IOP Conference Series: Materials Science and Engineering

IoT based guided fire fighting vehicle

To cite this article: A R M Raafeek *et al* 2022 *IOP Conf. Ser.: Mater. Sci. Eng.* **1258** 012062

IoT based guided fire fighting vehicle

A R M Raafeek[1, a], N Satheeskanth[2, b], J Joy Mathavan[3, c *], A Kunaraj[4, d]

[1,2,3,4] Department of Engineering Technology, Faculty of Technology, University of Jaffna, Kilinochchi premises, Ariviyal Nagar, Sri Lanka.

[a]arm.raafi69@gmail.com, [b]sathees117@gmail.com, [c]joymathavan1991@gmail.com, [d]kunaraj1984@gmail.com

Abstract. Fire accidents are occurring frequently nowadays in domestic and industrial environments with unpredictable climatic changes and human negligence. The proposed prototype is designed to detect such fire accidents and to extinguish the fire by remote operation of the user, and thereby reducing the risk of fire fighters involved. The movement of the vehicle is dictated by the combination of sensor-based inputs and user guidance. When the fire is detected by the fire detection sensor, the signal is immediately passed to the controller. GSM modules will be activated alerting the user about the fire accident. Once the alert is received, the user can guide the vehicle to the required location with the help of Blynk software & in-built camera module to extinguish the fire. The servo motor connected with the firefighting hose can control the direction and volume of water to be sprayed. The controls of the servo motors are with the user. The proposed firefighting vehicle is designed to function using Internet of Things (IoT), thereby enabling the user to control the fire from anywhere.

Keywords: *ESP32 cam, Arduino, Flame sensor, IoT, Blynk software, Guided vehicle, Fire hazard*

1. Introduction

Nowadays, domestic and industrial fire accidents are getting frequent. It increases the amount of damage caused by fire and also the risk to human lives [1]. A smart home automation system [2, 3] could be an easy solution to prevent small scale fire accidents from occurring in a home or to extinguish such fire hazard. But once it is spread out to the entire complex, the supporting factors for the fire cannot be controlled by the smart home automation system since the system is designed to control the fire only to that particular home. So, it won't control the fire on the entire building. Under such a situation, a fire extinguishing vehicle is necessary to control the fire throughout the entire complex. These needs paved the path to this research work. The proposed system aims at building a guided vehicle that can be installed in a domestic or industrial environment, to alert the user in case of fire accidents. This vehicle can be guided by the user through mobile phone control to the intended location where the fire accident is occurring and water can be sprayed to extinguish the fire via mobile phone control. The velocity, volume and the direction of water while spraying can also be controlled by the user. The developed vehicle can be observed in the screen of the mobile phone from far away to guide the motion of the vehicle and thereby the user can communicate with it to effectively extinguish the fire. IoT (Internet of

Things) integration enables the guided vehicle to organise, analyse and process data, allowing the user to make optimum decisions on a real-time basis. By this way, the damage that can be caused by fire before the arrival of the fire extinguishing squad can be drastically reduced and the risk of involvement of fire extinguishing squad can also be minimised. The chance of life loss and / or injury in a normal automobile fire accident can be reduced by automatic door unlocking system [4]. But fire extinguishing squads are the people who are dedicated to stopping the fire even at the expense of their lives. So, this research work targets to minimise human involvement to stop any fire accidents.

2. Literature review

Automatic Guided Vehicles (AGV) are increasingly utilised in the logistics in smart warehouse [5] operations due to their increased efficiency [6]. Hiroshi Yoshitake et al in their research, proposed a system using AGV that works on real time holonic scheduling algorithms to improve the efficiency in warehouses. This AGV transports both inventory shelves and sorting shelves to the picker point simultaneously, preventing the movement of the picker across the warehouse. At the same time, the role of the AGVs in smart logistics [7] are also increasing steeply. The use of computer vision in vehicle automation [8] for guiding AGV in complicated environments are also discussed in this research work. The automatic guided vehicle follows the magnetic tape [9] attached to the floor or desired predefined trajectory [10] and identifies the destination, and load or unload based on the RFID (Radio Frequency Identification Definition) tag. This system works well for loading and unloading where guided systems have to travel only through well predefined paths. Kajan. K et al [11] have described an automatic guided vehicle which is controlled by PLC (Programmable Logic Controller) and integrated with Arduino using Transmission Control Protocol (TCP) communications to connect any third-party devices with the PLC. However, these prototypes are developed to work in the industrial environment with predefined paths for AGV movement. Kelber et al [12] in their research paper described automated guided vehicles that can be guided by human machine interface such as joystick and mobile phone in contrast to the conventional pedal and steering wheel arrangements. The automation was made using the technology available in 2003 and still inspired us for the proposed research work. Butdee and Suebsomran [13] in their research work, described an automatic guided vehicle that can be guided based on the colour tape sensed by the Charge Coupled Device (CCD) camera sensor. Edge detection to identify the red tape against its background is performed by the Laplacian operator and the control is provided by the PLC controllers. However, for firefighting, this method of guiding the robot will not be effective as the sources of fire incidents are unpredictable and therefore it will be difficult to move based on colour tape. Ratul Ahmed Rahat et al [14] developed a firefighting mechanism which can be operated by both manual and automatic mode. Water is sprayed in case of manual operation and CO_2 is sprayed in automatic operation. The robot was built using obstacle avoidance [15, 16] algorithm and detection of fire was performed by fire and smoke sensors. Once the fire is extinguished, it is important to patrol [17] the region to make sure that the fire is properly extinguished. Rakib and Sarkar [18] introduced a firefighting autonomous robot controlled by a PID (proportional–integral–derivative) controller that can throw water using a centrifugal pump once fire is detected. However, guiding mechanisms are not well developed in these prototypes. A clear guiding mechanism is designed by Kunaraj et al to be a guided robot which can be operated by an operator from a distance; but their objective is landmines detection in war-torn regions [19]. The idea of using hybrid fuzzy PID [20] controllers is also utilised in mobile robots to improve the performance of the robot and increase the dynamic response of the robot. The robot can avoid obstacles [21], detect flames and track through to extinguish the fire. Robots are not only utilised to extinguish the fire but also using a block of robots [22] the fire or nuclear radiation can be prevented. Water or lead solution pumped through those chains of robots can act as shields to protect humans from any harmful flares and radiations. Yet reliable models that can work in the robust and real time environment are still in the developing stage.

IOP Conf. Series: Materials Science and Engineering 1258 (2022) 012062 doi:10.1088/1757-899X/1258/1/012062

3. System description

When a fire accident occurs from different sources, the fire detection sensor senses the fire and sends the signal to the Arduino controller. According to that signal, the Arduino controller sends commands to the GSM (Global System for Mobile communication) module as shown in figure 1. The GSM module in turn will send a message as "Emergency fire alert" to the user or owner of the particular domestic / industrial complex. Based on the signal, the user may guide the fire fighting vehicle using Blynk software. While guiding, he can consider the observations obtained from the inputs of the camera module. Once the target is reached, then the user can activate the servo motor to spray the water to extinguish the fire. The outline of the proposed prototype is shown in figure 2.

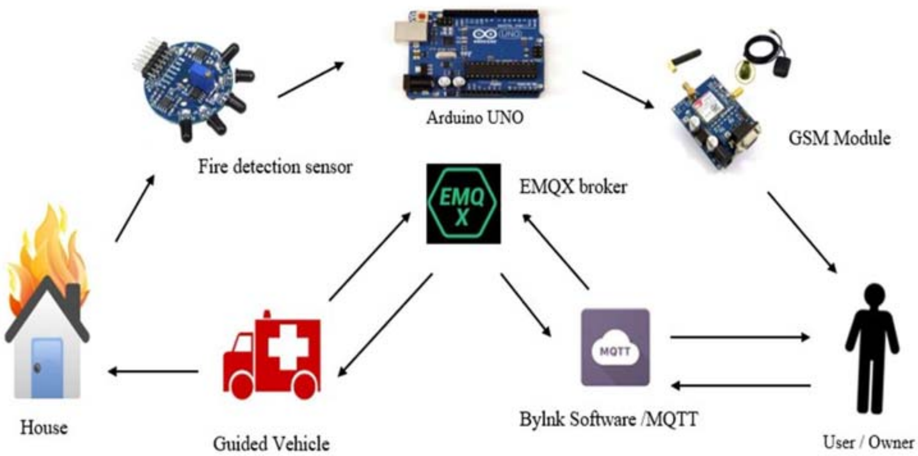

Figure 1. Block diagram of the proposed work

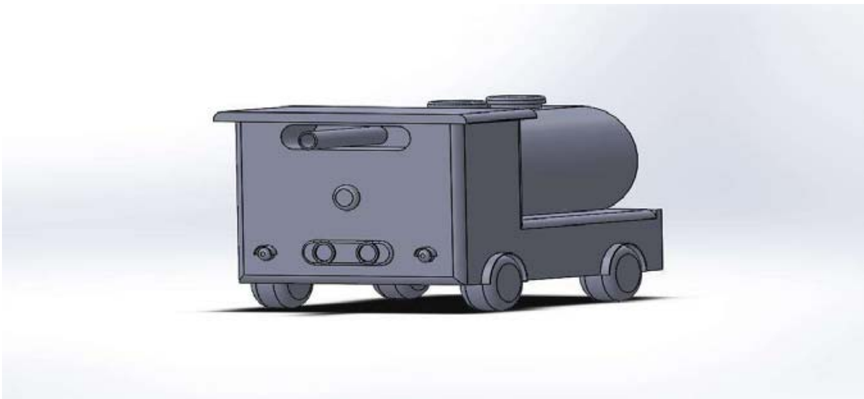

Figure 2. Outline of the proposed firefighter

Meanwhile, using ESP camera module, damages caused by the fire can also be monitored by IoT (Internet of Things) from far away. GSM modules are attached as a backup option to reach out the user through SMS or emergency calls in case of any network issues. The flow diagram of the operation of the fire sensing module is shown in figure 3 and the function of the fire fighting vehicle is shown in figure 4 respectively.

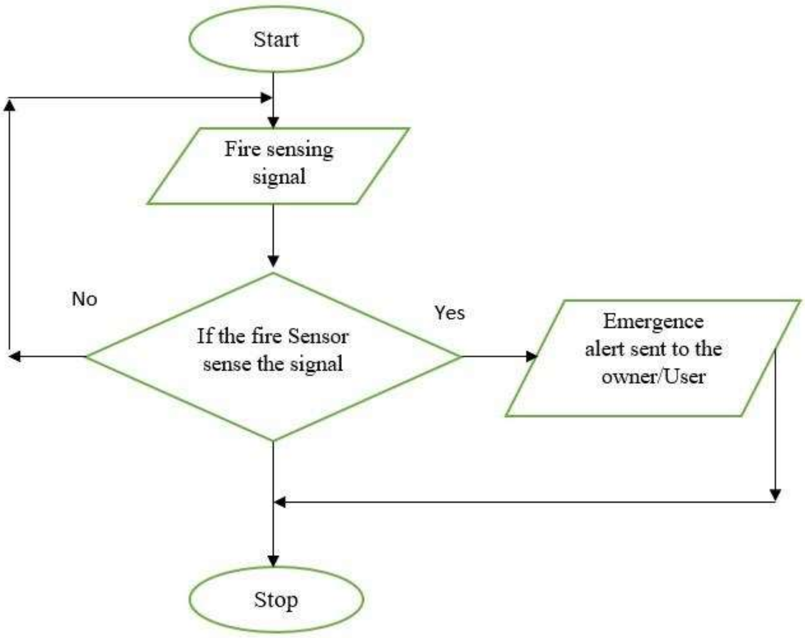

Figure 3. Flow diagram of fire sensing module

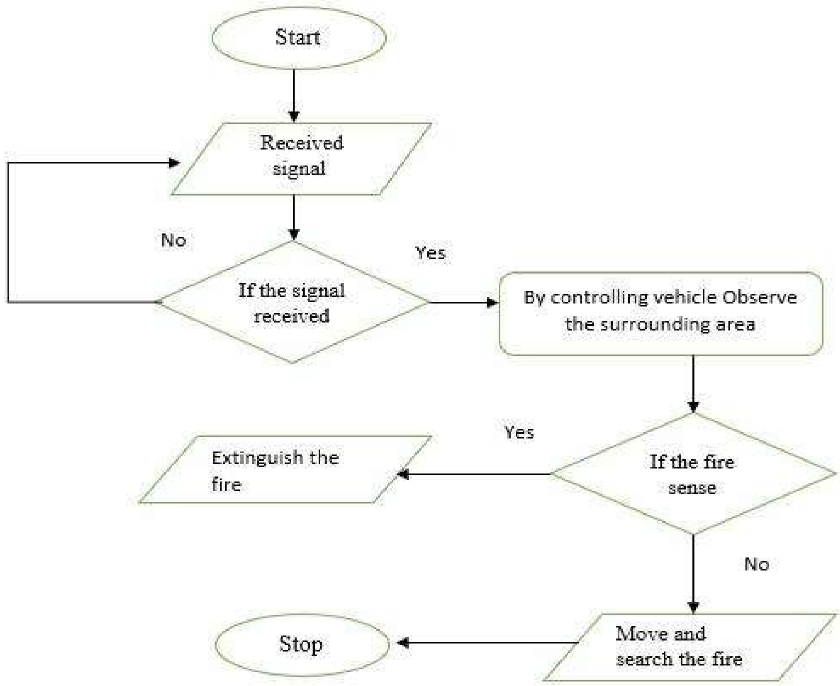

Figure 4. Flow diagram of firefighting guided vehicle

IOP Conf. Series: Materials Science and Engineering 1258 (2022) 012062 doi:10.1088/1757-899X/1258/1/012062

Table 1. Specification of the hardware components.

Hardware components used	Specification
Arduino UNO	Microcontroller: ATmega328P Operating voltage: 5V Flash memory 32KB Clock speed 16MHz Analog I/O pins: 6 Digital I/O pins:14
ESP Camera	802.11b/g/n/Wi-Fi Operating voltage: 3.3V Input voltage: 5V Flash memory: 4 MB Clock speed: 160MHz GPIO ports: 9
Ultrasonic sensor	Power supply: 3.3V-5V Operating current: 8mA Range distance:3cm-350cm Measuring angle:15 degree
Blynk Software	All supported hardware and devices Connection mode: Wi-Fi, Bluetooth, Ethernet, USB (serial), and GSM
Motor	Rated voltage: 3-6V Operating speed(6V): 200+/-10% RPM Gear ratio: 1:48 Shaft: dual-shaft
Motor drive controller	Diver model: L298N Power supply: 5V-35V Peak current: 2A Operating current range: 0-36mA Maximum power: 25W
GSM module	Model type: SIM800L Power supply: 3.8V-4.2V SIM card socket: microSIM

	Supported frequencies: Quad-band (850/950/1800/1900 MHz)
DC water pump	Voltage range: 2.5V-6V Operating current: 130-220 mA Hydraulic head 40-110cm Power: 0.4-1.5W
Servo motor	Speed: 0.12sec/60 degrees(6V) Torque:1.5kf-cm (4.8V), 2.0kgf-cm(6V) Voltage:4.8V-6V

3.1 Fire sensing system

In the proposed system, once the fire incident is sensed by the fire detection sensor, the controller sends the user an emergency fire alert message through the GSM module. In this system, SIM800L is used as transmitter considering its affordability and its GPRS (General Packet Radio Service) transmission capability to send and receive SMS (Short Message Service) and Voice call. The schematic diagram shown in figure 5 depicts the connection between Arduino uno fire sensor and GSM sim 900D module.

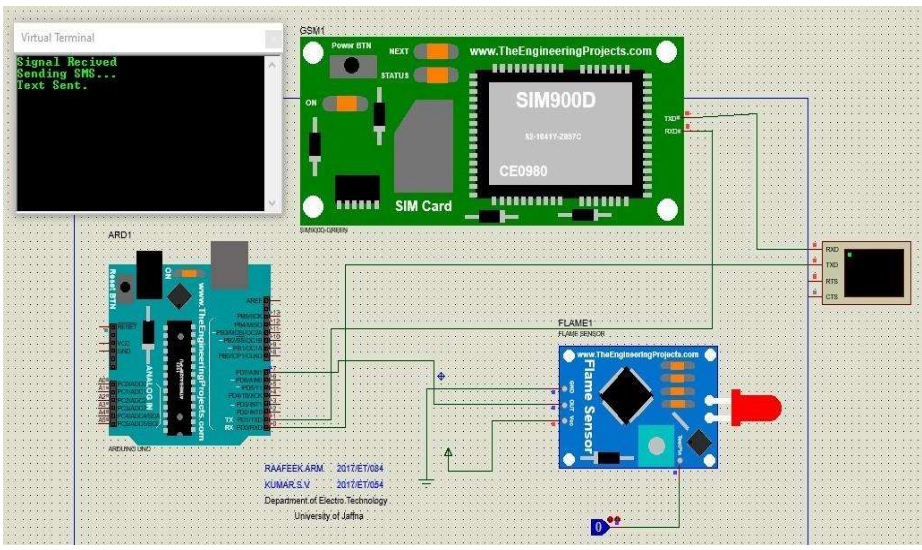

Figure 5. Emergency fire alert message sending mechanism

3.2 Vehicle controlling system

Vehicle controlling system comprises several parts such as video streaming, obstacle detection system, lighting facility, water level observation system, and water spraying system. Forward, backward and sideways movement of the vehicle is controlled using the L298N motor driver. Users can control the movement of the vehicle using the ESP32 camera module attached to the vehicle. Once the ESP32 camera module is connected to the internet, through the Blynk application installed in the mobile phone of the user, the vehicle can be operated. The schematic diagram showing the connection between Arduino uno motor driver and stepper motors are shown in the figure 6.

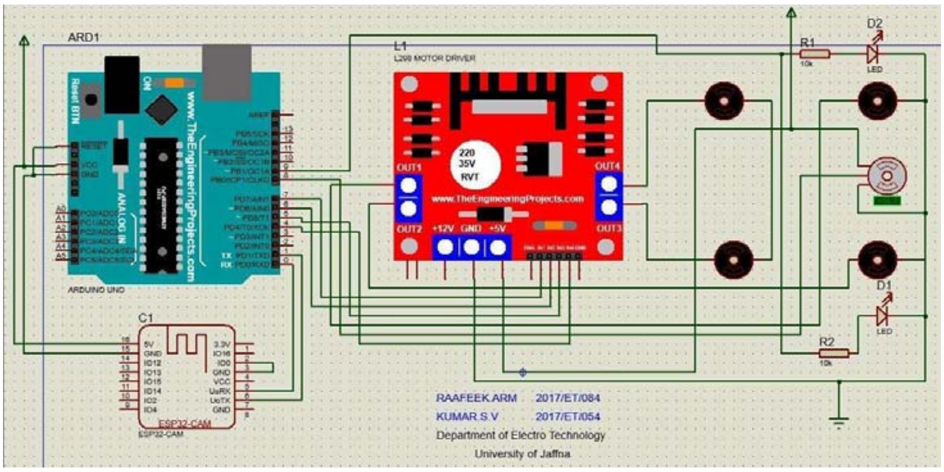

Figure 6. Vehicle controlling system

3.3 Water level observation

The proposed system uses water to control the fire. Therefore, it is mandatory to monitor the level of water in the tank. The level of water is monitored by the water level sensor which acts like a potentiometer to vary the electric resistance according to the level of water. When the level of water in the tank falls below predefined critical value, it sends an alarm signal to the user to refill the water tank. The schematic diagram showing the connection between Arduino uno and water sensor is shown in figure 7.

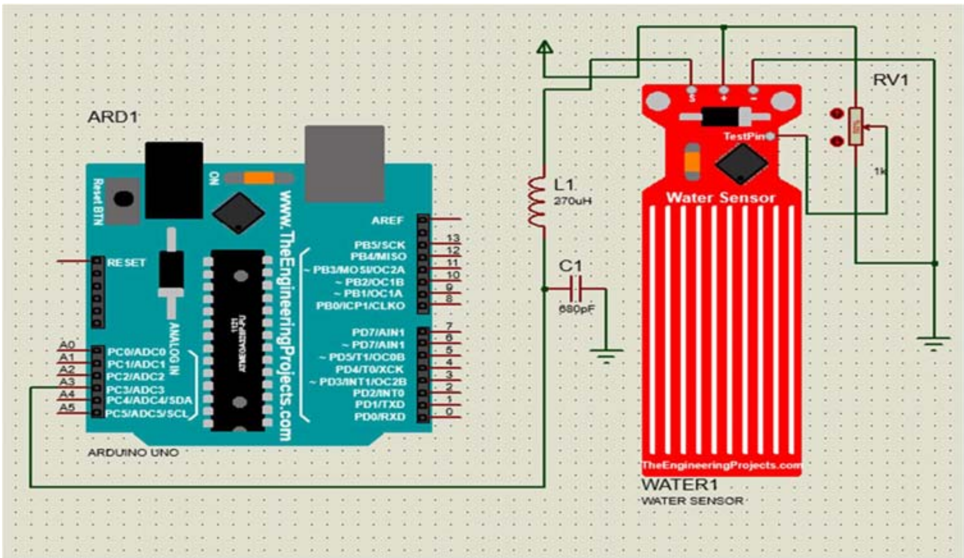

Figure 7. Water level observation

3.4 Obstacle detection system
The presence of an obstacle detection system in the guided fire fighting vehicle is to identify the obstacles on its way and to alert the user. Once the obstacle in the path of the robot is identified using an ultrasonic sensor, a sound buzzer is activated alerting the user about the presence of obstacles. This obstacle detection mechanism will be helpful while fumes created by fire block the view of the camera. The schematic diagram of the obstacle detection system is shown in figure 8.

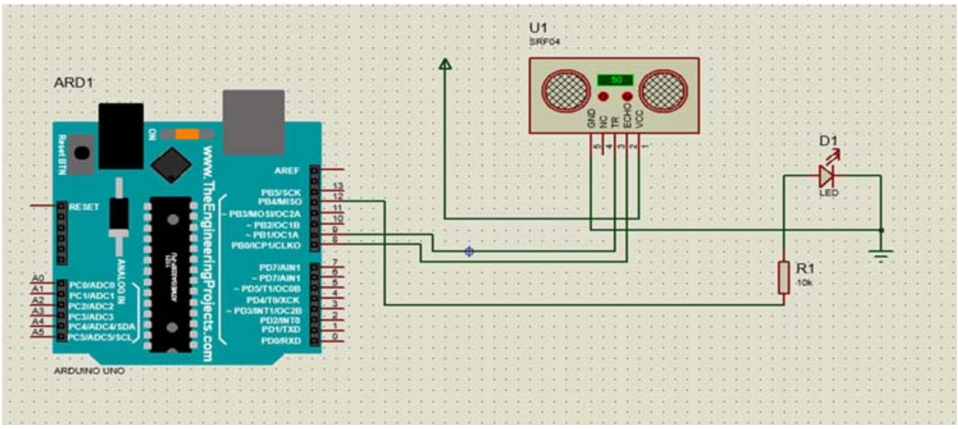

Figure 8. Obstacle detection system

3.5 ESP32 cam with Arduino configuration system
FTDI or Arduino can be used to upload code for ESP32 Cam boards. Arduino is used in this research as the external programmer for uploading the code to the ESP32 Cam board, since the connection port is unavailable in ESP32. The method of uploading the code using an external programmer is described below. Initially, configure the Arduino 5V to ESP32 Cam board power pin and Arduino ground pin to the ground pin of ESP32 module as shown in figure 9. The Arduino ground pin is again connected to the reset pin of Arduino. Arduino TX pin is connected to UOT pin of ESP32 cam and Arduino RX pin is connected to UOR pin of ESP32 cam. Once the configurations are completed, Arduino UNO can be used as a programmer to ESP32 module.

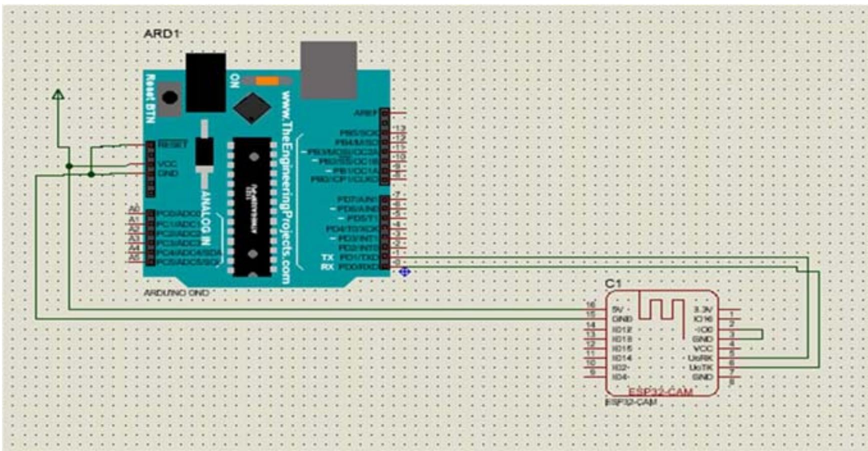

Figure 9. ESP32 cam with Arduino configuration

3.6 Software controlling system

To control and monitor the surroundings, the Blynk application shown in figure 10 is used. Based on the alarms received from the vehicle, it should be guided using the Blynk application which is integrated with the ESP32 cam board, telecasting video streaming using internet connection. This application contains several features to connect the device. It has Wi-Fi, Ethernet, serial port connection and several widgets such as button, slider, joystick and video streaming. In this system, control switches are provided for controlling the headlight, water spray and water nozzle adjustment. Joystick is provided to control the forward, backward, left and right motions of the vehicle and video streaming is enabled for sharing the live video streaming.

Figure 10. Vehicle controlling system

3.7 LAN to WAN IP address Forwarding system

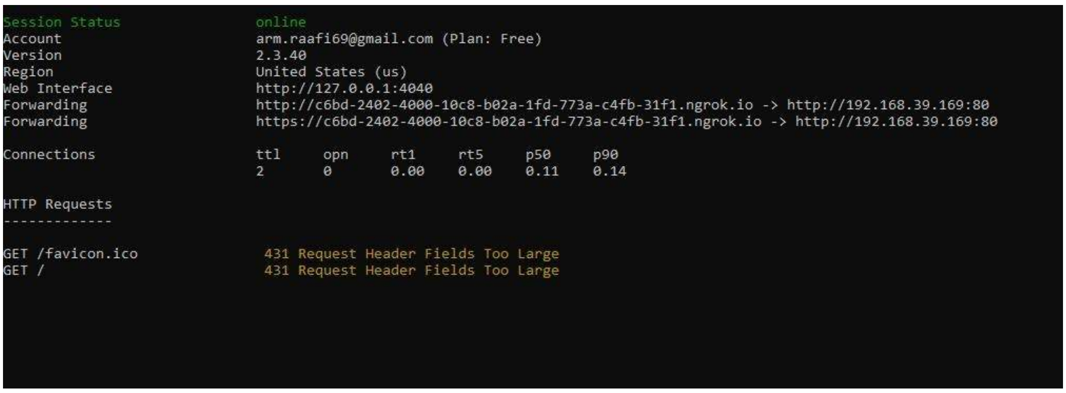

Figure 11. WAN IP address Forwarding

In order to access the ESP32 remotely, IP addresses can be forwarded using the NGROK application as shown in Figure 11. Using the IP address, the ESP32 cam board can be accessed from any part of the world.

4. Results and discussion

An IoT based guided fire fighting vehicle was constructed and tested. The final prototype designed based on the aerodynamic requirements are shown in figures 12 and 13. The proposed IoT-based firefighting-guided vehicle includes fire sensing elements, water level sensing elements, obstacles sensing elements, lighting elements, application control and live video streaming. For each of these applications, suitable sensors are employed and integrated with the controller. For the purpose of fire detection, heat detection sensor is used; for obstacle detection, ultrasonic sensor is used; and for the live video streaming, ESP32 camera module is used.

The fire detection sensor senses the fire and sends the signal to the Arduino controller. According to that signal, the Arduino controller sends commands to the GSM (Global System for Mobile communication) module. The GSM module in turn will send an alert message to the user. Based on the signal, the user may guide the fire fighting vehicle using Blynk software, considering the observations obtained from the inputs of the camera module. The fire fighting vehicle is designed to move forward, backward and sideways as directed by the commands from the operator. Once an obstacle is detected, a buzzer is triggered to alert the user. Once the fire is detected water can be pumped directly towards the fire at varying speed as determined by the command centre to put away the fire. Meanwhile, using ESP camera module, damages caused by the fire can also be monitored by IoT from far away. GSM modules are attached as a backup option to reach out the user through SMS or emergency calls in case of any network issues. The designed prototype functions effectively to detect the fire.

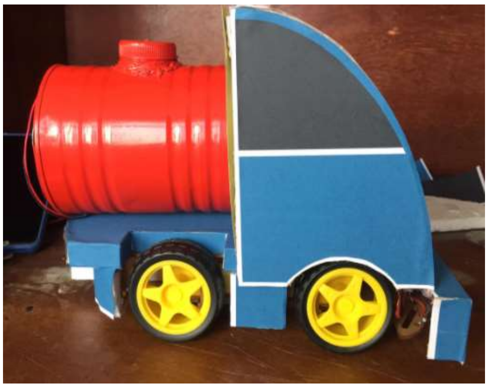

Figure 12. Side view of the prototype fire fighting vehicle

Figure 13. Front view of the prototype fire fighting vehicle

5. Conclusion and Future scope

In the proposed IoT-based firefighting guided vehicle, all the inbuilt devices were controlled using the Blynk application specifically designed for this purpose. The user can connect either PC or mobile phone to any network as the module. Therefore, the exchange of signals takes place frequently which can be monitored from any part of the world. Proposed firefighting guided vehicle would be useful for extinguishing fire when no one is around a domestic or industrial complex. The IoT based firefighting guided vehicle proves to be effective especially for the people who are away while having the loved ones in their home with no one to take care of them. It is also useful in corporate offices when the workers are away from the office building. The status of the place can be monitored and controlled from anywhere easily.

In the future, several features can be added to this system like providing first aid, notification to emergency units and identifying the human inside smoke. This system is built using an Arduino UNO controller which includes limited features and functionalities. For effective control and increased efficiency, a wireless control of ESP32 can be used. Proposed plan of the IoT-based firefighting guided vehicle is entirely adaptable and can be effortlessly extended and applied to bigger structures by expanding to high torque motors, high-capacity water tanks and enhanced control devices.

6. References

[1] National Fire Protection Association 2019, "Firefighter Fatalities in the United States – 2018," June.

[2] Satheeskanth N, Marasinghe S D, Rathnayaka R M L M P, Kunaraj A and Joy Mathavan J 2022 IoT-Based Integrated Smart Home Automation System. In: Karuppusamy P, Perikos I., García Márquez F.P. (eds) *Ubiquitous Intelligent Systems. Smart Innovation, Systems and Technologies*, vol **243**, pp 341-355. *Springer, Singapore*. https://doi.org/10.1007/978-981-16-3675-2_26.

[3] Kunaraj, A., Mathavan, J.J., Mathushan, M., Kamalesan, G.M. (2021). "Hardware Implementation of Smart Home Automation System Using Aurdino UNO ". In: Sengodan, T., Murugappan, M., Misra, S. (eds) *Advances in Electrical and Computer Technologies. Lecture Notes in Electrical Engineering*, vol **711**. Springer, Singapore. https://doi.org/10.1007/978-981-15-9019-1_48

[4] Mathavan J J, Faslan A W, Basith N U A and Wanigasinghe W V S D 2020 "Hardware Implementation of Fire Detection, Control and Automatic Door Unlocking System for Automobiles" *4th International Conference on Trends in Electronics and Informatics (ICOEI)* (48184), 2020, pp. 125-129, doi: 10.1109/ICOEI48184.2020.9142990.

[5] Koster R de, Le-Duc T, and Rood bergen K J 2007 "Design and control of warehouse order picking: A literature review", *Eur. J. Oper. Res*., **182**, no. 2, pp. 481–501.

[6] Wang biao, Xiwei Z 2017, "Design of Intelligent Logistics System for Power Plant Based on AGV[J]", *Automation Applications*, **11**: 142-144, 152

[7] Schmidtke N, Behrendt F, Wagner M, Alina B. Rettmann and Theresa Ansorge, 2020, *5th International Conference on Logistics Operations Management (GOL)*, pp. 1-9, doi: 10.1109/GOL49479.2020.9314741.

[8] Kelly A, Nagy B, David S and Unnikrishanan R 2007 "An Infrastructure-Free Automated Guided Vehicle Based on Computer Vision", *Robotics and automation magazine*, **14** (3).

[9] Xing Wu, Peihuang L, Qixiang C, Chidong Z, Shen ke and Jin che 2012 'Design and control of material transport system for automated guided vehicle', *UKACC International Conference on Control*, Control pp 765 -770.

[10] Gupta N, Singhal A and Rai J K, 2014 "Path Tracking of Automated Guided Vehicle", 2014, *Seventh International conference on contemporary computing (IC3)* pp. 260-264, doi: 10.1109/IC3.2014.6897183.

[11] M. Kajan, J. Šovčik, F. Duchoň, L. Mrafko, M. Florek and P. Beňo, 2014, "Sensoric subsystem of automated guided vehicle: TCP communication between SIMATIC S7 PLC and Arduino," *23rd International Conference on Robotics in Alpe-Adria-Danube Region (RAAD)*, pp. 1-6, doi: 10.1109/RAAD.2014.7002258

[12] Christian R Kelber, Rubem Sprenger Dreger, Guilherme Klein Comes, Daniel Webber, Juliano Schirmbeck, Roberto Hoffmann Netto and Diogo Albert Borges; 2003 "Cell-phone guided vehicle, an application based on a drive-by-wire automated system", *IEEE Intelligent Vehicles Symposium, Proceedings*, pp. 645–649.

[13] Butdee S and Suebsomran A 2009 'Automatic Guided Vehicle Control by Vision System', 2009 *IEEE International Conference on Industrial Engineering and Engineering Management* pp. 694–697.

[14] M. R. A. Rahat, M. M. Rashid, M. C. Dey and T. Banik, 2020, "Design and Implementation of a Safety Fire Fighter (SAFF) Robot with Dual Controlling Mechanism," *2020 IEEE Region 10 Symposium (TENSYMP)*, pp. 937-940, doi: 10.1109/TENSYMP50017.2020.9230709.

[15] Tong feng, Xu Lufeng and Tong Daoling, 2002, "An ultrasonic obstacle avoidance system for firefighting robot," *Proceedings of the 4th World Congress on Intelligent Control and Automation (Cat. No.02EX527)*, 2002, pp. 1219-1222 vol.2, doi: 10.1109/WCICA.2002.1020775.

[16] Yamamoto, M., Ushimi, N and Mohri, A 1999 Development of sensor-Based Navigation for Mobile Robots Using Target Direction Sensor, *Journal of Robotics and Mechatronics* Vol.**11** No.1 pp. 39-44.
[17] Mittal S, Rana M K, Bhardwaj M, Mataray M and Mittal S 2018 "Cease Fire: The Fire Fighting Robot", *International Conference on Advances in Computing, Communication Control and Networking (ICACCCN)*, Greater Noida (UP), India pp. 1143-1146.
[18] Rakib T and Sarkar M A R 2016 "Design and fabrication of an autonomous firefighting robot with multisensory fire detection using PID controller", *5th International Conference on Informatics, Electronics and Vision (ICIEV*), Dhaka pp. 909-914.
[19] A. Kunaraj, M. Mathushan, J. J. Mathavan and G. M. Kamalesan, "Sensor Controlled Defence Purpose Robot for Landmine Detection," *2020 International Conference on Smart Electronics and Communication (ICOSEC)*, 2020, pp. 42-47, doi: 10.1109/ICOSEC49089.2020.9215338.
[20] Teng-Yi Wang and Chia-Der Chang 2018 “Hybrid Fuzzy PID Controller Design for a Mobile Robot”, *IEEE International Conference on Applied System Invention (ICASI)*, pp. 650-653, doi: 10.1109/ICASI.2018.8394340.
[21] Gao, Shang et al. “Vision and Infra-Red Sensor Based Fire Fighting Robot.” *2018 IEEE 61st International Midwest Symposium on Circuits and Systems (MWSCAS)* pp: 873-876.
[22] Amano H, Osuka K and Iwano Y 2005 "Development of robotic wall system to protect victims”, *ICAR '05. Proceedings, 12th International Conference on Advanced Robotics*, Seattle, WA, pp. 579-586.