Computing. CCC 2017.Communications in Computer and Information Science, vol 735. Springer, Cham

[13] Internet of Things (IoT) has garnered a good chunk of limelight with the emerging advancements in technologies. It comprises heterogeneous devices embedded with sensors, which are able to communicate directly with each other without any human intervention. In this paper, a survey has been done on authentication and privacy in IoT using Blockchain during Forest Fire. The purpose of Blockchain is to design a data structure to construct a distributed ledger of transactions that cannot be tampered by any third party. The blockchain is formed by cryptographically linked blocks of transactions. Public-key cryptography is used to sign transactions among users in blockchain technology. It achieves privacy very strongly as it is very difficult to modify or delete blocks of data which are stored in the ledger of blockchain. [13] Datta S., Das A.K., Kumar A., Khushboo, Sinha D. (2020) Authentication and Privacy Preservation in IoT Based Forest Fire Detection by Using Blockchain – A Review. In: Nain N., Vipparthi S. (eds) 4th International Conference on Internet of Things and Connected Technologies (ICIoTCT), 2019. ICIoTCT 2019.Advances in Intelligent Systems and Computing, vol 1122. Springer, Cham

[14] Enhancements in the communication technologies have led to the origin of Wireless Sensor Networks. They allow inter-transmission of the information with or without using the Internet facilities. The detection of forest fire is one of the crucial utilizations of WSN, and our matter of concern is to focus on the detection of fire and monitoring the transfer of information. In this regard, we design an efficient real-time setup which accumulates the information from various places, and uploads them on the remote web server. Through WiFi, the information from numerous places having an Internet facility is transmitted to an intermediary server, and the same is uploaded

on the remote web server using the Internet. We employ a NodeMCU micro-controller which has a built-in ESP 8266 Wi-Fi module for establishing steadfast communication within the network. Moreover, we implement the proposed elucidation on the Arduino Integrated Development Environment (IDE). [14] Ahlawat H.D., Chauhan R.P. (2020) Detection and Monitoring of Forest Fire Using Serial Communication and Wi-Fi Wireless Sensor Network. In: Singh P., Bhargava B., Paprzycki M., Kaushal N., Hong WC. (eds) Handbook of Wireless Sensor Networks: Issues and Challenges in Current Scenarios. Advances in Intelligent Systems and Computing, vol 1132. Springer, Cham

Problem Statement

Usually carbon dioxide levels and other hazardous gas levels are measured using separate instruments. This becomes inefficient as more equipment is required to measure hazardous gas levels. Alerts are broadcasted through physical means and are not automated. Evacuation protocols are executed without automation. All our sensors are integrated with one central microcontroller. The microcontroller is responsible for relaying the data to a shared database, from where the processed data is retrieved. Location data is broadcasted from the server to all clients in the nearby area.

Proposed Solution

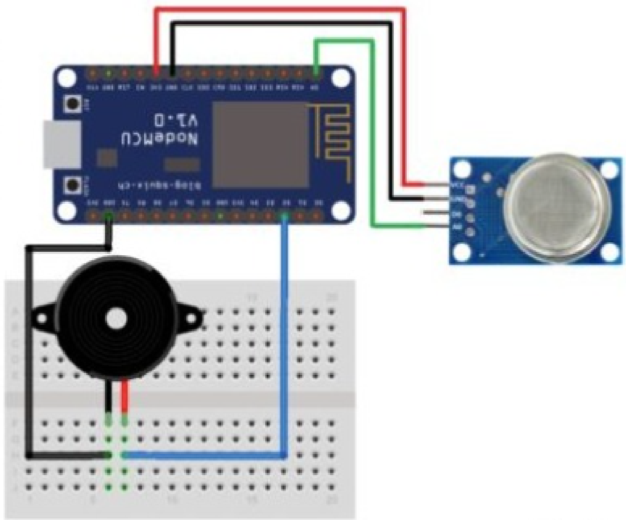
Researchers have developed the new software framework to integrate a wide range of devices and services and efficiently manage resources.

In addition, based on this, they developed a smart helmet to respond to disaster safety accidents. The smart helmet collects, generates, and converts information on sensors (infrared camera, electro optical camera, drone camera, oxygen residual sensor, 6- axis inertial sensor, and smart watch) and it can be monitored through head mounted display(HMD) and the Command Center .

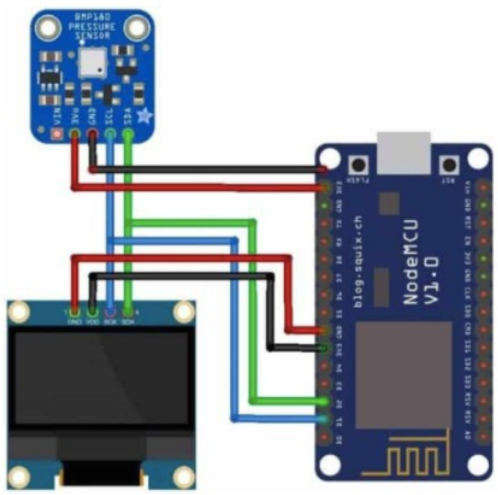
Finally, they developed a simulator and generated data based on scenarios, and also tested all devices and services outdoors.

SENSORS USED

- DHT11 – Temperature and Humidity Sensor 7: DHT11 is a low-cost digital sensor for sensing temperature and humidity. This sensor can be easily interfaced with any micro-controller such as Arduino, Raspberry Pi etc. to measure humidity and temperature instantaneously
- MQ3 – Flammable Gas Sensor: MQ3 Flammable gas sensor for detecting a wide range of gases, including Alcohol, benzene, CO, and methane. It is ideal for use in the office or factory. The MQ3 gas sensor has high sensitivity to methane, carbon mono-oxide and LPG, also sensitive to inflammable gases. BMP 180 - Atmosphere Pressure Sensor:



- BMP180 -- is one of the sensors of the BMP XXX series. They are all designed to measure Barometric Pressure or Atmospheric pressure. BMP180 is a high precision sensor designed for consumer applications. Barometric Pressure is nothing, but the weight of air applied on everything. The air has weight and wherever there is air its pressure is felt.



Experimental Details

Node MCU

NodeMCU is a low-cost open source IoT platform.It initially included firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which was based on the ESP-12 module. Later, support for the ESP32 32-bit MCU was added.

Both the firmware and prototyping board designs are open source.

The firmware uses the Lua scripting language. The firmware is based on the eLua project and built on the Espressif Non-OS SDK for ESP8266. It uses many open-source projects, such as lua-cjson and SPIFFS. Due to resource constraints, users need to select the modules relevant for their project and build a firmware tailored to their needs. Support for the 32-bit ESP32 has also been implemented.

THINKSPEAK

ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize and analyze live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by your devices to ThingSpeak.

With the ability to execute MATLAB code in ThingSpeak you can perform online analysis and processing of the data as it comes in. ThingSpeak is often used for prototyping and proof of concept IoT systems that require analytics.

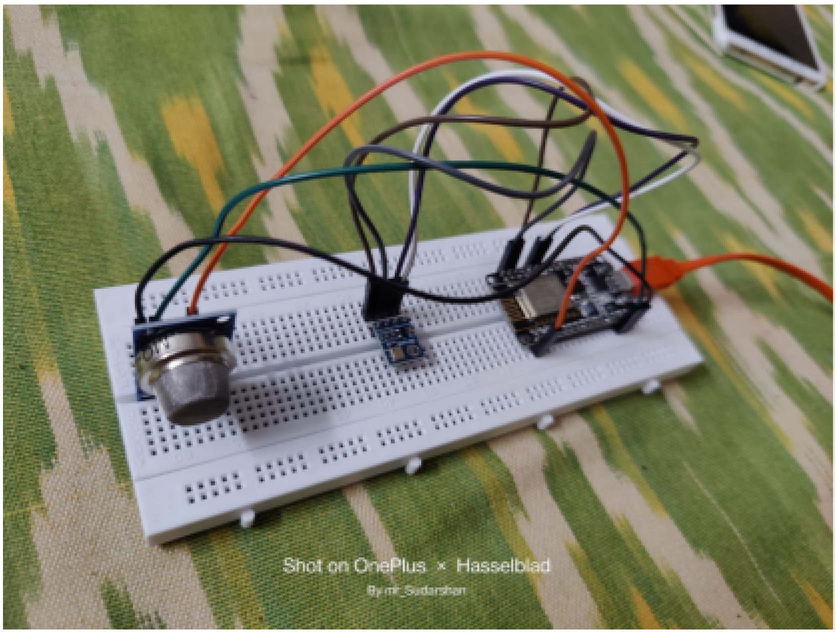
The MVVM architecture, which is used widely by many companies, was found to be the best fit for this application. Research was also done for finding the best dependency injection framework for the application.The benchmarks for the Koin and Dagger framework seemed to be promising.We proceeded with the Koin framework as it provides a simpler DSL (Domain Specific language) than the Dagger framework.

The application uses the ThingSpeakKotlin API to retrieve the data from the NodeMCU microcontroller.

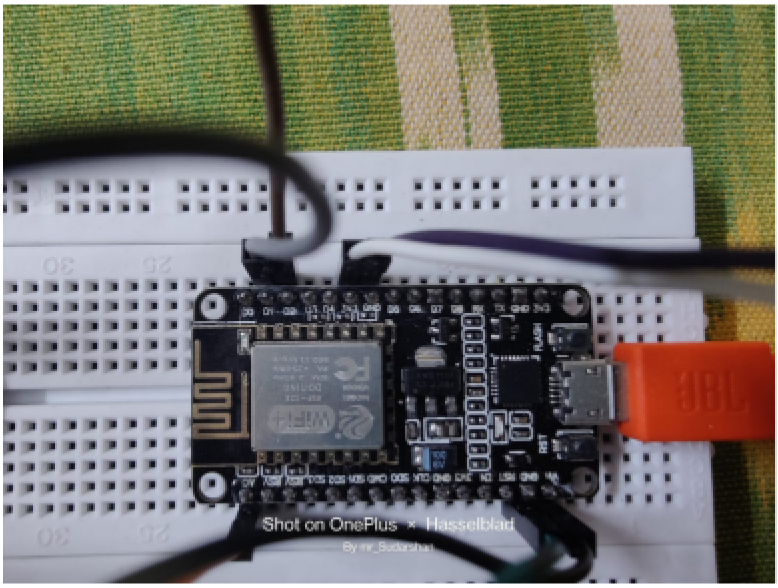
NODE MCU CODE LINK

https://codeshare.io/nzXwLn

Results and Discussion



Circuit Snapshots



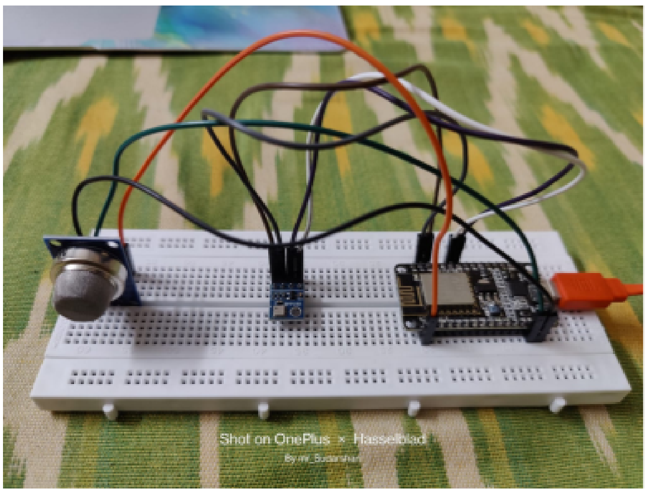


Figure. DHT11 Temp and BMP180 sensors

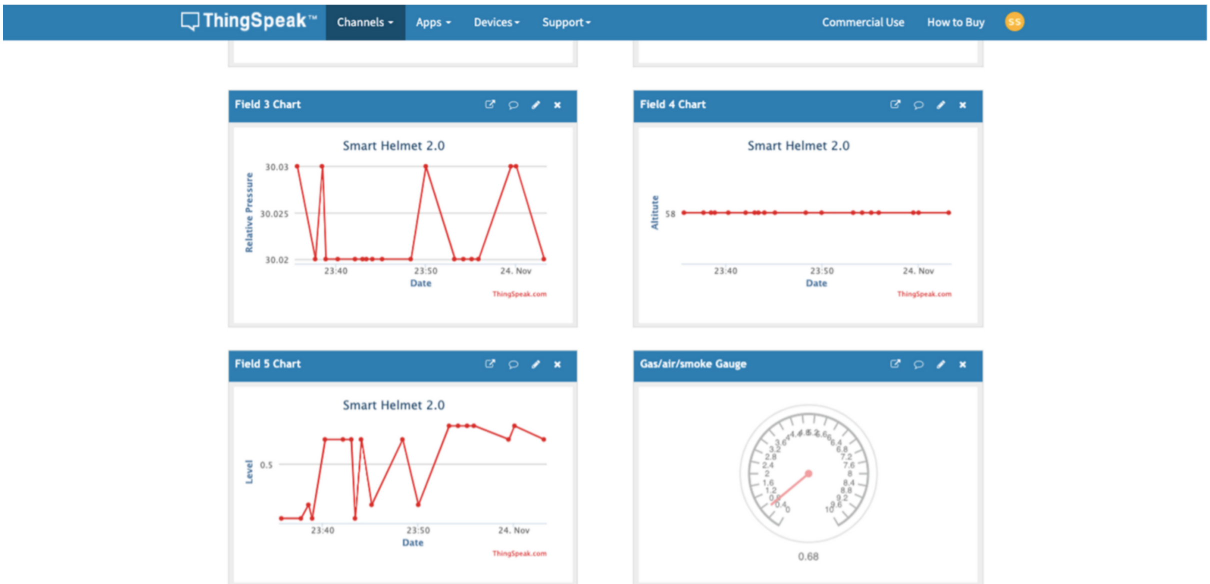


Figure. MQ3 Sensor

Conclusion

At the end of completing this project we aim to achieve the development of following product features. The sentinel fire fighter helmet will send and retrieve information by using six sensors connected to a central microcontroller capable of connecting to nearby WiFi networks. When information from the environment will be extracted, we will be capable of sending this information using WiFi following the IOT protocol to a remote real-time database where it is stored and processed. When this information will be retrieved, it will be used to create a app user interface that will display the information in a real-time framework to show changes as they happen. This interface will allow all subscribers to the app to monitor the situation different firefighters are and providing assistance when needed.

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[8] Ouni, S., TrabelsiAyoub, Z. &Kamoun, F. , Auto-organization approach with adaptive frame periods for IEEE 802.15.4/zigbee forest fire detection system , Auto-organization approach with adaptive frame periods for IEEE 802.15.4/zigbee forest fire detection system , Springer-Verlag 2019

[9] Ramesh P.A., Siva Prasad Y.A., Chidananda G. , Monitor and Abolish the Wildfire Using Internet of Things and Cloud Computing , Advances in Intelligent Systems and Computing, vol 1054. Springer (2020), Singapore

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[11] A Cloud and Contiki based Fire Detection System using Multi-Hop Wireless Sensor Networks, ICEMIS '18: Proceedings of the Fourth International Conference on Engineering & MIS 2018June 2018 Article No.: 66 Pages 1–5

[12] Aguirre J., Ordóñez A., Ordóñez H. (2017) Low-Cost Fire Alarm System Supported on the Internet of Things. In: Solano A., Ordoñez H. (eds) Advances in Computing. CCC 2017.Communications in Computer and Information Science, vol 735. Springer, Cham

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[14] Ahlawat H.D., Chauhan R.P. (2020) Detection and Monitoring of Forest Fire Using Serial Communication and Wi-Fi Wireless Sensor Network. In: Singh P., Bhargava B., Paprzycki M., Kaushal N., Hong WC. (eds) Handbook of Wireless Sensor Networks: Issues and Challenges in Current Scenario's. Advances in Intelligent Systems and Computing, vol 1132. Springer, Cham