VIVEKANAND EDUCATION SOCIETY'S INSTITUTE OF TECHNOLOGY
Department of Computer Engineering

Project Report on

FireBird

In partial fulfillment of the Fourth Year, Bachelor of Engineering (B.E.) Degree in Computer Engineering at the University of Mumbai Academic Year 2017-2018

Submitted by
Aniket Bote (D17 - C, Roll no - 10)
Roshan Devadiga (D17 - C, Roll no - 17)
Devashish M Gopalani (D17 - C, Roll no - 20)
Bhavesh Khubnani (D17 - C, Roll no - 31)

Project Mentor
Mr. Richard Joseph

(2019-20)

VIVEKANAND EDUCATION SOCIETY'S INSTITUTE OF TECHNOLOGY
Department of Computer Engineering

Certificate

This is to certify that ***Aniket Bote, Roshan Devadiga, Devashish M Gopalani and Bhavesh Khubnani*** of Fourth Year Computer Engineering studying under the University of Mumbai have satisfactorily completed the project on "***FireBird***" as a part of their coursework of PROJECT-II for Semester-VIII under the guidance of their mentor ***Prof. Richard Joseph*** in the year 2019-2020 .

This thesis/dissertation/project report entitled ***FireBird*** by ***Aniket Bote, Roshan Devadiga, Devashish M Gopalani and Bhavesh Khubnani*** is approved for the degree of ***Bachelor of Engineering in Computer Engineering***.

Programme Outcomes	Grade
PO1,PO2,PO3,PO4,PO5,PO6,PO7, PO8, PO9, PO10, PO11, PO12 PSO1, PSO2	

Date:

Project Guide:

Project Report Approval
For
B. E (Computer Engineering)

This thesis/dissertation/project report entitled ***FireBird*** by ***Aniket Bote, Roshan Devadiga, Devashish M Gopalani and Bhavesh Khubnani*** is approved for the degree of ***Bachelor of Engineering in Computer Engineering***.

Internal Examiner

External Examiner

Head of the Department

Principal

Date:
Place:

Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

---	---
---	---
(Aniket Bote, 10)	(Roshan Devadiga, 17)
---	---
---	---
(Devashish M Gopalani, 20)	(Bhavesh Khubnani, 31)

Date:

ACKNOWLEDGEMENT

We are thankful to our college Vivekanand Education Society's Institute of Technology for considering our project and extending help at all stages needed during our work of collecting information regarding the project.

It gives us immense pleasure to express our deep and sincere gratitude to Assistant Professor **Mrs. Priya R.L** (Project Guide) for her kind help and valuable advice during the development of project synopsis and for her guidance and suggestions.

We are deeply indebted to Head of the Computer Department **Dr.(Mrs.) Nupur Giri** and our Principal **Dr. (Mrs.) J.M. Nair ,** for giving us this valuable opportunity to do this project.

We express our hearty thanks to them for their assistance without which it would have been difficult in finishing this project synopsis and project review successfully.

We convey our deep sense of gratitude to all teaching and non-teaching staff for their constant encouragement, support and selfless help throughout the project work. It is great pleasure to acknowledge the help and suggestion, which we received from the Department of Computer Engineering.

We wish to express our profound thanks to all those who helped us in gathering information about the project. Our families too have provided moral support and encouragement at several times.

Computer Engineering Department
COURSE OUTCOMES FOR B.E PROJECT

Learners will be to,

Course Outcome	Description of the Course Outcome
CO 1	Able to apply the relevant engineering concepts, knowledge and skills towards the project.
CO2	Able to identify, formulate and interpret the various relevant research papers and to determine the problem.
CO 3	Able to apply the engineering concepts towards designing solution for the problem.
CO 4	Able to interpret the data and datasets to be utilized.
CO 5	Able to create, select and apply appropriate technologies, techniques, resources and tools for the project.
CO 6	Able to apply ethical, professional policies and principles towards societal, environmental, safety and cultural benefit.
CO 7	Able to function effectively as an individual, and as a member of a team, allocating roles with clear lines of responsibility and accountability.
CO 8	Able to write effective reports, design documents and make effective presentations.
CO 9	Able to apply engineering and management principles to the project as a team member.
CO 10	Able to apply the project domain knowledge to sharpen one's competency.
CO 11	Able to develop professional, presentational, balanced and structured approach towards project development.
CO 12	Able to adopt skills, languages, environment and platforms for creating innovative solutions for the project.

Abstract

In the world where fire accidents are increasingly common and the brave first responders always risk their lives to save the lives of others. Unfortunately, history tells that these brave first responders do not survive most of the time. To save as many lives as possible it is important to leave dangerous tasks to machines. One such device is drone, it provides great maneuverability and doesn't risk any personnel. Drones can also gather information at greater speed, reliability and are also able to drop items.The proposed solution tackles all the problems using drone equipped with sensors, Ability to detect fires and monitor the risk of fire spreading to nearby structures. Generation of a heat map to understand which regions have higher temperatures and cater to them on a priority basis. Generation of 2D map for firefighting personnel to get a better information on positions of trapped victims in fires and determine best course of action. Ability to put out a fire in case of unreachable areas or in situations where using unmanned drone is the safest approach. Generation of toxicity reports and identify fire pattern incase of wildfires which will be useful for evacuations.

INDEX

Chapter 1 : Introduction

1.1 Introduction:

Fire related accidents are increasingly becoming common. Reading articles like these “Fire outbreak is the third biggest risk to business continuity and operations, according to India Risk Survey (IRS) 2018. In IRS 2016, fire outbreak was ranked eighth biggest risk to businesses.” only makes the statement more valid. And along with it having casualties of firemen like “2 firemen who died in well tragedy were feted for work-TOI” only makes us question the system to its core.Hence in this project we aim to reduce the burden of firemen by making a drone, the actual first responder instead of a fireman and hence potentially saving actual human lives. This is an IOT based drone system which will provide valuable information about the situation and save lives of people directly affected by the tragedy and the first responders. The proposed approach will help the firemen to gage the fragile situation before hand by checking if there is any human inside and also check for harmful gases if any. Even though the percentage is less but the sheer increase in the amount of fire related accidents leading to huge amount of first responders taking action makes this issue a serious one and hence cant be ignored. Also, along with it drone will help to improve response to the tragedy and hence save lives of people trapped inside. Along with it a functionality of gaging distance from drone and dropping a Fire Extinguisher Ball inside the fire to control the fire quickly will only help the firemen.

1.2 Motivation:

Whenever a fire breaks out, firefighters have to reach the location of casualty as fast as possible to make sure the loss is minimum.This may not be possible as many times there are many unknown variables present like from where to enter the buildings, where are stranded human beings, what are the gases and temperature present inside buildings.

1.3 Problem Definition:

Increase in the frequency of fire outbreaks is a serious issue which is faced by every urban centre in this world and the firemen dealing with this situation often find it difficult to make out which places are ablaze, where humans and animals are stranded and from where can they actually rescue the injured party.Smoke generated due to fire blocks the vision of firemen and makes it impossible for firemen to see the affected area and help the casualties. If smoke isn't an issue, carrying a water-pipe/fire-extinguisher in a hazardous place where they don’t even have any idea about the

whereabouts is a threat to their lives as well. To ease this process, a solution is needed which is equipped with the most recent technologies. Firefighter drone is our approach as the solution. Increase in the frequency of fire outbreaks is a serious issue which is faced by every urban centre in this world and fireme often find it difficult to make out which places are ablaze, where humans and animals are stranded and what would be safest entry,exit and rescue points. The location and intensities of fire is unknown, which causes problems during the rescue operation. Smoke generated due to fire blocks vision of firemen and makes it difficult for firemen to see the affected area. Smoke generated due to burning of items in a household is sometimes toxic in nature which hinders the rescue process.If smoke isn't an issue, carrying a water-pipe/fire-extinguisher in a hazardous place where firefighters have limited information is dangerous as well. To ease this process, a solution is needed which is equipped with the data gathering technologies which can map environment in real time and do so without endangering any lives.

1.4 Existing System:

1. Robofire:
    a. Robofire is the latest asset of our fire department. It was recently used in a major fire outbreak in MTNL building, Bandra.
    b. Robofire was used by the fire department to control a level-4 fire.
    c. It is a remote controlled instrument and trained individuals are required to guide this bot.
    d. This bot can travel only on land and is able to capture images at the spot of accident.
    e. It is also able to carry the water pipe to the spots where it is difficult for a fireman to reach.
    f. Hence, to carry out all the above functionalities it is the robot is quite big, heavy and space occupying.

2. Fire Tender:
    a. ‘Fire Tender’, ‘Fire truck’, ‘ Fire engine’ and ‘Fire appliance’ are used interchangeably.

b. The primary purposes of a fire engine include transporting firefighters to an incident scene, providing water with which to fight a fire, and carrying other equipment needed by firefighters.
c. Specialized apparatus are used to provide hazardous materials mitigation and technical rescue.
d. A typical modern fire engine will carry tools for a wide range of firefighting tasks, with common equipment including a pump, a water tank, hoses, ground ladders, hand tools, self-contained breathing apparatuses, BLS (basic life support) equipment, and first aid kits.
e. Many fire vehicles are based on standard vehicle models (although some parts may be upgraded to cope with the demands of the vehicles' usage).
f. They are normally fitted with audible and visual warnings, as well as communication equipment such as two-way radios and mobile computer technology.

1.5 Drawbacks of Existing Systems:

1. Traditional Methods
    a. This includes using fire tankers and ladders to quench the fire. This solution has been used since centuries but modern urban centers have become more dense in the last decade, hence these solutions have numerous shortcomings which have resulted in many more casualties.

       Ladders cannot reach high rise buildings which have popped up in the last decade.
    b. Electrical fires have become more common and if water is used to quench electrical fires more casualties may occur, hence information gathering is a must. Traditional systems are reactive and rely mostly on human instinct and instantaneous decision making due to lack of information. Moreover, lack of proper equipment to deal with a situation is also an important drawback of **Traditional Methods**.

2. Robofire:
    a. Robofire is very heavy as it has to incorporate all the various functionalities.
    b. The robot works only on land thus it won’t have the ability to quench fires which are present at great height.

c. It requires human assistance to operate.
d. The camera installed on it takes photos with low quality.
e. The cost of the robot is Rs. 1 crore.

1.6 Relevance of the Project:

Fire related accidents are increasingly becoming common. Fire outbreak is the third biggest risk to business continuity,operations and human lives.

To reduce the damage and save as many lives as possible it is important to leave dangerous tasks to machines. One such device is drone, it provides great maneuverability and doesn't risk any personnel. Drones can also gather information at greater speed,reliability and are also able to drop items. Also the smoke generated due to fire, blocks the vision of firemen and makes it impossible for firemen to see the affected area and help the casualties.

1.7 Methodology Used:

The methodology that we plan to use for the project is the Agile Methodology. Agile methodology works in short cycles of its phases. All the phases get updates as the project advances. There are six phases in this methodology

1. Requirement Gathering:- In this phase, all the requirements that need to be fulfilled will be discussed. Also, the equipment required to make the drone will be listed. The data required for the machine learning will be collected.
2. Planning:- The entire plan to make the Firefighter drone will be made along with the schedule to complete the project in time.
3. Design:- The complete design of the final product will be made so that everything becomes clear and the team can start making the project according to the design.
4. Develop:- The process to develop the final product begins here. Step by step development of the product will be done according to the plan and design.
5. Integration and Testing:- In this phase the product developed till now will be tested. In future stages of the project, the different parts developed in every cycle get integrated and then testing is done.

6. Evaluation and Feedback:- In this phase the mentor will evaluate the progress and give valuable feedback on how to proceed. This is a very important phase as it gives the much required review.

7. Agile Methodology has been chosen as it gives us time to time feedback which will help us to improve our project. Also, working in cycles gives us a chance to upgrade the plan and design for the better. Frequent interaction with the mentor would keep us in proper path to successful completion of the project.

Chapter 2: Literature Survey

2.1 Research Papers Referred:

1. **"Altitude Detection using altimeter on raspberry pi-MPL3115A2"**

The MPL3115A2 employs a MEMS pressure sensor with an I2C interface to provide accurate Pressure/Altitude and Temperature data. The sensor outputs are digitized by a high resolution 24-bit ADC. Internal processing removes compensation tasks from the host MCU system. It is capable of detecting a change in only 0.05 kPa which equates to a 0.3m change in altitude. Demonstration with raspberry pi using python code.

2. **"Embedded Autonomous Robotic System for Alive Human Body Detection and Rescue operation"** by Rajeev Joshi,Pratap Chandra Poudel,Pankaj Bhandari of Department of Electronics & Communication, N.I.T., Raichur, Karnataka, India. The paper proposes a new approach for detecting alive human beings in devastating environments using a low cost autonomous robot.The proposed alive human body detection system uses a specific set of sensors that gives information about the presence of a living human body and a low quality camera to acquire a video of scene of the environment.The data and information required to be acquired and processed for rescue operation are less. So, it is very cost effective and faster to be applied in real-time operating environment.

3. **"*A detection method using ultrasonic sensors for avoiding a wall collision of Quadrotors*"** *by Kenjiro Niwa,Keigo Watanabe and Isaku Nagai.* Unmanned aerial vehicles (UAVs) can be applied as an inspection method for infrastructures such as tunnels, bridges, etc. In particular, UAVs being capable of vertical takeoff and landing (VTOL) are suitable for photographing inspection sites using cameras, because it need not use a runway and can hover.From the obtained experimental results, the mounting position of the sensor fixing device, which can detect the wall surface existing in all directions around the airframe, was determined.However, a measurement distance error of about 40 mm occurred depending on the position of the object to be detected.

4. **3D environmental mapping of mobile robot using a low-cost depth camera** by Kazuya Nakajima, Chinthaka Premachandra, Kiyotaka Kato The light weight of ultrasonic sensors makes them useful for collecting environment information from mobile robots. Ultrasonic sensors are generally used in a circular formation in surface-moving robots, but this is not suitable for small flying robots, which require small size and light weight. Here we created a movable ultrasonic range

sensor by combining a small, lightweight servomotor and a single ultrasonic range sensor. This sensor could perform 360° measurements of the distance between objects and the robot. We furthermore constructed a measurement system to perform 3D environment mapping and self-localization by equipping a small flying robot with this movable ultrasonic range sensor and a ground-facing ultrasonic range sensor for altitude measurements. We verified the system by means of a flight test and found that 3D environment mapping and self-localization were realized in real time.

5. **Measurement of kinematics of a flying disc using an accelerometer** by yuji ohgi In this study, a tri-axial accelerometer was attached to a flying disc to measure the kinematics during flight. A subject performed disc throwing. High speed video cameras were used to capture release and end points to validate boundary measurements. Results of the acceleration wave showed a sinusoidal pattern during the flight phase. According to the results of an additional verification experiment, we classified components of the acceleration wave during the flight phase to estimate the angular velocity of the disc, and validated it using high speed video cameras.

2.2 Articles referred:

This newspaper article narrates the incident of a fire outbreak at MTNL building, Bandra in July'19. For the first time a robot named RoboFire was used to extinguish a fire outbreak. The fire was a level 4 fire. This robot has the ability to release 3,800 litres of water in just a few minutes. The robot was operated by a human and the cost of the robot is of Rs. 1 crore. Everybody was evacuated safely from the building and no casualties were reported. The latter reports also pointed out that the bot was unable to capture clear images at the site of accident to perform further analysis with its help.

2.3 Interactions with domain experts:

Interviewee's name: Shri H.D.Parab

Address: Ward E, Bapurao Jagtap Marg, Near Municipal Corporation, Byculla, Mumbai, Maharashtra 400008

Occupation: Deputy Chief Fire Officer (Mumbai)

Interview and Answers :

Q1.What is the average temperature in fire breakouts?

Ans: The Temperature is Approximately 800 to 900 Degree.

Q2.Types of Fires and how to deal with them?

Ans : Electrical accident,gas leaks moreover outside urban fires, wildfires is also an issue in many states.

Q3.Have you thought of using drones for tackling fires?

Ans: Yes, the idea of implementing drone based solution for tackling fire based accidents has been circulating in the department for a while and our technical team is already working on it and they have also developed the system specification requirements for the drone.

Q4. What all information will be required by you to tackle a situation effectively?

Ans: The number of people trapped inside the building/area,the location of humans and animals trapped in fire, the level of fire, exact location on fire in the building, the level of toxic gases, the safe route to guide the people and animals out of the building,etc

Q5. How do you communicate during a rescue mission?

Ans: We use PA system and LF private radio network to communicate and send commands,instructions and locations of trapped victims.

Q6. How does the constant requirement of facing the toxic environment affect your health? (Firefighters)

Ans : All of us are well protected moreover we see to it that while we are saving lives, we don't endanger more people and take unnecessary risks. Hence it's not an issue.

2.4 Patent Search:

1. Unmanned aerial vehicle for situational awareness to first responders and alarm investigation.
    a. During periods of emergency first responders use an unmanned aerial vehicle equipped with sensors.
    b. This vehicle is assigned to a control center for a designated incident while automatically tasking the unmanned aerial vehicle with the initiation of the incident

response to autonomously without the control center taking active control of the unmanned aerial vehicle.

2. Cognitive load reducing platform for first responders
    a. A cognitive load reducing platform which comprises of sensors that collect information about an environment as sensor data.
    b. A processor processes the sensor data into enhanced characterization data having a reduced amount of data.
    c. An output device electronically communicate the enhanced data to a user such that the enhanced data reduces the cognitive load of the user.

3. A multipurpose drone for extinguishing fire and saving a life
    a. The present invention relates to a multipurpose unmanned aerial vehicle(drone) capable of extinguishing fire and saving a life, which is used to rapidly airdrop multiple lifesaving airbags etc into a scene of an accident in time of emergency while flying freely or through remote control.
    b. The drone comprises an aerial vehicle control unit which itself has a multiple rotors thrust force and a fluid injection unit.
    c. Drone arrives at an accident, which has a difficulty to allow direct approaching of a firefighter or an ambulance in time, to selectively airdrop airbags to multiple people to be rescued and throwing multiple equipment like a fire extinguisher to a place where a fire accident occurs, thereby rapidly suppressing fire.

Chapter 3: Requirements

3.1 Definition of Requirement Gathering :

Requirements elicitation (also known as Requirements Gathering or Capture) is the process of generating a list of requirements (functional, system, technical, etc.) from the various stakeholders (customers, users, vendors, IT staff, etc.) that will be used as the basis for the formal Requirements Definition.

The process is not as straightforward as just asking the stakeholders what they want their system to do, as in many cases, they are not aware of all the possibilities that exist, and may be limited by their immersion in the current state. For example asking people in the 19th Century for their requirements for a self-propelled vehicle, would have just resulted in the specification for a faster horse-drawn carriage rather than an automobile. Beware the old adage, "it's everything I asked for, but not what I need"!

What Techniques Can Be Used?

- Interviews - These are an invaluable tool at the beginning of the process for getting background information on the business problems and understanding a current-world perspective of what the system being proposed needs to do. You need to make sure that your interviews cover a diverse cross-section of different stakeholders, so that the requirements are not skewed towards one particular function or area.
- Questionnaires - One of the challenges with interviews is that you will only get the information that the person is consciously aware of. Sometimes there are latent requirements and features that are better obtained through questionnaires. By using carefully chosen, probing questions (based on the information captured in prior interviews), you can drill-down on specific areas that the stakeholders don't know are important, but can be critical to the eventual design of the system.
- User Observation - One of the best ways to determine the features of a system, that does not result in "paving the cowpath" (i.e. building a slightly improved version of the current state) is to observe users actually performing their daily tasks, and ideally recording the actions and activities that take place. By understanding the holistic context of how they perform the tasks, you can write requirements that will reinvent the processes rather than just automating them, and will ensure that usability is paramount.
- Workshops - Once you have the broad set of potential requirements defined, you will need to reconcile divergent opinions and contrasting views to ensure that the system will meet the needs of all users and not just the most vocal group. Workshops are a crucial tool that can be used to validate

the initial requirements, generate additional detail, gain consensus and capture the constraining assumptions.

- Brainstorming - This is a powerful activity, which can be performed either in the context of a workshop or on its own. By considering different parts of the system and considering 'what-if' scenarios, or 'blue-sky' ideas, you can break out of the context of the current-state and consider visionary ideas for the future. Tools such as whiteboards or mind-mapping software can be very helpful in this phase.
- Role Playing - In situations where the requirements depend heavily on different types of user, formal role-playing (where different people take on the roles of different users in the system/process) can be a good way of understanding how the different parts of the system need to work to support the integrated processes (e.g in an ERP system).
- Use Cases & Scenarios - Once you have the high-level functional requirements defined, it is useful to develop different use-cases and scenarios that can be used to validate the functionality in different situations, and to discover any special exception or boundary cases that need to be considered.
- Prototyping - There is truth to the saying "I don't know what I want, but I know that I don't want that!". Often stakeholders won't have a clear idea about what the requirements are, but if you put together several different prototypes of what the future could be, they will know which parts they like. You can then synthesize the different favored parts of the prototypes to reverse-engineer the requirements.

3.2 Functional Requirements:

1. Detect humans
    i. Humans should be detected in the presence of fire and smoke
    ii. This can be done using combinations of sensor.
2. Creation of Area Map
    i. Drone should be able to map environment, placement of objects and also locate best exits inside of a structure.
    ii. This can be done using ultrasonic sensors and gyro sensor.
3. Creation of Heat Map

i. Drone should be able to create a heat map. On the basis of this, the drone would be able to figure out the regions with higher temperatures and would be able to cater to them on a priority basis.

4. Detect and avoid Collision
    i. Drone should be able to avoid hanging objects and objects that get in close proximity to it.
    ii. This can be achieved with the help of ultrasonic Sensors.
5. Maintain Stability using Gyro Sensor.
    i. Drone should maintain its position and stability in raging flames.
    ii. Adjust movements by using gyro sensor.
6. Fall Detection
    i. Accelerometer and Gyro Sensor will detect when drone has fallen and become immobile.
7. Detect toxicity of the area with the help of gas sensors.
    i. Accurate temperature reading and toxicity levels should be reported to drone operator using onboard appropriate sensors.

3.3 Non-Functional Requirements:

The Non-functional requirements of the system are:

1. Efficiency
    a. The speed of data transfer will affect how fast firemen can utilise the information and hence determine its effectiveness.
    b. The speed of data processing will affect how fast drone can transmit the information and hence determine its effectiveness.
2. User-friendliness
    a. Firemen should be able to control drone effectively with minimal training.
    b. Software used to monitor and interpret data must be intuitive and responsive.
    c. Drone Setup must be fast and simple.
    d. Troubleshooting must be useful and fast.

3. Reliability

a. Data interpretation software acting as a frontend should be extremely responsive and shouldn't fail at providing basic functionalities it was meant for.
b. Sensor data captured must be accurate and reliable enough to act upon.
c. Precautions and measures to avoid possible failures must be implemented.

3.4 Constraints:

1. Proper operation/working of drone and sensors at high temperatures:
2. Since the drone is exposed to an extreme environment where the temperature might exceed 700-800 degree the electrical components like sensors may get damaged or stop working completely.
3. Insulation of certain components may decrease their accuracy and efficiency:
4. To make the drone fire resistant at such high temperatures it is necessary to properly insulate the required components of the drone so that it remains unaffected upto a certain degree of temperature. But the insulating material might affect the sensors by decreasing the accuracy and efficiency of the sensors used on the drone.
5. Operation in smoke and toxic environment will shorten final product's life cycle:
    a. Generally the environment at a fire accident is quite hazardous with the release of dense smoke generated due to fire there is high amount of toxic gases present such as asphyxiants, carbon monoxide (CO), and hydrogen cyanide,etc.These gases are very harmful and might hamper various components of drone resulting in short life span of the drone.
6. Unreliable internet connection will cause problems:
    a. Poor or slow internet connection will cause delays in data transmission between the server and the drone and hence such data will be useless in dynamic situations.Hence having a strong internet connection is very important for tackling the given situation.
7. Drone Flight time is limited by technology:
    a. The drone has a finite amount of flight time for it's working and hence has to perform all it's functional activities in the stipulated amount of time given.Once the battery is drained and the drone cannot fly then the drone cannot perform any operation and hence becomes useless. So we have to take into consideration it's flight time in order to complete all the tasks effectively within the time bound.
8. Operational effectiveness varies drastically depending on environment:

a. Operational effectiveness of drones depends heavily on the type of environment it is facing.It's effectiveness varies drastically depending on the environment. For example if the drone is working in an environment where it faces less interference and obstructions it will have better performance compared to the environment with a lot of interferences.

9. Speed of processing the data relayed by drone and visualising it:The processing speed of the drone matters a lot while dealing with such high intense situations like a fire accident where reaction time is very limited and hence the speed at which the drone collects the data, processes it and visualizes it so that the human in charge can interpret the situation as quickly as possible.So if the processing speed is slow it can be a huge setback.

3.5 Hardware, Software, Technology and Tools Available:

Hardware	Software
● Quadcopter Frame ● Propellers ● Motors ● ESC ● Battery ● PID Micro controller ● Flight Controller ● Smoke Sensor ● Gyro and accelerometer sensor ● Temperature and Humidity Sensor ● Speaker ● Microphone ● Arduino Board along with Node MCU ● Raspberry Pi ● Ultrasonic Sensor	● Raspbian OS ● Django Framework ● Tensorflow and Sklearn models ● Flask module ● MySQL/Firebase/Postgres ● Android Studio ● Visualization Software (Seaborn)

Table 1: Technologies and equipments Available

3.6 Hardware & Software Utilized:

Name	Variations	Cost(Rs)	Quantity	Total Cost (Rs.)
Gas Sensors	MQ-9	155	1	155
	MQ-135	150	1	150
Temperature and humidity Sensor	Max6675	500	1	500
Motors	A2212 KV2200 MOTOR	379	4	1516
UltraSonic Sensor		200	10	2000
Accelerometer and Gyoscope (Rpie verification)	MPU-6050	150	1	150
ESC	SimonK 30A 2-3S Brushless ESC For RC Model	399	4	1596
Raspberry Pie	4	5250	1	5250
Microphone		200	1	200
Speaker	Lm386+speaker	340	1	340
Propellor	Orange HD Propellers 9443(9X4.3) DJI Carbon Fiber Black 1CW+1CCW-1pair	877	4	3508
Frame		799	1	799

	DJI F450 Quadcopter frame Kit			
Battery	ZOP Power LiPo Battery 11.1V 5400MAH 3S 25C - T Plug	4499	1	4499
Charger	iMAX B6-AC B6AC Lipo NiMH RC Battery Balance Charger	2599	1	2599
Fire Extinguisher Ball		1098	1	1098
Robotic arm - to drop ball		750	1	750
Arduino		450	2	900
Node mcu		360	2	720
Jumper Wires		220	3	660
Drone controller Remote		3000	1	3000
Heat Insulating Material	DEI 010460 Reflect-A-Cool Heat Reflective Adhesive Backed Sheets, 12" x 12"	2300	1	2300
Sub Total				**34540**

Final Total	**Rs. 34540**

Table 2: Cost sheet for the proposed solution

Rationale for selecting aforementioned Equipment:

- Quadcopter Frame - *DJI F450*
  - Provides best value for money and reduces the number of motors required too.
  - Built from high quality glass fiber and ultra durable polyamide nylon.
  - Arms are reinforced and much more stronger to prevent and reduce breakage.
  - Integrated PCB connections for direct soldering your ESCs.
  - Colored arms for orientation to keep you flying in the right direction.
  - Large mounting tabs on main frame bottom plate for easy camera or other accessories mounting.
  - Pre-threaded brass sleeves for all of the frame bolts.
  - Easy assembly.

- Propellers - *Orange HD Propellers 9443 (9X4.3) DJI Carbon Fiber*
  - 8 inch carbon fibre propellers provide optimum thrust required.
  - Durable plastic construction provides both lightness and rigidity.
  - The Orange HD Propellers 9443(9X4.3) DJI Carbon Fiber Black comes with Epoxy resin cover.
  - Very strong and lightweight.
  - Quick to release, quick to attach
  - New design propellers, with greater aerodynamic efficiency, good lifting capacity.

- Motors - *A2212 Brushless 2200KV DC motor* x 4
  - A2212 is a brushless outrunner DC motor specifically made to power Quadcopters and Multirotors. It is a 2200kV motor. It provides high performance, super power and brilliant efficiency. These motors are perfect for medium size quadcopters with 8 inch to 10 inch propellers. Use this to build powerful and efficient quadcopters.
  - Perfect with our F450 quadcopter frame.
  - Our 30A ESCs can be used to drive the motor.

- ESC - *4 X 30A Brushless ESC (with bullet connectors)*

- Safe power function : regardless of the throttle stick in any position the motor will not start immediately.
- Throttle Calibration function : Adapt to different remote throttle travel difference, improve throttle response linearity, with a smooth, delicate feel and excellent speed linear speed.
- Low Voltage Protection Mode, Low-voltage protection threshold.

- Remote For Drone - *FS-CT6B 6ch 2.4GHz transmitter & receiver*
  - It has 0.8W transmitter with range up to 1km line of sight.
  - Specifications: Channels: 6. Frequency: 2.4GHz.

- Gyroscope - MPU6050
  - The MPU6050 devices combine a 3-axis gyroscope and a 3-axis accelerometer on the same silicon together with an onboard Digital Motion Processor (DMP) capable of processing complex 9-axis MotionFusion algorithms.
  - A sampling Rate of 32 kHz.
  - Supports both I2C and SPI interface.

- Ultrasonic Sensor - *4 X HC-SR04*
  - Ultrasonic Sensor: Drone needs to avoid collision with its surroundings especially in smoke and low visibility environment, for this a sensor such as ultrasonic can be utilized. This sensor has also been used for the generation of an area map. The sensor used for the above task is called HC - SR04
  - Ultrasonic Sensor: An ultrasonic sensor is as sensor which measures the distance of respective object by sending the sound wave of specific frequency. This sound wave is reflected after the collision with respective object and this wave is received by the ultra-sonic receiver. Distance is measured by calculating sending and receiving time of this sound wave.
  - Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle of work: (1) Using IO trigger for at least 10us high level signal, (2) The Module automatically sends eight 40 kHz and detect whether there is a pulse signal back. (3) IF the signal back, through high level , time of high output IO duration is the time

from sending ultrasonic to returning. Test distance = (high level time×velocity of sound (340M/S) / 2.

- Gas Sensor - *MQ9 and MQ5*
  - This sensor has been used to determine the presence of any harmful gases in the area and also its amount. This data would be helpful in finding safe entry and evacuation points for firefighters and also help in determining the proper equipment to quench the fire effectively. Two types of gas sensors, MQ-9 and MQ-135 have been used for serving the above purpose.
  - The MQ-9 module is useful for gas leakage detection (in home and industry). It is suitable for detecting LPG, CO, CH4. Because of its high sensitivity and quick response time, measurements can be taken as soon as possible.
  - The MQ-135 gas sensor is used in air quality control equipment and is suitable for detecting or measuring of NH_3, NOx, alcohol, benzene, smoke and CO_2.

- Temperature Sensor - *DHT11*
  - In many cases the temperature inside a fire can reach upto 800 degree celcius and it is imperative for firemen to detect these zones to focus their efforts effectively. For firefighters to know about the regions which are at high temperatures, a heat map is generated. For the generation of the heat map, a sensor called DHT11 has been used.

.

Chapter 4: Proposed Design

4.1 Block Diagram of the Proposed System:

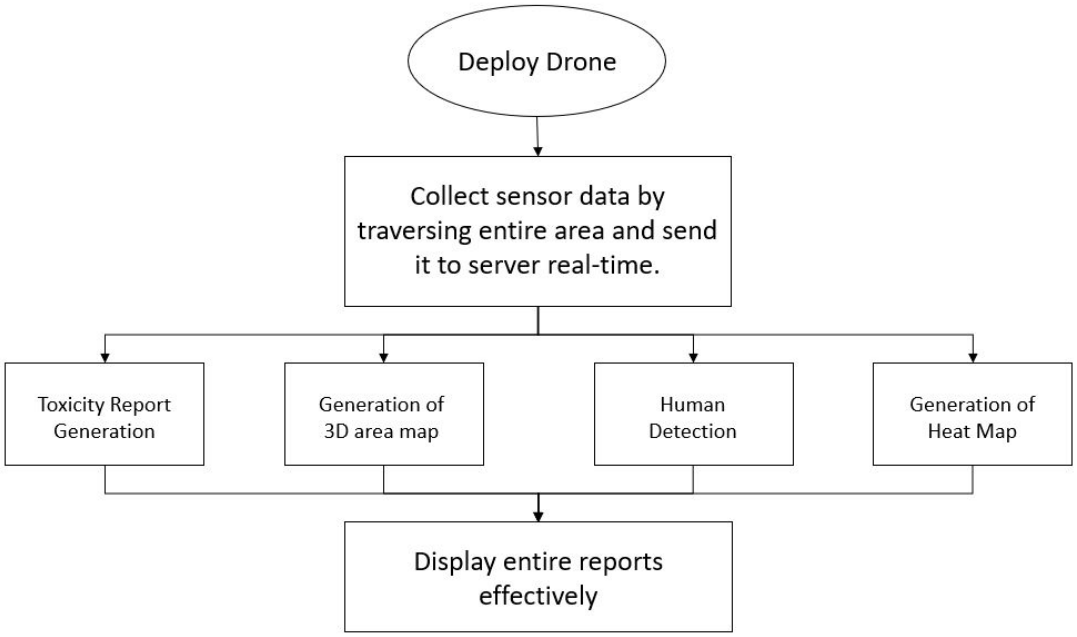


Figure 1: Block Diagram of Proposed System

The above figure is the block diagram of our proposed system. First the drone is deployed from the fire station. Once the drone reaches the site of casualty, the drone enters the area through a safe point. With the help of the sensors on board, the drone starts making the area map and heat map. As the maps are being created, the drone also uses the gas sensor to collect data about the various gases present in there. All these reports generated are then sent to the server from where the firefighters can access it.

4.2 Modular Diagram:

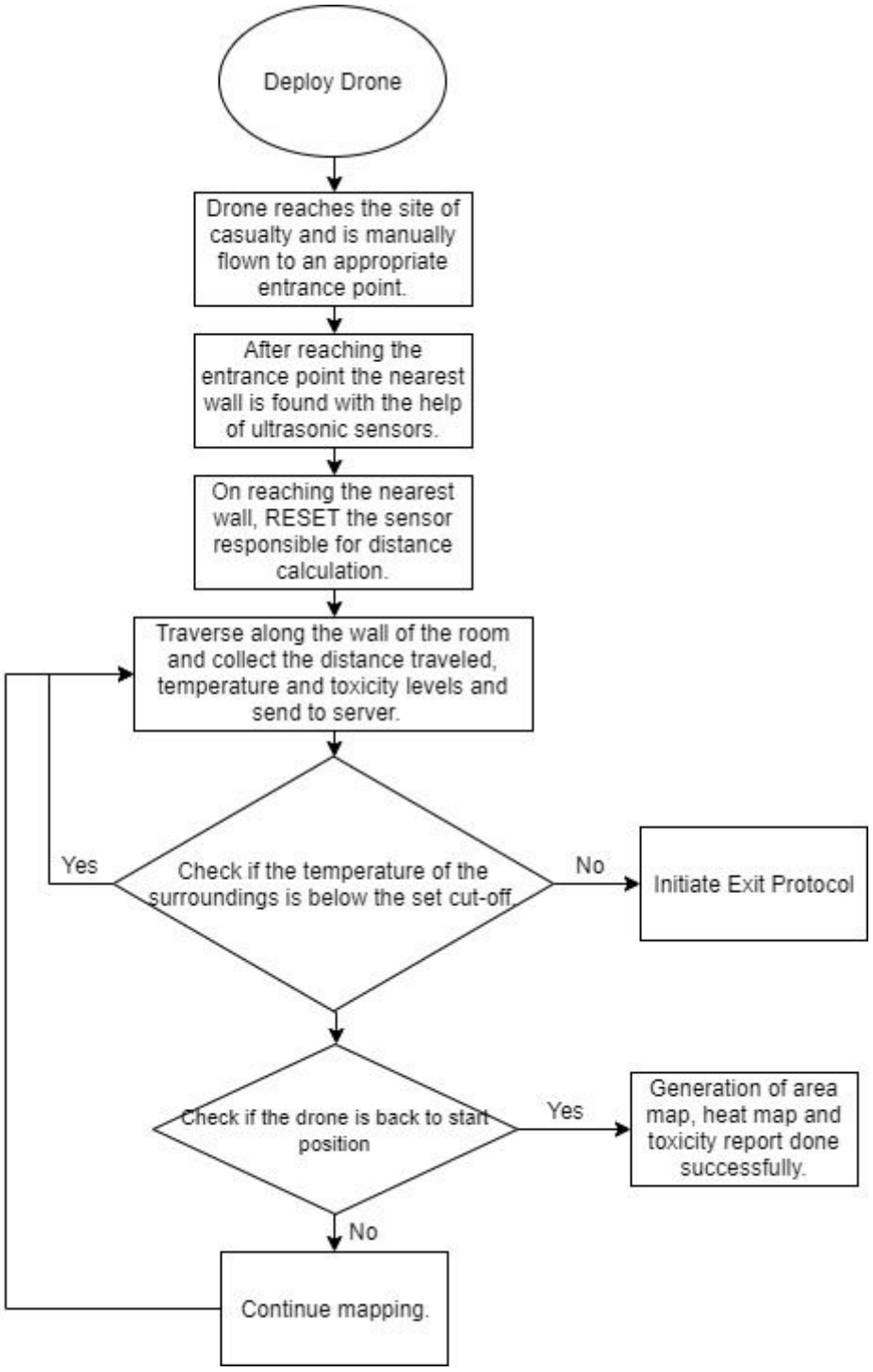


Figure 2: Modular Diagram

The above diagram is our modular diagram. Since multiple modules work together, we have made a single diagram. First the drone is deployed from the fire station. Once the drone reaches the site of casualty, the drone enters the area through a safe point. Once the drone enters into the infrastructure,

the drone finds the nearest wall with the help of the ultrasonic sensors on board. Once the nearest wall has been found, the drone hovers towards it. When the drone reaches the nearest wall, the sensors responsible for distance calculation are resetted. Now the drone traverses along the wall of the room and collects data such as amount of distance travelled, temperature of the area which it is traversing through and toxicity levels of the area. All this data is being sent to the server and the area map is being generated over there. The fire-fighters have access to the server from where they can get the required area maps, heat maps and toxicity reports. As the drone is traversing in the room, a check of surrounding temperature is being done simultaneously. As soon as the temperature of the surrounding exceeds the set cut-off value, the drone initiates an exit protocol. This would ensure the safety of the drone as it would prevent the drone from entering regions with extremely high temperatures.

4.3 Detailed Design with Explanation:

- DFD Level 0

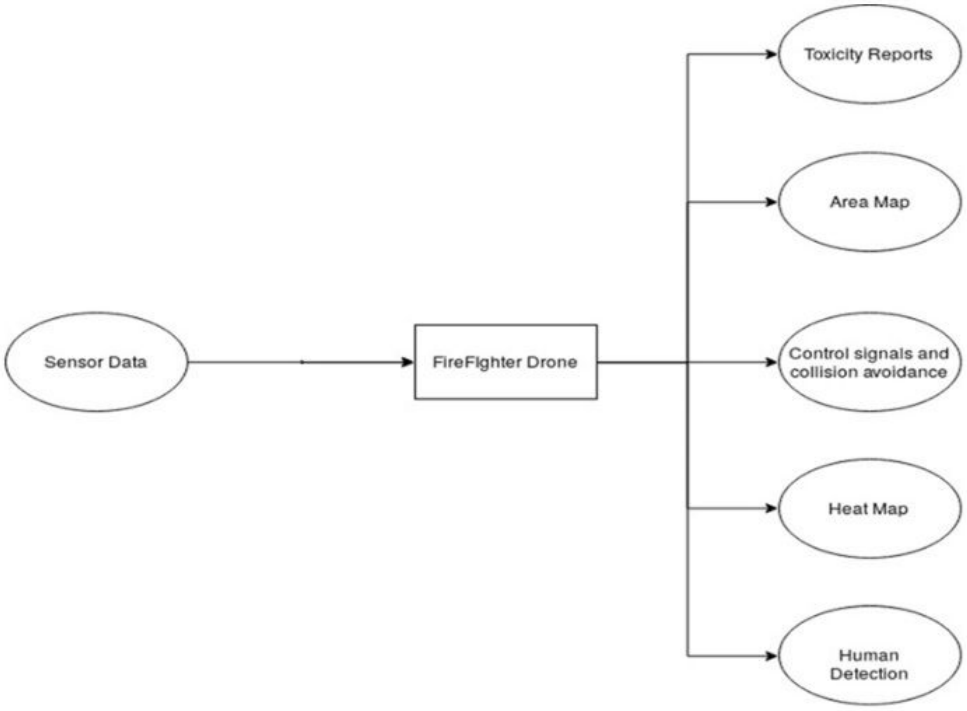


Figure 3: DFD Level 0

The above figure represents the Level 0 Data flow diagram. This depicts the high level functionality of the proposed solution. The system is designed to perform area map generation, heat map

generation, collision detection and generate toxicity reports with the help of inputs provided by the various sensors on board.

- DFD Level 1

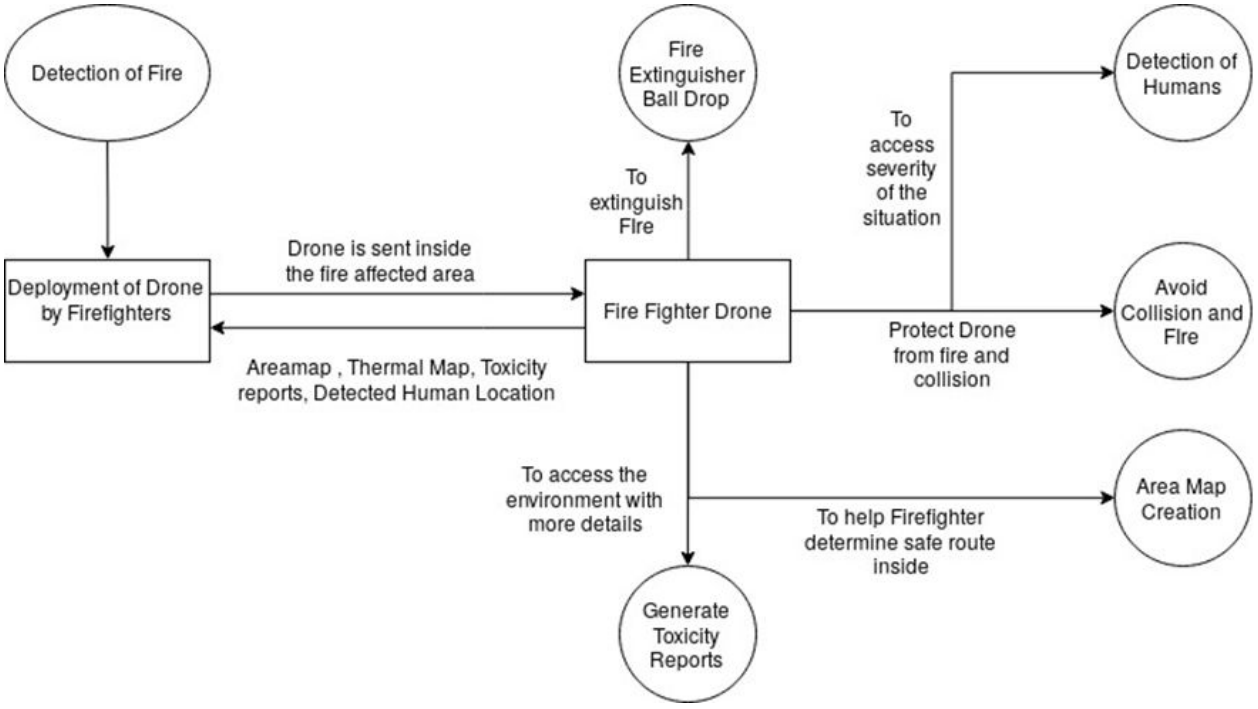


Figure 4: DFD Level 1

Level 1 data flow diagram provides a detailed understanding of the system as compared to level 0 data flow diagram. In the above diagram, it is shown that first the drone is deployed in the area of casualty. After being deployed, it generates an area map and heat map. The generated area map and heat map will help firefighters to make an efficient fire extinguishing and evacuation plan. The generated heat map will also be used to deploy fire extinguishing balls. In addition, toxicity reports are generated with the help of the gas sensors present on board and collision prevention is performed to protect the drone from collision.

4.4 Project Scheduling & Tracking using Timeline / Gnatt Chart:

Figure 5: Gantt Chart

- Proposal Drafting
    - Requirement Gathering
    - Hardware research
    - Compatibility checks
    - Cost Planning
    - Inferences Research
    - Final Draft
- Development Phase 1
    - Collision Detection using Ultrasonic Sensor
    - Testing Collision detection
    - Orientation measurement using MPU-6050
    - Distance measurement using accelerometer
    - Testing of orientation and distance measured

- Development Phase 2
    - Area map using Ultrasonic Sensor
    - Testing Area map generated using Ultrasonic Sensor
    - Generation of Toxicity reports using MQ sensors
    - Temperature and Humidity estimation using thermocouple
    - Testing Reports and data generated through sensors and thermocouple
- Development Phase 3
    - Area map generation with both camera and ultrasonic sensors
    - Lidar connection with Rpie
    - Area map generation using Lidar
    - Testing Area map generated using Lidar
- Development Phase 4
    - Construction of Drone
    - Heat map generation using Thermocouple
    - Testing Heat map generated with thermocouple
- Development Phase 5
    - Drone schematic simulation
    - Flight code generation
    - Testing of drone and tuning
- Integration phase

- Arduino and Node MCU integration
- Drone and sensors integration

- Testing
  - Unit Test
  - Function Test
  - Integration Test
  - Regression Test
  - System Test
  - User Acceptance Test

Test Completed

Chapter 5: Implementation Details

5.1 Algorithms and Flowcharts for the respective modules developed:

1. Collision Avoidance

One of the most important functionalities associated with a drone is to prevent itself from colliding with nearby objects such as walls of a room. To enable this functionality, ultrasonic sensors can be used. A basic implementation of this has been carried out by our team. We have taken six ultrasonic sensors and we have attached all of them to the arduino board. The distance is calculated with the help of time taken by the ultrasonic sound wave to travel.

Distance = (Duration*0.34)÷2

The distance was calculated accurately. If distance was below a certain threshold for any of the sensors, output was given to indicate collision course. If more than one sensor was covered, then the sensor which would be present closest to the wall would first indicate collision course. This methodology carried out was reliable and almost instantaneous. Maximum measurable distance is 2m (limited by sensor).

2. MPU

The MPU6050 IMU has both 3-Axis accelerometer and 3-Axis gyroscope integrated on a single chip.The gyroscope measures rotational velocity or rate of change of the angular position over time, along the X, Y and Z axis. The outputs of the gyroscope are in degrees per second, so in order to get the angular position we just need to integrate the angular velocity.

The MPU6050 can measure gravitational acceleration along the 3 axes and using some trigonometry math we can calculate the angle at which the sensor is positioned. So, if we fuse, or combine the accelerometer and gyroscope data we can get very accurate information about the sensor orientation.

The MPU6050 IMU is also called six-axis motion tracking device or 6 DoF (six Degrees of Freedom) device, because of its 6 outputs, or the 3 accelerometer outputs and the 3 gyroscope outputs.

First we need to include the Wire.h library which is used for the I2C communication and define some variables needed storing the data.

To get sensor raw data, we need to first perform 2’s complement on sensor data of Accelerometer and gyroscope.

After getting sensor raw data we can calculate acceleration and angular velocity by dividing sensor raw data with their sensitivity scale factor as follows,

Accelerometer values in g (g force)

Acceleration along the X axis = (Accelerometer X axis raw data/16384) g.

Acceleration along the Y axis = (Accelerometer Y axis raw data/16384) g.

Acceleration along the Z axis = (Accelerometer Z axis raw data/16384) g.

Gyroscope values in °/s (degree per second)

Angular velocity along the X axis = (Gyroscope X axis raw data/131) °/s.

Angular velocity along the Y axis = (Gyroscope Y axis raw data/131) °/s.

Angular velocity along the Z axis = (Gyroscope Z axis raw data/131) °/s.

3. Flight Control

Flight control logic is an important part of drone. It is the core component which manipulates and controls the speed of different motors in order to generate required results.

a. ALGORITHM :

Input : Angles measured from MPU sensor.

variables : x and y

constraints : -360 to 360

Action to be performed (action)

variable - action

possible actions - left, right, up, down, hover etc.

Output : Speed of different motors to perform particular action

s1 - speed of motor 1

s2 - speed of motor 2

s3 - speed of motor 3

s4 - speed of motor 4

Motor Configuration : X - configuration

1 2

3 4

i. Start

ii. Calculate x and y for drone at position of rest.

iii. If action = left :

- Increase the speed of 2nd and 4th motor

Else If action = right :

- Increase the speed of 1st and 3rd motor

Else If action = forward :

- Increase the speed of 3rd and 4th motor

Else If action = backward :

- Increase the speed of 1st and 2nd motor

Else If action = up :

- Increase the speed of all the motor.

Else If action = down :

- Decrease the speed of all the motor

Else If action = hover :

- Initialize flagx = 0 and flagy = 0
- Calculate x2 and y2 using MPU sensor.
- IF x2 > 180:

Calculate x2 = 360 - x2

Assign flagx = 1

- IF y2 > 180:

Calculate y2 = 360 - y2

Assign flagy = 1

- Calculate xd = x2 - x and yd = y2 - y
- IF xd <=20 and yd <= 20:

Maintain constant speed of motors

- ELSE IF xd >20 and yd <= 20:

IF flagx = 1:

Increase the speed of 3rd and 4th motor

ELSE:

Increase the speed of 1st and 2nd motor

- ELSE IF xd <=20 and yd > 20:

IF flagy = 1:

Increase the speed of 1st and 3rd motor

ELSE:

Increase the speed of 2nd and 4th motor

- ELSE IF xd > 20 and yd > 20:

IF flagx = 1 and flagy = 1:

Increase speed of motor 4

IF flagx = 1 and flagy = 0:

Increase speed of motor 3

IF flagx = 0 and flagy = 1:

Increase speed of motor 1

IF flagx = 0 and flagy = 0:

Increase speed of motor 2

4. Area Mapping:

The proposed solution for creating an area map is based on the use of ultrasonic sensors. Except for ultrasonic sensors there are other multiple sensors which can be used to generate an area map. One such sensor is the LIDAR sensor. The LIDAR sensor is efficient in making an area map as it is fast. Data from the LIDAR sensor can be collected quickly and with very high accuracy. Another few benefits of this sensor are that it can be operated with minimum human dependance and also it is operational during both day and night. But one of the major drawbacks of the LIDAR sensor is that it is very expensive. Another con of the sensor is that very large datasets are difficult to interpret. Since we wanted to build an economical solution, we have used ultrasonic sensors to build the area map. A total of 4 ultrasonic sensors have been used for the same. The orientation was such that each ultrasonic sensor was present on one side of the drone. The ultrasonic sensor placed at the back of the drone is used for getting the amount of distance travelled by the drone. Rest of the sensors are used to determine when the drone should take a turn and in which direction it should do so. All of this data is then sent to the server where the 2D area map is generated using the transmitted information.

Transmission and generation of the area map is near instantaneous process hence making it feasible in a high risk environment such as firefighting. The algorithm for creation of area map is as follows:

Collection of data:

In the below algorithm an array has been used in which the measures of each wall along with the direction in which the turn has been taken is stored. In the algorithm, distanceBack means the distance measured by the ultrasonic sensor present at the back of the drone. Similarly, distanceRight means the distance measured by the right ultrasonic sensor of the drone, distanceLeft means the distance measured by the left ultrasonic sensor of the drone and distanceFront means the distance measured by the front ultrasonic sensor of the drone.

The algorithm used for this is as follows:

i. On the basis of the left and right sensor readings, find the nearest wall and traverse towards it. If the drone has traversed towards the left wall goto step (ii) else goto step (vii).
ii. While (true) do step (iii), (iv), (v) and (vi).
iii. Get the value of all sensors.
iv. if ((9<=distanceLeft<=15) and (distanceFront>=10))
    Hover in forward direction.
v. if ((distanceLeft>15) and (distanceFront>=10))
    Add the distance of the back sensor to the array.
    Add 1 to the array.
    Rotate Left by 90 degrees.
vi. if ((9<=distanceLeft<=15) and (distanceFront<10))
    Add the distance of the back sensor to the array.
    Add 0 to the array.
    Rotate Right by 90 degrees.
vii. While (true) do steps (viii), (ix), (x) and (xi).
viii. Get value of all sensors.
ix. if ((9<=distanceRight<=15) and (distanceFront>=10))
    Hover in forward direction.
x. if ((distanceRight>15) and (distanceFront>=10))
    Add the distance of the back sensor to the array.
    Add 0 to the array.
    Rotate Right by 90 degrees.
xi. if ((9<=distanceRight<=15) and (distanceFront<10))
    Add the distance of the back sensor to the array.

Add 1 to the array.

Rotate Left by 90 degrees.

The array generated by the above algorithm is sent to the server where the area map is generated with the help of a python script.

Chapter 6: Testing

6.1 Definition of testing:

Software testing is a process, to evaluate the functionality of a software application with an intent to find whether the developed software met the specified requirements or not and to identify the defects to ensure that the product is defect free in order to produce the quality product.

Software Testing Definition according to **ANSI/IEEE 1059** standard – A process of analyzing a software item to detect the differences between existing and required conditions (i.e., defects) and to evaluate the features of the software item.

6.2 Types of testing:

1. **Alpha Testing**
    a. It is the most common type of testing used in the Software industry. The objective of this testing is to identify all possible issues or defects before releasing it into the market or to the user.
    b. Alpha Testing is carried out at the end of the software development phase but before the Beta Testing. Still, minor design changes may be made as a result of such testing.
    c. Alpha Testing is conducted at the developer's site. In-house virtual user environment can be created for this type of testing.
2. **Acceptance Testing**
    a. An Acceptance Test is performed by the client and verifies whether the end to end the flow of the system is as per the business requirements or not and if it is as per the needs of the end-user. Client accepts the software only when all the features and functionalities work as expected.
    b. It is the last phase of the testing, after which the software goes into production. This is also called User Acceptance Testing (UAT).
3. **Ad-hoc Testing**
    a. The name itself suggests that this testing is performed on an Ad-hoc basis i.e. with no reference to the test case and also without any plan or documentation in place for such type of testing.
    b. The objective of this testing is to find the defects and break the application by executing any flow of the application or any random functionality.

c. Ad-hoc Testing is an informal way of finding defects and can be performed by anyone in the project. It is difficult to identify defects without a test case but sometimes it is possible that defects found during ad-hoc testing might not have been identified using existing test cases.

4. **Accessibility Testing**

   a. The aim of Accessibility Testing is to determine whether the software or application is accessible for disabled people or not.

   b. Here, disability means deaf, color blind, mentally disabled, blind, old age and other disabled groups. Various checks are performed such as font size for visually disabled, color and contrast for color blindness, etc.

5. **Beta Testing**

   a. Beta Testing is a formal type of Software Testing which is carried out by the customer. It is performed in the Real Environment before releasing the product to the market for the actual end-users.

   b. Beta Testing is carried out to ensure that there are no major failures in the software or product and it satisfies the business requirements from an end-user perspective. Beta Testing is successful when the customer accepts the software.

6. **Back-end Testing**

   a. Whenever an input or data is entered on front-end application, it stores in the database and the testing of such database is known as Database Testing or Backend Testing.

   b. There are different databases like SQL Server, MySQL, and Oracle, etc. Database Testing involves testing of table structure, schema, stored procedure, data structure and so on.

   c. In Back-end Testing GUI is not involved, testers are directly connected to the database with proper access and testers can easily verify data by running a few queries on the database.

   d. There can be issues identified like data loss, deadlock, data corruption etc during this back-end testing and these issues are critical to fixing before the system goes live into the production environment

7. **Browser Compatibility Testing**

   a. It is a subtype of Compatibility Testing (which is explained below) and is performed by the testing team.

b. Browser Compatibility Testing is performed for web applications and it ensures that the software can run with the combination of different browser and operating system. This type of testing also validates whether web application runs on all versions of all browsers or not.

8. **Backward Compatibility Testing**
   a. It is a type of testing which validates whether the newly developed software or updated software works well with the older version of the environment or not.
   b. Backward Compatibility Testing checks whether the new version of the software works properly with file format created by an older version of the software; it also works well with data tables, data files, data structure created by the older version of that software.
   c. If any of the software is updated then it should work well on top of the previous version of that software.
9. **Black Box Testing**
   a. Internal system design is not considered in this type of testing. Tests are based on the requirements and functionality.
10. **Unit Testing**
   a. Testing of an individual software component or module is termed as Unit Testing. It is typically done by the programmer and not by testers, as it requires detailed knowledge of the internal program design and code. It may also require developing test driver modules or test harnesses.
11. **Usability Testing**
   a. Under Usability Testing, User-friendliness check is done. The application flow is tested to know if a new user can understand the application easily or not, Proper help documented if a user gets stuck at any point. Basically, system navigation is checked in this testing.
12. **White Box Testing**
   a. White Box Testing is based on the knowledge about the internal logic of an application's code.
   b. It is also known as Glass box Testing. Internal software and code working should be known for performing this type of testing. Under these tests are based on the coverage of code statements, branches, paths, conditions, etc.

6.3 Types of testing considered with justification

1. **Acceptance Testing :**
    a. Acceptance testing is an important testing carried out before the completion of a product. It is carried out by a client. Since this is an industry product, acceptance testing is carried.
2. **Back-end Testing:**
    a. The final solution is in the form of a website which the client will access. The website has usage of database hence backend testing is carried out.
3. **Black Box testing:**
    a. Black box testing will be carried out in order to test the behaviour of the system under certain conditions.
4. **GUI testing:**
    a. GUI testing is necessary since the result will be displayed on GUI itself.
5. **Integration testing:**
    a. The project consists of different modules integrated together to form the final system. In order to ensure the proper integration, integration testing is necessary.
    b. This testing deals with the process of confirming whether all the modules can be integrated properly.
    c. In integration testing we connected all the external hardware like ultrasonic sensors, speaker and microphone, gas sensors and DHT sensor on the drone and checked if all the systems were performing as expected.

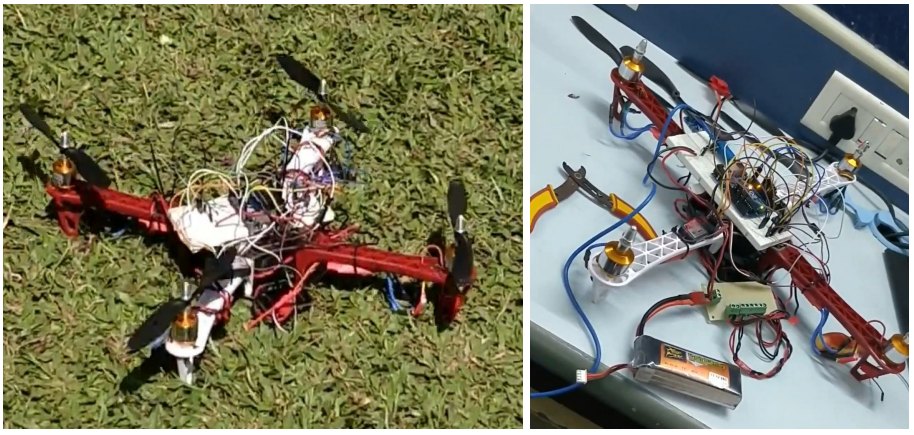


Figure 6: Images of Drone after integration

6. **Negative testing:**

   a. The project involves the data captured from sensors. There is a high possibility of it being corrupt. Therefore negative testing is carried out so that system behaves as expected even with invalid input.

7. **Unit Testing:**

   a. The project consists of small modules which are integrated. The unit testing of these small modules is necessary so that they produce expected output.

Gas Sensors:- In this module, the MQ9 and MQ135 sensors are tested to see the output. These outputs are then represented in charts on the website.

Figure 7: Arduino Monitor displaying results of MQ 9 Sensor

DHT sensor:- In this module, the temperature and humidity of a particular area is tested and the accuracy is checked. The accuracy of the temperature was ±10%.

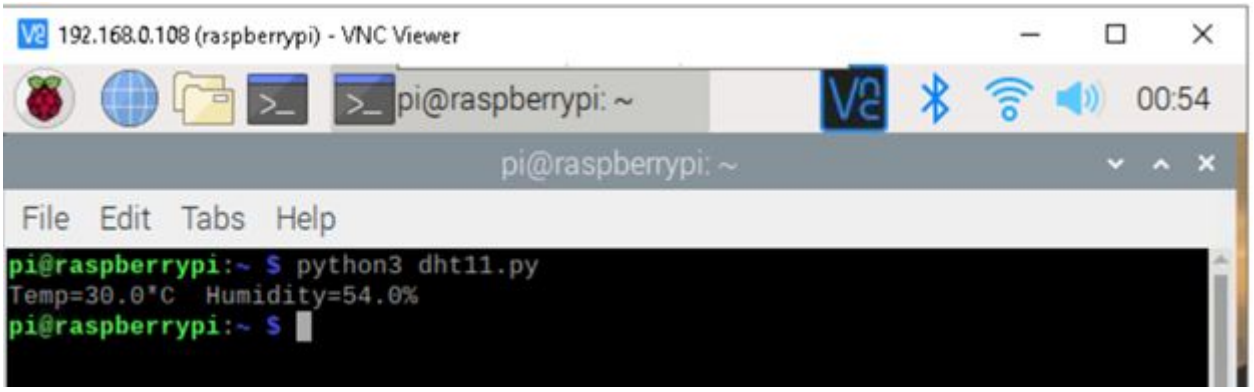


Figure 8: Displayed results of real time humidity and temperature using DHT11 sensor

8. System Testing:

System testing is similar to integration testing, but instead of integrating modules into programs for testing, programs are integrated into systems for testing the interfaces between programs in a system. System testing can be defined in many ways, but a simple definition is that validation succeeds when the software functions in a manner that can be reasonably expected by the customer.

9. Acceptance Testing:

Once the system tests have been satisfactorily completed, the system is ready for acceptance testing. Acceptance testing is the process whereby actual users test a completed information system in the environment where it will eventually be used, the end result of which is the user's acceptance or rejection.The admin and staff at Company accepted the proposed system after testing.

6.4 Various test case scenarios considered

1. System behaviour in case of sensors sending corrupted data.
2. System behaviour in case of Database connection failure.
3. System behaviour in case of Sensor failure.
4. System behaviour for invalid username/password input.
5. System behaviour for network failure.
6. System behaviour under maximum load.

6.5 Inference drawn from tests:

1. Sensor sending corrupted data:

If sensors send corrupted data the application fails to generate reports for displaying. To avoid this the data is checked at the server as well as on embedded device for corruption. Only after validation the data is used for generation of reports.

2. Database connection failure:

If database connection fails the system tries to re-establish the connection every 30 secs until the connection is established.

3. Sensor Failure:

Sensor failure is identified if sensors stop sending data altogether. If this occurs the live report generation will be stopped until the sensors start sending the data again.

4. Username/password invalid input :

The invalid username and password characters can result in system crash. Hence the validation on the server side is performed before verification of login details.

5. Network Failure:

Network failure will result in complete loss of control over the sensors and drone. Hence this state should be avoided.

6. Maximum Load:

The system can withstand the maximum load easily.

Chapter 7: Result Analysis

7.1 Module(s) under consideration

1. **Construction of UAV**
    - UAV or unmanned aerial vehicle was constructed in phases:
    - First part involved construction of an actual drone which includes assembling a quadcopter frame. On top of that frame various components for the drone are added which are:
        - Motor: Motors which are added must be at least 1000kv so as to have sufficient power for it to fly.
        - ESC: ESC or electronic speed controller must be attached to the drone equal to the number of motors on drones on drone as every motor requires an Esc. Hence in case of a quadcopter 4 Esc's must be added.
        - Propeller: Carbon fiber propellers are used to have sufficient strength and longevity in life span for propellers.
        - Battery: Battery can be chosen from 2200 mah to 5400 mah depending on the need and time to flight which is required.**Toxicity report generation using MQ-sensors**
        - MQ gas sensors help us detect the hazardous gases in the surrounding. Integrating this sensor to our drone will help us detect the harmful gases around the accident spot and take necessary precautions for the same. With the help of the output received from this sensor, we can also classify the fire into one of the four levels of fire, thus helping the firemen take required precautions and equipment for themselves as well as during the rescue operations.
2. **Area Map Generation:**
    - For the generation of an area map the drone makes use of 4 ultrasonic sensors.
    - The ultrasonic sensor present at the back side of the drone is used to measure the distance of each wall.
    - These measurements collected are accurate with a minimal error. Once the traversing of the drone is done the measurements stored in the array are sent to the database.
    - These measurements are then later accessed by a python script present on the server side which then produces an area map.
3. **Collision Avoidance:**
    - To protect the drone from colliding into walls, a collision avoidance algorithm was built.
    - This algorithm made use of 6 ultrasonic sensors, one at each side and one at the top and bottom.
    - Whenever the drone comes close to an object, the collision avoidance algorithm prevents the drone from colliding into that object.
4. **Integration of sensors and drone**
    - The motherboard on which the drone is operating is the NodeMCU and Arduino.

- NodeMCU - This board is responsible for very important functionalities like having ultrasonic sensors on it for collision prevention and area map generation while traversing the surrounding. It is also equipped with a Gyro sensor to measure the angle of rotation and adjust the speed motors. To control the speed of motors it is also connected with the ESC's as ESC is mainly responsible for speed control of motors.
- Arduino - This board is used to connect the gas sensors to it which help to generate toxicity reports.

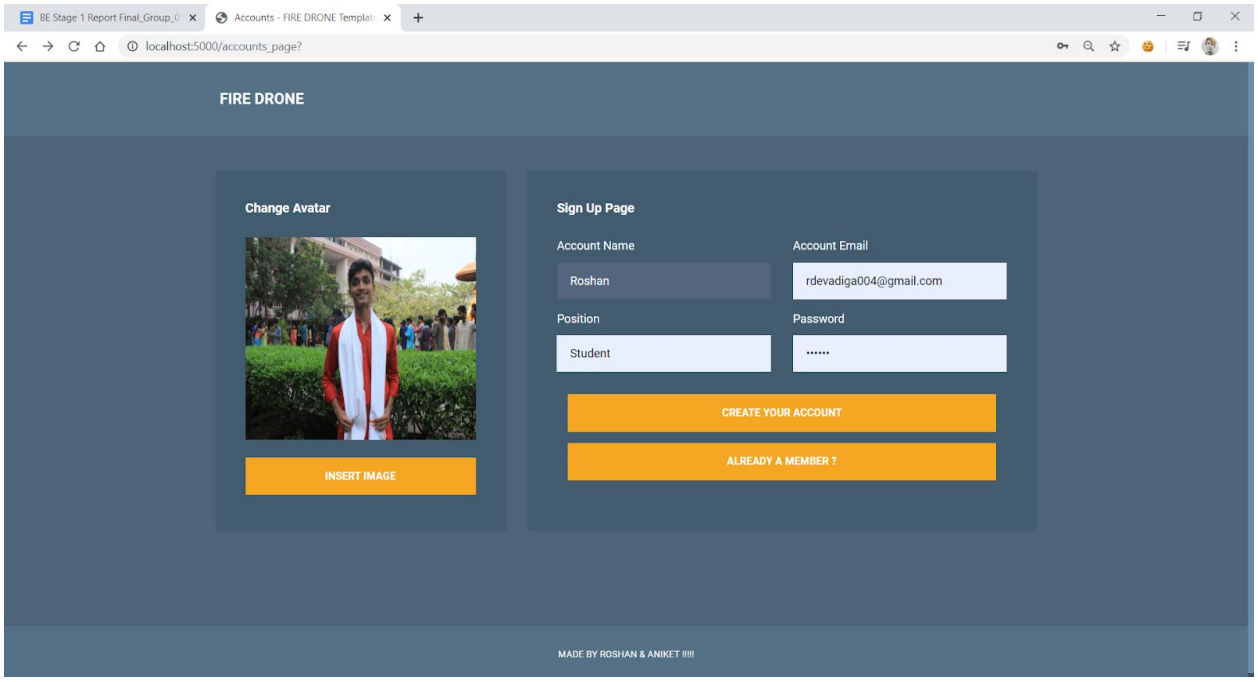
5. **Toxicity and Temperature report generation using MQ9 and DHT11 sensors:**
    - The MQ-9 module is useful for gas leakage detection (in home and industry). It is suitable for detecting LPG, CO, CH4. Because of its high sensitivity and quick response time, measurements can be taken as soon as possible.
    - In many cases the temperature inside a fire can reach upto 800 degree celcius and it is imperative for firemen to detect these zones to focus their efforts effectively. For firefighters to know about the regions which are at high temperatures, a heat map is generated. For the generation of the heat map, a sensor called DHT11 has been used.
    - With the help of these outputs received from these sensors, we can also classify the fire into one of the four levels of fire, thus helping the firemen take required precautions and equipment for themselves as well as during the rescue operations.

7.2 Parameters considered

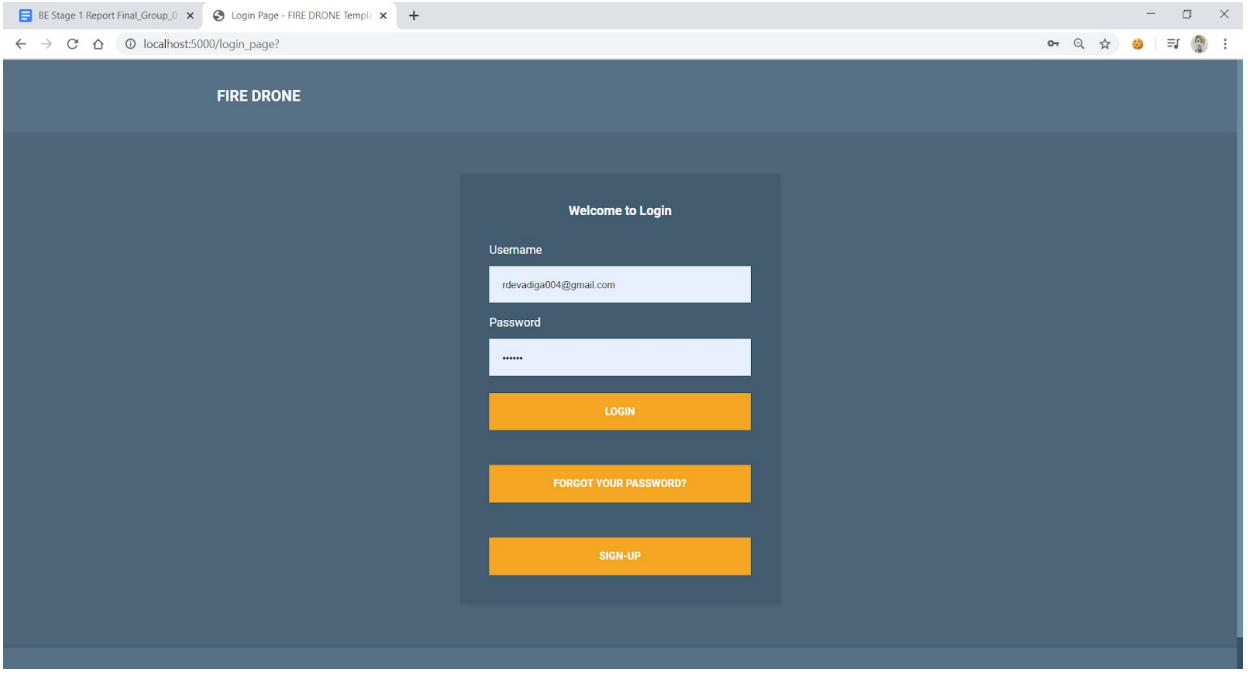
- Time Taken for Generation of charts
- Data latency and Accuracy
- Ultrasonic Reliability test in smoke.

7.3 Screenshots of User Interface (UI) for the respective module

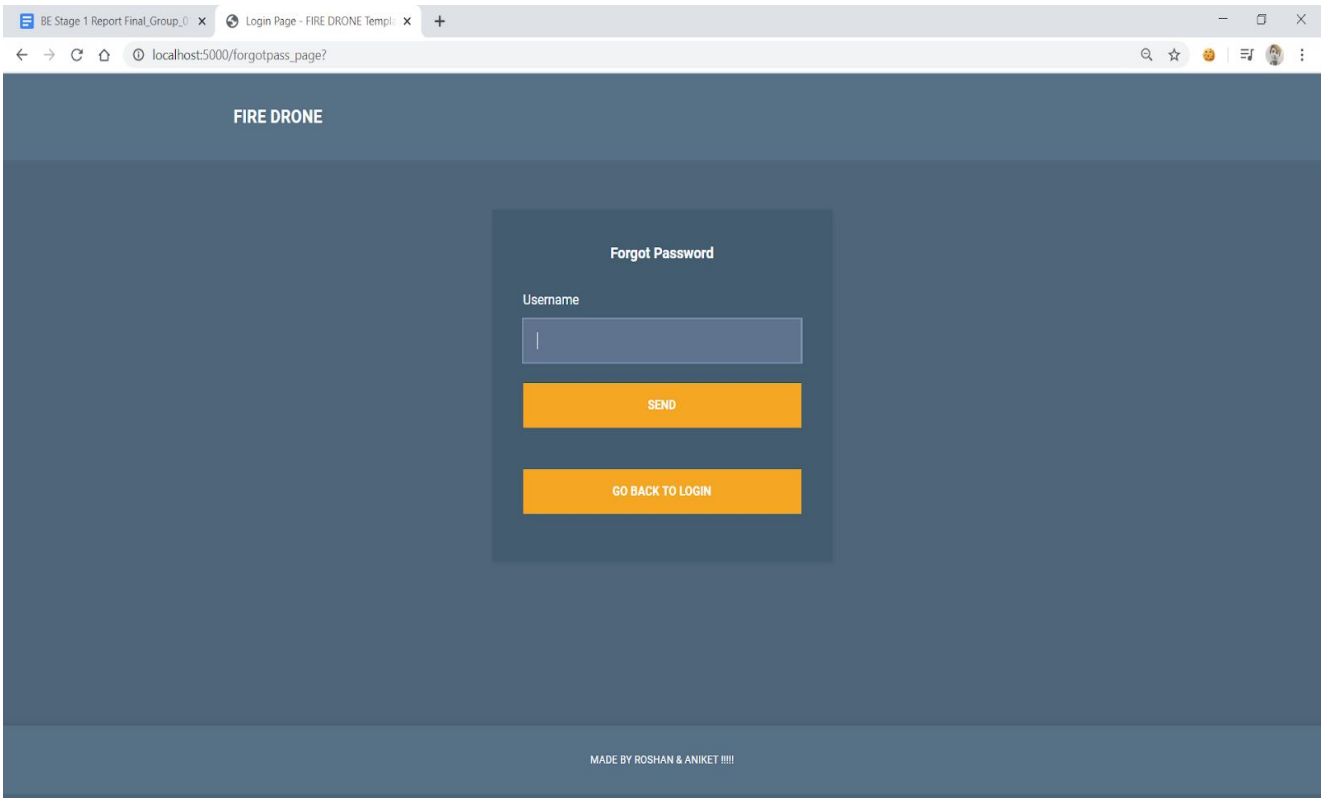
1. SignUp Page for Users to create their account:



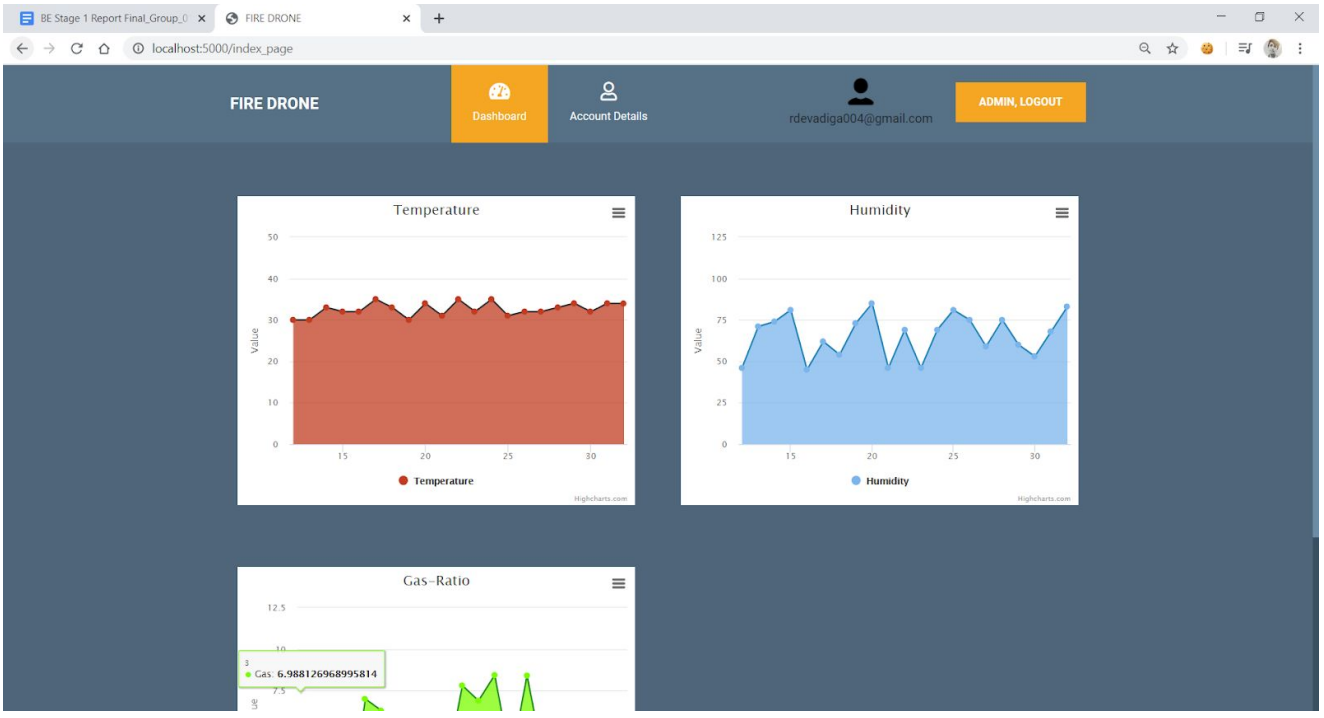
2. Login Page for Existing Users to Login:



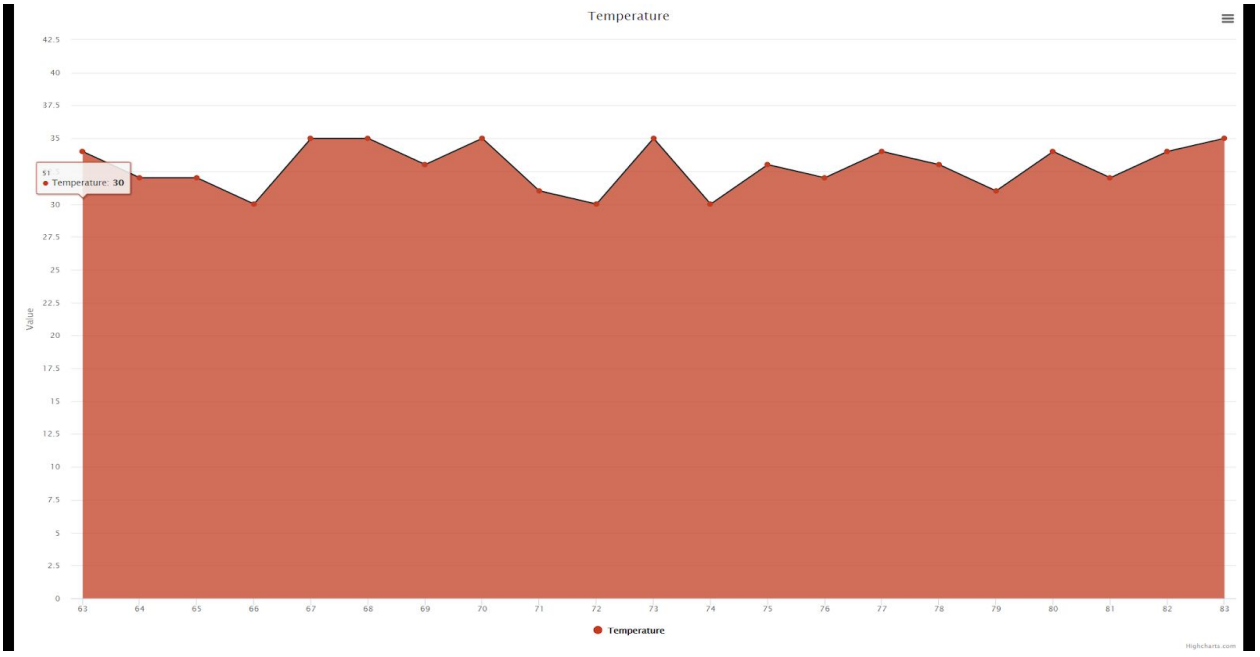
3. Forgot Password Page in case any user forgets their password:



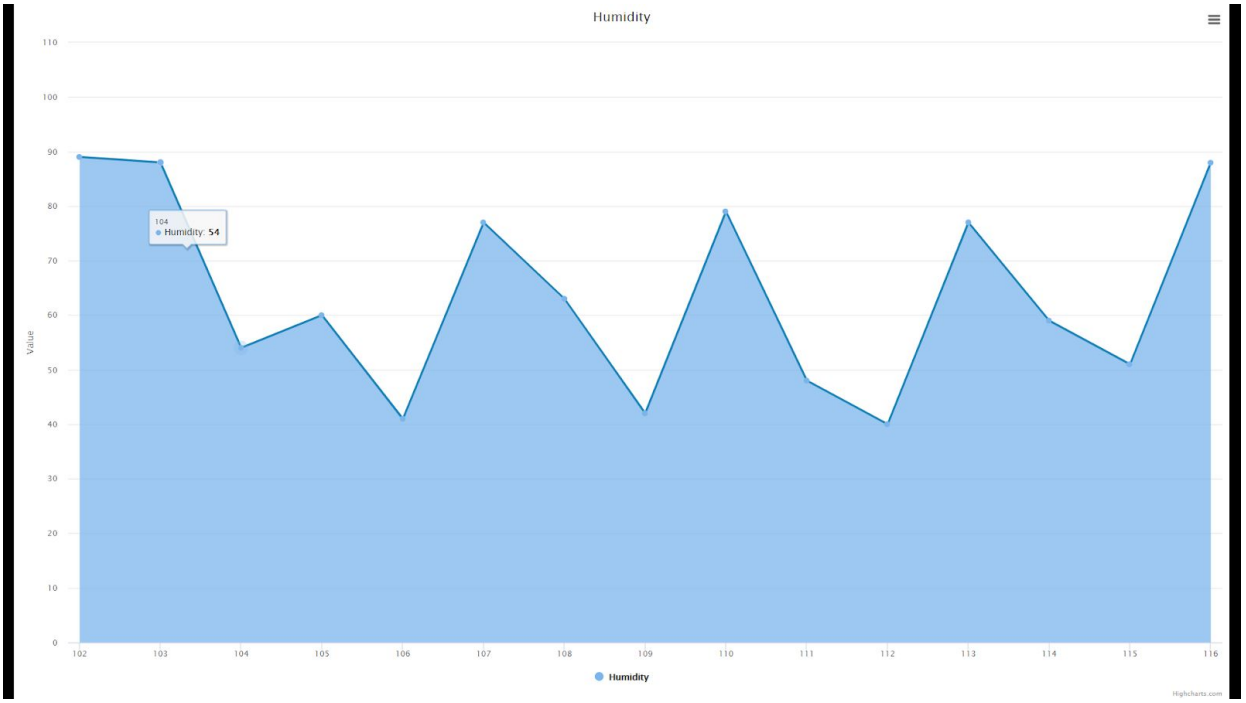
4. Dashboard Page of our Website consisting of all the important aspects of our User Interface such as the 3 real time graphs via(Temperature,Humidity,Gas)



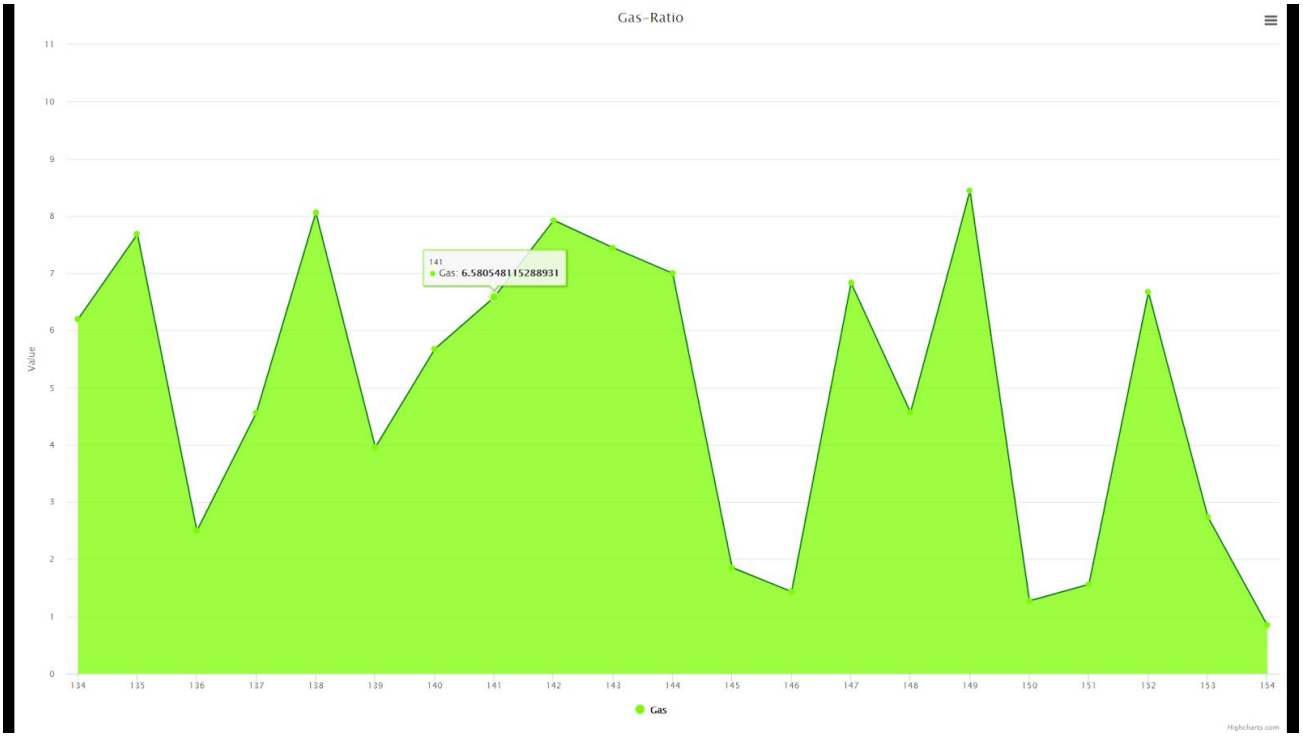
5. Temperature Graph to represent live temperature data captured through DHT11 sensor where the X-axis represents time stamp and Y-axis represents the Temperature in Degree Celsius:



6. Humidity Graph to represent live humidity data captured through DHT11 sensor where the X-axis represents the Time Stamp and Y-axis represents the Humidity in Degree Celsius:



7. Gas Graph to represent live surrounding gas levels captured through MQ9 sensor where the X-axis represents the Time stamp and Y-axis represents the gas-ratio value:



7.4 Evaluation of the developed system (Accuracy, Effectiveness, Efficiency)

A. Proposed Evaluations:

1. Drone Flight Parameters.
    a. Using a PID controller along with accelerometer and gyroscope signals for stabilizing the drone in the air.
    b. The measured angle can be fed as the error value to the PID controller. One thing to be mentioned is that gyroscope and accelerometer measured values must be converted into angular value.
    c. Gyro sensor value should not fluctuate randomly.
    d. Acceleration should not exceed certain limits.
    e. Collision should be avoided at all costs.

f. Latency.

2. Proper/Stability of connection and setup of NodeMCU sensors.
    a. Latency.
    b. Efficiency of storing real time data.
    c. Efficiency of accessing stored data.
3. Heatmap
    a. Reliability in high temperatures.
    b. Efficiency of DHT11 sensor.
    c. Comparison with map generated with other sensors.
4. Effectiveness of Fire extinguisher ball
    a. Effectiveness of extinguisher ball on different types of fire.
    b. Accuracy of selecting best location for dropping the ball.

B. Determination of Efficiency:

1. Flight controller:
    a. The action passed on by Blynk app takes 0 - 0.5 s to reach the processing unit due to signal delays of wireless transmission.
    b. The pipeline from receiving action to generation of commands for individual motors takes 0 - 1 s depending on the complexity of command.
    c. An intentional delay of 0.5 is introduced during the measurement of sensor values in the pipeline due inability of the processor to handle fast input.
2. Area Map Generation:
    a. A slight delay will be present during the generation of the area map because of the deliberate delay introduced during the collection of data from ultrasonic sensors.

C. Determination of Accuracy:

1. The degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard is accuracy.
2. In our project, accuracy will be achieved when-
    a. The flight controller will perform the directed actions perfectly
    b. The chemical sensors will be able to determine the gas levels correctly
    c. Accuracy of other Sensor readings.
3. These can only be tested after complete implementation.

D. Reports on Sensitivity Analysis:

1. Flight Controller:
    a. The system cannot handle unknown inputs.
    b. If at any instance of time, the system gets unknown input it will execute its fail safe mechanism and return the drone to safety.

7.5 Graphical outputs of the various scenarios considered:

1. Area Map:

As said in the implementation section, once the ultrasonic sensors collect the required data, the data is sent to the firebase. This data present in the firebase is then retrieved by our python script. Once the data is retrieved, it is run through an algorithm which generates an area map. The above diagram is an example of an area map which has been generated by our python script.

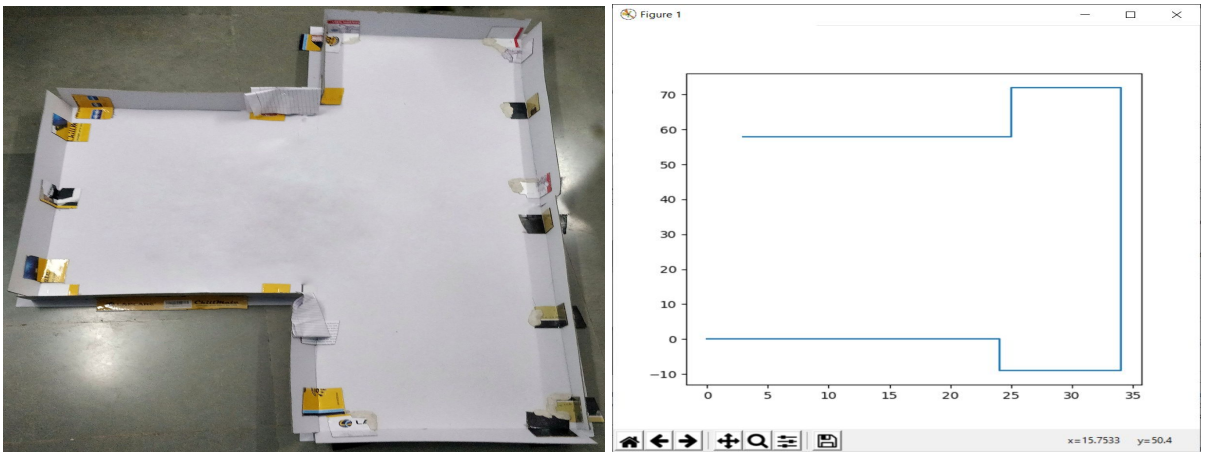


Figure 9: The left figure is the actual environment and on the right is the area map of it.

2. Toxicity Report:

To generate the toxicity report we are using the MQ-9 sensor. The sensor is highly sensitive and responsive so the data can be collected real time at a very high speed.

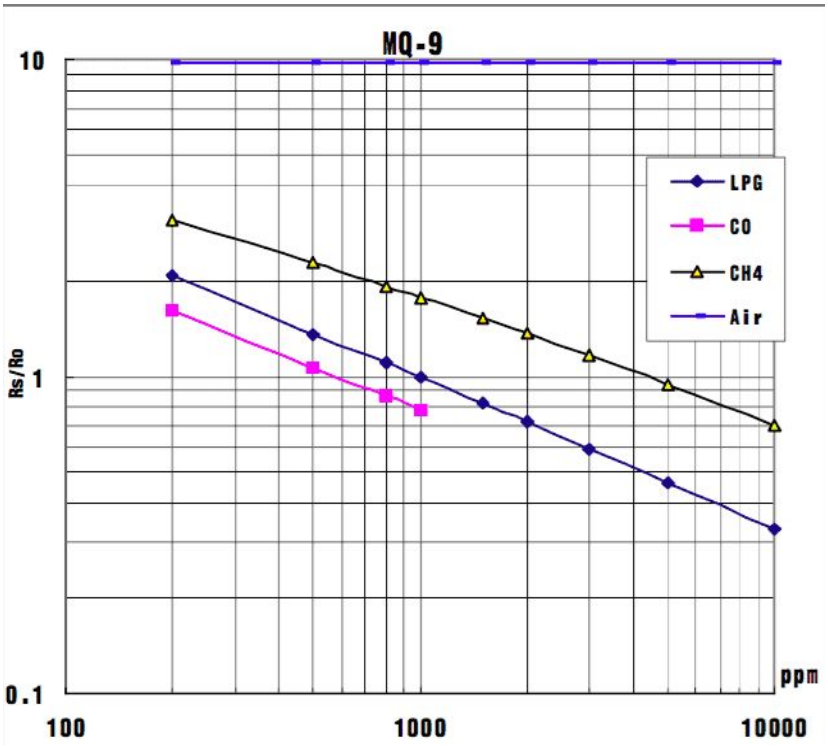


Figure 10: Standard Data Graph of MQ-9 Sensor where Y-axis represents RS/R0 ratio and X-axis represents PPM concentration

It detects density of gases in the range of 100ppm to 10000ppm. The sensor calculates the concentration of the gases on the basis of resistance ratio. The ratio consists of two variables 'R0' which is the sensor resistance of LPG in 1000ppm concentration and 'Rs' i.e. internal resistance of sensor that varies with density of gas. Figure 4 represents the standard data-sheet of the MQ9 sensors. As per the figure, we can only test the gases in the concentration range of 0.02% to 1% i.e. 200ppm to 10000ppm.

3. Temperature and Humidity Report:.

Here we use a DHT11 sensor to calculate surrounding temperature and humidity. It detects water vapor by calculating the electrical resistance between 2 electrodes. The relative humidity is calculated by the change in resistance between the electrodes, higher the relative humidity lower is the resistance between the electrodes and vice-versa. Similarly, for measuring temperature the sensor uses a negative temperature coefficient thermistor, which basically causes a reduction in resistance with increase in temperature.

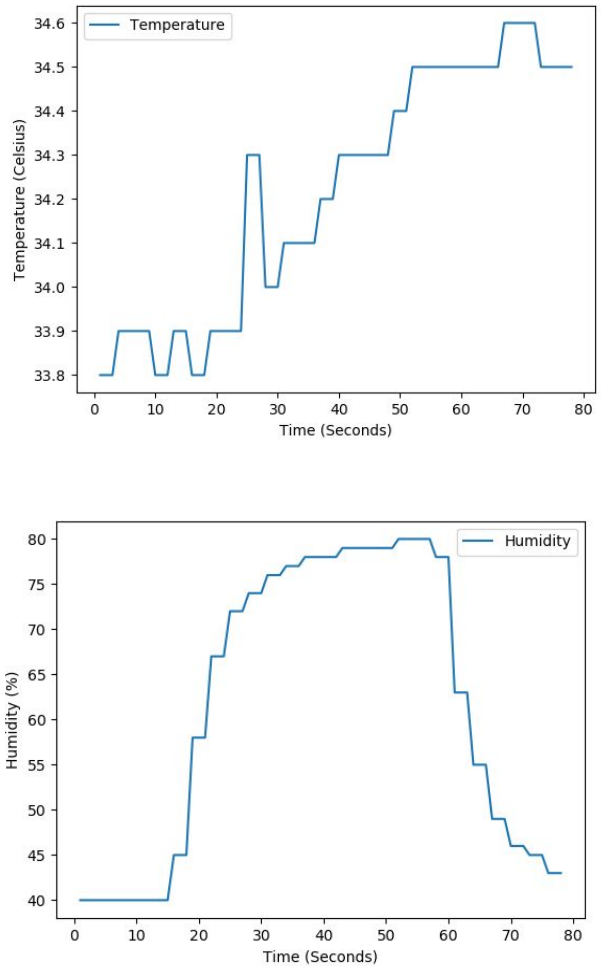


Figure 11: Temperature vs Time Graph and Humidity vs Time Graph

7.6 Comparison with the existing systems (w.r.t. results)

Robofire, an asset of our fire department was recently used in a major fire outbreak in MTNL building, Bandra.

Existing System (Robfire)	**Proposed Solution**
High cost solution (1 cr)	Low cost solution (40k)
Huge size	Small size
Manual navigation	Autonomous navigation
Works on land therefore unsuitable for residential areas	Works in air therefore suitable for residential and other small environment

Gives no information about the position of human beings, structure of environment, entry and exit points, presence of harmful gases.	Provides information about the position of human beings, generates area maps to provide structural information, and generates toxicity reports.
Does not generate heatmap of the environment	Generates heatmap of the environment.
Requires skilled human operator	Does not require a skilled human operator.

Table 3: Comparison between existing system and proposed solution

Chapter 8: Conclusion

8.1 Limitations

- Stability Of Flight
  - Flight of Drone depends on Flight controller used and calibration of ESC and motors.
  - Arduino libraries lack the support for Drone programming and one can only do so much calibration, as a result stability of drone is medicare and latency between control input and output exists.

- Time of Flight
  - Battery capacity with the amount of time it takes to recharge makes time of flight hardly over 20 minutes.
  - As a result, drone operator needs to be quick and efficient.

- Durability
  - In a Dangerous and Volatile Environment such as a Fire, Drone frame and sensors may stop working due to high temps, hence drone should only be used as a means of Surveillance and not quenching the fire.
  - Reliability of sensor data degrades with the change in environment as well.

- Latency
  - In high stress and time critical environment data must be made available instantaneously to save lives or be useful, however hardware and software are prone to failure and such a scenario needs to be tackled or avoided.

8.2 Conclusion:

Using UAVs like drones allow for information gathering without risking personnel. Moreover, the information gathered is more accurate and visualised which allows firefighters to respond more quickly. Toxicity reports generated will allow for determining high risk areas and hence help personnel to focus their attention where needed. 2D map and Heatmap generated will enable mapping environments inaccessible to humans because of fire, such as collapsed entrances or narrow slums. Moreover for complex indoor areas which have many entries and exits, this data is useful for determining best entry and exit points for firefighters,thus saving crucial time.

8.3 Future Scope:

Solving existing limitations and improving the product as a whole, This can be done as follows :

- Improving stability by using a proper Flight Controller instead of Arduino based.
- Improving TOF by simply having a spare battery ready to hot-swap between flights.
- Accounting for latency in visualization of data making it more accurate.
- Improving durability by providing heat insulation to components.

Chapter 9: References

9.1 Newspaper Articles Referred:

1. The article given below basically narrates the incident of a fire outbreak at the MTNL building in Bandra which took place in July'19. It talks about the debut of the firefighting robot, Robofire.

https://www.dnaindia.com/india/report-mumbai-mtnl-building-fire-firefighters-use-newly-inducted-robofire-to-douse-flames-2774785

9.2 Interaction with Domain Experts:

1. **Interviewee's name:** Shri H.D.Parab
   Address: Ward E, Bapurao Jagtap Marg, Near Municipal Corporation, Byculla, Mumbai, Maharashtra 400008
   Occupation: Deputy Chief Fire Officer (Mumbai)

9.3 Research Papers Referred:

1. ***"Use of Fire-Extinguishing Balls for a Conceptual System of Drone-Assisted Wildfire Fighting"*** *by Burchan Aydin, Emre Selvi, Jian Tao and Michael J. Starek.*
https://drive.google.com/file/d/1zuEg0s1CQq9QoeKsvY9pip6r1ZT4B-vY/view

2. ***"3D environment mapping and self-position estimation by a small flying robot mounted with a movable ultrasonic range sensor"*** *by Kazuya Nakajima, Chinthaka Premachandra and Kiyotaka Kato.*
https://www.sciencedirect.com/science/article/pii/S2314717217300120

3. ***"Measurement of kinematics of a flying disc using an accelerometer"*** *by Reno Konayagi, Yuji Ohgi.*
https://www.researchgate.net/publication/239424424_Measurement_of_kinematics_of_a_flying_disc_using_an_accelerometer

4. ***"A detection method using ultrasonic sensors for avoiding a wall collision of Quadrotors"*** *by Kenjiro Niwa, Keigo Watanabe, Isaku Nagai.*

https://ieeexplore.ieee.org/document/8016028/authors#authors

5. **Altitude detection and control using altimeter and barometer**

https://www.instructables.com/id/Raspberry-Pi-MPL3115A2-Precision-Altimeter-Sensor--1/

6. ***"Generation the 3D Model Building by Using the Quadcopter"*** *by T.T. Bertrama, T.T. Bockb, A.G.Bulgakovc and A.A.Evgenovd, Germany, Russia.*

https://pdfs.semanticscholar.org/3a43/e793a2d8c8f426ac6d475c767886075101a2.pdf

7. **Toxicity sensors**

http://davidegironi.blogspot.it/2014/01/cheap-co2-meter-using-mq135-sensor-with.html

https://tutorials-raspberrypi.com/configure-and-read-out-the-raspberry-pi-gas-sensor-mq-x/

9.4 Research Patents Referred:

1. Unmanned aerial vehicle for situational awareness to first responders and alarm investigation.

https://worldwide.espacenet.com/publicationDetails/biblio?II=1&ND=3&adjacent=true&locale=en_EP&FT=D&date=20170918&CC=KR&NR=101779293B1&KC=B1

2. Cognitive load reducing platform for first responders

http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=drone&s2=%22fire+fighter%22&OS=drone+AND+%22fire+fighter%22&RS=drone+AND+%22fire+fighter%22

3. A multipurpose drone for extinguishing fire and saving a life

http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=11&f=G&l=50&co1=AND&d=PTXT&s1=drone&s2=%22fire+fighter%22&OS=drone+AND+%22fire+fighter%22&RS=drone+AND+%22fire+fighter%22

9.5 Links related to our Project:

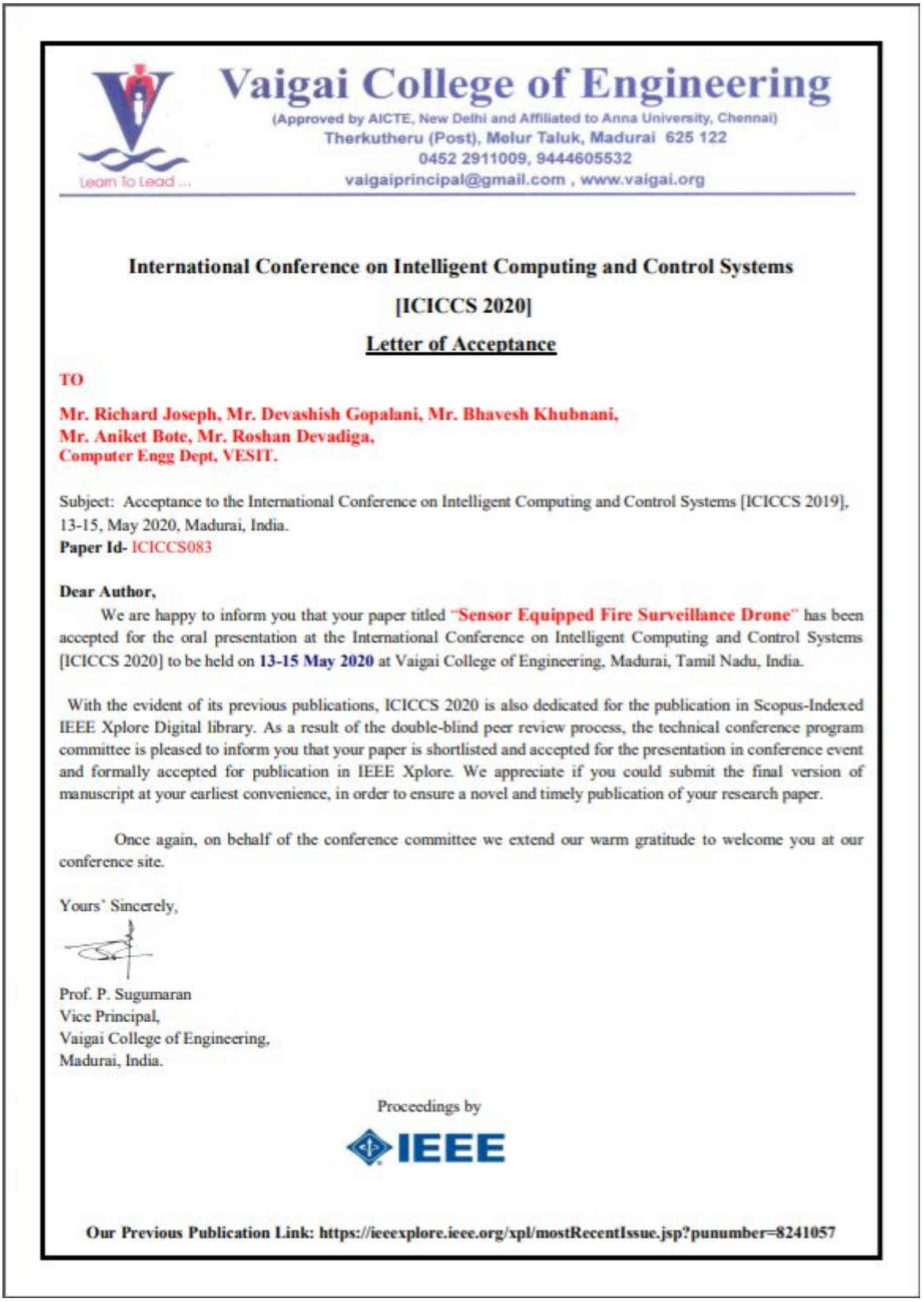
1. Demo of collision avoidance:
   https://www.youtube.com/watch?v=5YU5aD-GnfM

2. Drone orientation detection using MPU6050:
   https://www.youtube.com/watch?v=ir4p11vDqtw
3. Flight Controller Simulation with the help of Blynk App:
   https://www.youtube.com/watch?v=I0yY_0ne_Eo

10. Appendix

10.1. Paper I

a. Paper published



Vaigai College of Engineering

(Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai)
Therkutheru (Post), Melur Taluk, Madurai 625 122
0452 2911009, 9444605532
vaigaiprincipal@gmail.com , www.vaigai.org

Learn To Lead ...

International Conference on Intelligent Computing and Control Systems

[ICICCS 2020]

Letter of Acceptance

TO

Mr. Richard Joseph, Mr. Devashish Gopalani, Mr. Bhavesh Khubnani,
Mr. Aniket Bote, Mr. Roshan Devadiga,
Computer Engg Dept, VESIT.

Subject: Acceptance to the International Conference on Intelligent Computing and Control Systems [ICICCS 2019], 13-15, May 2020, Madurai, India.
Paper Id- ICICCS083

Dear Author,

We are happy to inform you that your paper titled "**Sensor Equipped Fire Surveillance Drone**" has been accepted for the oral presentation at the International Conference on Intelligent Computing and Control Systems [ICICCS 2020] to be held on **13-15 May 2020** at Vaigai College of Engineering, Madurai, Tamil Nadu, India.

With the evident of its previous publications, ICICCS 2020 is also dedicated for the publication in Scopus-Indexed IEEE Xplore Digital library. As a result of the double-blind peer review process, the technical conference program committee is pleased to inform you that your paper is shortlisted and accepted for the presentation in conference event and formally accepted for publication in IEEE Xplore. We appreciate if you could submit the final version of manuscript at your earliest convenience, in order to ensure a novel and timely publication of your research paper.

Once again, on behalf of the conference committee we extend our warm gratitude to welcome you at our conference site.

Yours' Sincerely,

Prof. P. Sugumaran
Vice Principal,
Vaigai College of Engineering,
Madurai, India.

Proceedings by

IEEE

Our Previous Publication Link: https://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=8241057

b. Project review sheet