A Smart Approach for Human Rescue and Environment Monitoring Autonomous Robot

Sk. Shariful Alam, Tanim Ahmed, Md. Shakibul Islam, Md. Mustahsin Farhan Chowdhury
Department of Electronics and Communication Engineering, Khulna University of Engineering & Technology, Khulna-9203, Bangladesh
Email: ssalam@ece.kuet.ac.bd, {ahmed1609030, islam1609027, chowdhury1609028}@stud.kuet.ac.bd

***Abstract*—Taking all aspects under consideration regarding accidents caused by natural disasters there creates a situation where we cannot access some places physically, so we came up with an idea to help us to do so. The main motto of the human rescue and environment monitoring robot is to assist in rescue missions, monitoring the environment of inaccessible places, and finding the position of the person to be rescued using video feedback. The four-wheeled robot is designed to be driven both manually and autonomously. The robot consists of multiple sensors for avoiding obstacles as well as it incorporates various sensing modules for monitoring the surrounding environment where all the data is presented to the user end. For visual monitoring, a camera is integrated into the module, and to detect an endangered person a motion sensor is available in the robot which makes the system a smart approach for human salvage.**

***Index Terms*— four-wheeled robot, rescue, ssh terminal, sensor, serial monitor, wireless**

I. Introduction

Nature serves humankind with the same law, first the need, then the means. Recently, there are a lot of headliners about the natural disasters in our daily newspapers and one becomes a part of it involuntarily. This kind of act from nature causes ruins where one can get stuck and cannot by himself get out of it, help is needed that requires a mapping of how to do it. Technology has advanced to such an extent that most rescue missions are mapped out by robots [1]. The gist of our work lies in the collaboration with the rescue team by providing information about places difficult to access.

The four-wheeled driven robot obtains its mobility employing four high torque motors. The robot consists of many sensors for avoiding obstacles [2] which denotes the automatic driven part. It is driven manually using a wireless input device that is controlled by the user. The environment is monitored using various available environment sensing modules where the data is presented to the user through a Bluetooth module. A camera module is present which is connected to a Raspberry Pi which enables video feedback via SSH terminal, it is fitted to a pan-tilt bracket where the viewing angle can be changed utilizing servo motors. A motion sensor is used in the robot to alarm the presence of an endangered person, after that the camera module via real-time video streaming tells the situation of the surrounding [3] and the endangered person [4]. There are two lights present to aid the robot depending on the brightness in the surrounding where the intensity can be controlled by the user. The robot is powered by a rechargeable lithium-polymer and lithium-ion battery pack.

The data from the robot are transmitted wirelessly to the user. The video is displayed from a pre-build server in the Raspberry Pi which requires no internet connectivity rather can be accessed by an IP address from any device which is connected in the same network [5]. The environmental data is viewed through a serial monitor using an android application. The viewing angle is also seen along with video feedback. According to the user's preference switching from manual to automatic controlling and vice versa is possible. Emergency deliveries such as first aid kit and necessary dry foods can also be provided inside the robot.

II. Related Works

Two decades ago, it came to conscience that mobile robots are necessary for assistance in rescuing systems by providing information about unexplored escapade areas, hence mapping a possible safer route for rescuing [6]. For this visual data is necessary for the surroundings as safety measures for ensuring proper drilling and locating the victim at that instant. Providing food and medical supplies is also necessary in some cases [7]. Alongside the visual data, the environmental data parameters including temperature, humidity, and airflow also need to be taken into account [8], before sending out the rescue team with necessary precautions [9]. A wireless sensor network system is used in the tracking of human presence by means of signal strength and human body heat taking the suppression indices and AIS-based tracking system into account [10]. From visual data, it is possible to classify human-body using stereo vision in presence of other objects in the surrounding [11]. An approach for controlling the robot as well as getting visual information is by using a Raspberry Pi to communicate via a webpage [12]. As the technology advances, autonomous and semi-autonomous bots are viable with sensors being attached that can send data of

Manuscript received September 11, 2020; revised March 1, 2021.

doi: 10.18178/ijmerr.10.4.209-215

the surroundings and also the video feedback to the user [13]. Users can also control the mobility of the robot wirelessly employing remote control, whilst having the crash avoiding property [14]. Fuzzy MIMO control algorithm [15] and map-matching using colour data [16] are some of the ways for avoiding obstacles efficiently. Traversal mapping is also a method of gathering information to make decisions about inaccessible regions where obstacles are located [17].

III. METHODOLOGY

The functional block diagram of the robot is shown below in Fig. 1.

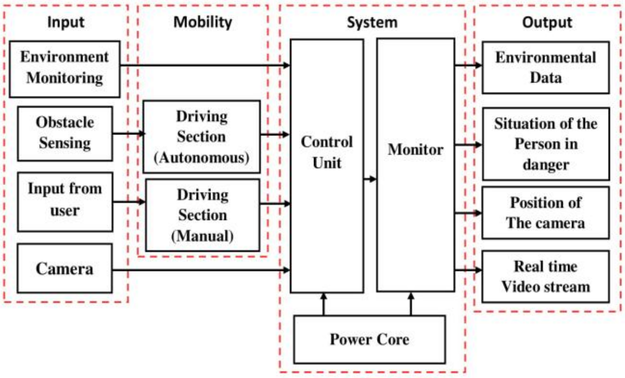

Figure 1. Functional block diagram of the robot

A. Input

The input section is divided into four subsections namely environment monitoring, obstacle sensing, input from the user, and camera.

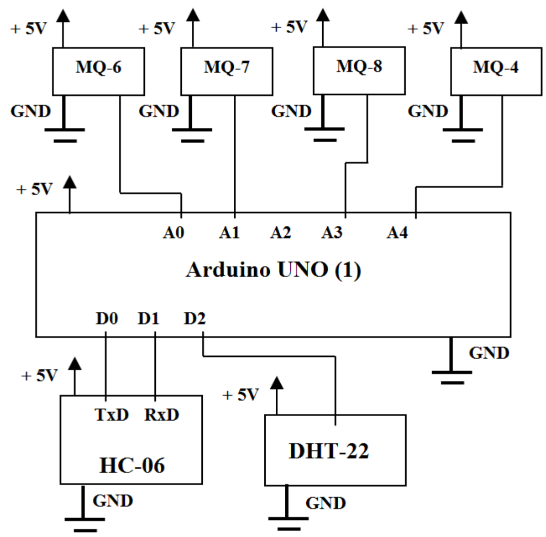

Figure 2. Connection diagram of the environment monitoring system

1) Environment monitoring

In most scenarios, there is a need to know the percentage of gases like oxygen, carbon monoxide, hydrogen, and some flammable gases. Extra precautions should also be taken by considering temperature and humidity because they might hamper with the rescuer and the rescuing necessities so a temperature and humidity sensor was used.

TABLE I. LIST OF ENVIRONMENT MONITORING SENSORS

Serial No.	Model No.	Uses
1	MQ-6	Sensing LPG, Butane, Propane gas.
2	MQ-4	Sensing Methane gas.
3	MQ-7	Sensing Carbon Monoxide gas.
4	MQ-8	Sensing Hydrogen gas.
5	DHT-22	Sensing temperature and humidity.

A glimpse of how the sensors are connected to one of the Arduino UNOs is shown below in Fig. 2.

2) Obstacle sensing

In this robot, three sonar sensors and a motion sensor (PIR sensor) were used considering them as an obstacle-avoiding mechanism and living body detection respectively. From the top view, the three sonars were placed on the front side and the other two on the left and right side in the front end maintaining proper separation. The motion sensor was placed below the front sonar sensor. Each sonar sensor was connected to one of the Arduino UNOs (Arduino UNO 2). The code was implemented in Arduino for obstacle sensing. The minimum distance for sensing an object in each sensor was set to 15 cm to avoid collisions and turn safely.

3) Input from user

Commands from the user were taken from the FS-CT6B transmitter. An overview of the transmitter with key mapping is given below in Fig. 3.

Figure. 3 FS CT-6B transmitter

4) Camera

The camera acts as the eye of this robot. The camera gives the user the visual data of the surroundings all the time. It was attached to a pan tilt bracket which was motorized using two servo motors so that it can show video feedback from different angles. The bracket can be navigated up and down to left and right altogether. The camera was placed at the top of the robot for a better view of the situation. The camera was connected to a Raspberry Pi and the servo motors were connected to an Arduino.

B. Mobility

The four-wheeled driven robot has four motors attached to it. The wheels were customized to maintain better friction. The motors are connected to two motor drivers (L298N). The connection diagram for the mobility section of the robot is given below in Fig.4.

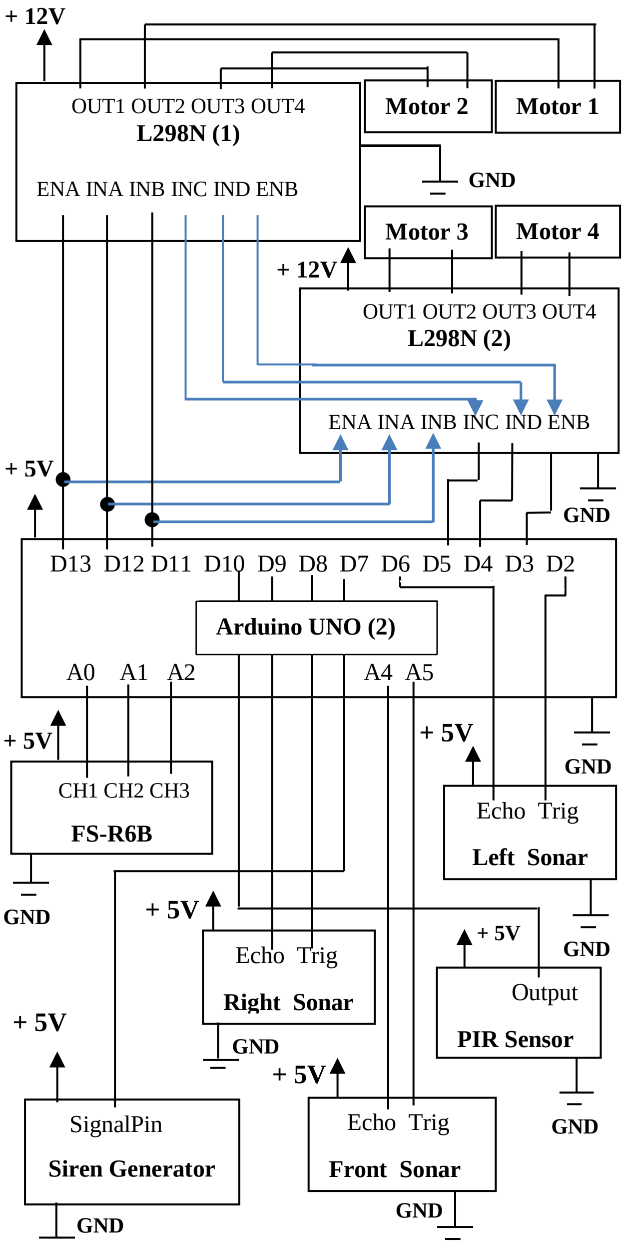

Figure 4. Connection diagram of mobility section

The blue lines in Fig. 4 indicate shorted wire. From Fig. 3 it can be seen that the mode of mobility can be changed from the transmitter. By inspecting the surroundings, the user decides the manoeuvring mode of the robot.

1) Manual driving section

For manual manoeuvring, the tank drive mechanism was implemented with the help of Arduino UNO. Two channels were used to manoeuvre the robot in different directions. The right analog stick is used to control the direction in which the robot will move. After the input from the user is being given, the RC pulse is mapped into a specified range of values then converted to a PWM signal from -255 to +255. The signal is then used to run the motors in a specific direction and speed.

2) Autonomous driving section

The autonomous driving mechanism depends on the values obtained from the sonar sensors which are then checked by the decision-making algorithm as shown in Fig. 5 which was programmed in the Arduino. Whenever the PIR motion sensor detects any living body, the robot comes to a halt. In that case, the manoeuvring of the robot is up to the decision of the user.

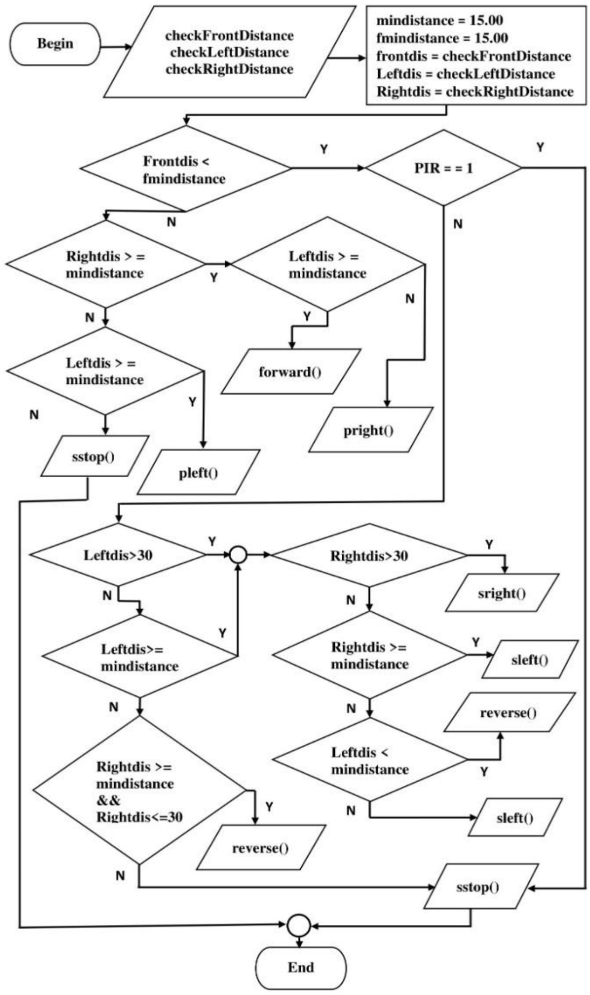

Figure 5. Flow chart of decision making for autonomous robot

If the autonomous driving section malfunctions, then the user might switch to manual mode. There might come a situation where the robot encounters a downward or an upward slope which will be visible to the user via video feedback. For the former case, the robot might over speed down the slope and the user can take control and avoid it. For the latter case, sometimes the sonar sensor reads the surface of the slope as a wall and might avoid that path, so in this case the manual manoeuvring is required. Also, when a pothole is encountered which is visible in video feedback but not detectable to the sonar sensor, the user can switch to manual mode.

A set of instructions regarding the decision-making algorithm is shown below in Table II.

TABLE II. DESCRIPTION OF DIFFERENT AUTONOMOUS DECISION-MAKING FUNCTION

Serial No.	Function Name	Description
1	forward()	moves forward
2	sright()	turns 90 degrees to the right
3	sleft()	turns 90 degrees to the left
4	pright()	turns approximately 30 degrees to the right
5	pleft()	turns approximately 30 degrees to the left
6	reverse()	moves backward
7	sstop()	comes to a halt

C. System

A Raspberry Pi 3 Model B+ was used for video feedback remotely from a server. Three Arduinos were used in this robot amongst them two were Arduino Uno and one was Arduino Nano. One of the Arduino Unos was used for environmental monitoring and pan-tilt controlling servos and the other was used for mobility. The Arduino Nano was used for controlling light intensity.

For booting up the whole robot two LiPo batteries and a power bank were used. The LiPo batteries were rated at 11.1V 2200mAh and the power bank at 5V 2.4A. One of the LiPo batteries was used for powering the motors and the sonar sensors, PIR sensor, and the siren module after passing through a power distribution board which reduces the voltage to 5V. The other one was used for the environmental monitoring section and controlling the light intensity. The battery fed power to the motor driver and the buck module. The motor driver was connected to the two LED discs. The buck module was connected to environment monitoring sensors and Arduino Uno after reducing the voltage to 5V. The power bank was used to boot up the Raspberry Pi. A power-saving mode is also included that reduces the RC pulse values to 50% of its original value which means less power is being used. It is enabled by using the switch in Fig. 3 on the top left corner.

The light intensity is controlled by rotating the switch in the transmitter that is shown in Fig. 3 on the right corner above the right analog stick. As the switch is rotated, the RC pulse from the transmitter is mapped into a specific range of values then converted to a PWM signal from 0 to +255. Here the direction of the current is unchanged. The intensity of the two LED discs is controlled simultaneously where the intensity increases by rotating clockwise and vice versa.

The connection diagram for controlling the light intensity is given below in Fig. 6.

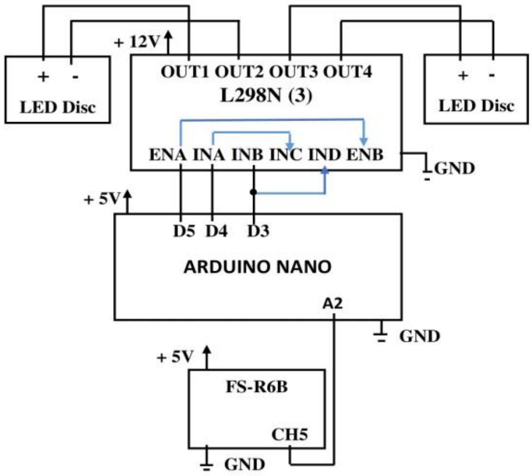

Figure 6. Connection diagram of light intensity controlling

D. Output

All the data collected must be sent to the user for further inspection and the decision of the rescue mission to be carried out.

1) Environmental Data

The environmental data transmitted by means of a Bluetooth module (HC-06) is connected to an Arduino and is viewed on the user's mobile phone using an application. Each of the environment monitoring sensors was programmed to give the percentage of the gases [18] and the temperature in degrees Celsius and humidity in percentage. The incoming data is continuous and can be controlled using the delay() function. A threshold level for each sensor was given and if the readings were above that level, then an alarming message is shown to the user. The serial data is shown in Fig.7.

A set of temperature readings were taken from the temperature sensor in the robot at different days, time, and places and compared with the actual temperature at that instant from Google weather shown in Table III. The gap between the values is mostly due to the area constraint, that is the sensor in the robot measures the temperature covering a very small area, and the data that Google collects is from a very much wide area. Other factors such as the heat generation of the many components in the robot were taking into consideration while the temperature readings were recorded.

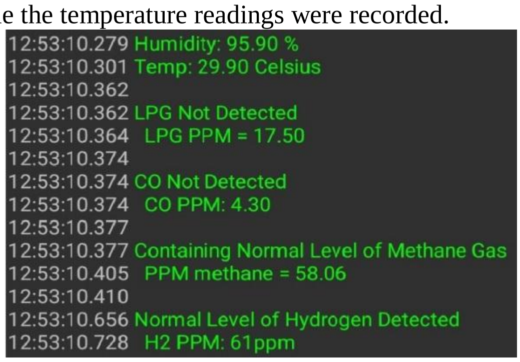

Figure 7. Environment monitoring sensors serial output

TABLE III. COMPARISON OF TEMPERATURE BETWEEN READINGS OF OUR ROBOT AND VALUES FROM GOOGLE

Number of tests	Measured value	Actual value (from Google)	Percentage Uncertainty
1	30.5	29	5.17%
2	30.5	28	8.92%
3	30.4	29	4.82%
4	30.9	29	6.55%
5	30.5	29	5.17%
6	29.9	30	0.33%
7	30.8	30	2.66%
8	31.0	30	3.33%
9	31.9	32	0.31%
10	31.8	29	9.65%

2) Situation of the person in danger

Two LED discs were attached to the front section of the robot to aid the robot in low light conditions. The intensity of the lights can be controlled by the user using the same transmitter used for manual driving. A First Aid box was attached to the robot to provide some necessary utilities for the victim.

The testing of the PIR sensor was done using a subject covering a distance of 500 cm consisting of 10 trials for each distinct distances. The trials were conducted and the number of successful trials were noted down for each distance and a graph was plotted as shown in Fig. 8.

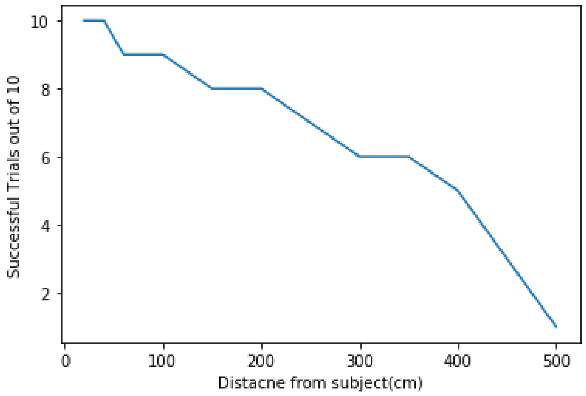

Figure 8. Graphical representation for testing PIR sensor for different distances detecting a subject out of 10 trials

The graph showed a downward slope meaning as distance increased the number of successful trials decreased. From these data, an optimum value for the sensor to detect a subject was determined. The value was used in the code for the PIR to work properly and avoiding collision with anything within that range.

3) Position of the camera

The movement of the pan-tilt can be controlled in the default server Flask and also the viewing angle was visible to the user as shown in Fig. 9. The Raspberry Pi was accessed remotely by using a VNC server [20].

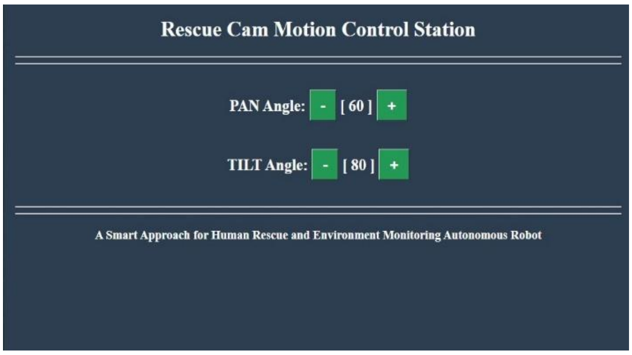

Figure 9. Control interface of the pan-tilt bracket

4) Real-time video stream

The visual data from the camera is transmitted using the SSH terminal of the Raspberry Pi. In the user's end, the Flask web server was used for real-time video feedback from the robot. A personal area network (PAN) was established by means of a router and that the web server can be accessed by staying on the same network using an IP address [19].

IV. SETUP

As for now the modeling of the robot is shown. Now let us look at how the robot looks when all the aspects from the block diagram are put under the same hood. The front, rear, right and left view of the robot with physical dimension is being provided below in Fig. 10 and Fig. 11.

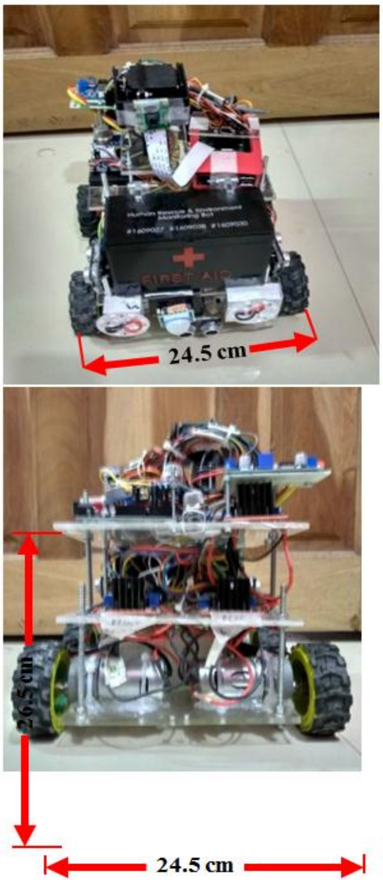

Figure 10. Front and rear view of the robot

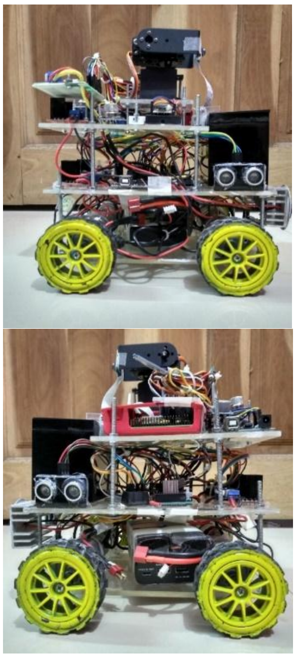

Figure 11. Right and left view of the robot

V. CONCLUSION

As the robot came to a stand, some challenges were faced that were eventually reduced to a minimal. Amongst them were that the delay of the PIR and the sonar sensor sometimes increased which lead to the misinterpretation of the robot, this was overcome by coding a portion where the user can take control of the robot and switch to manual driving which can be maneuvered using video feedback. Another issue was that all sensors required a voltage of 5V so it was solved by using a power distribution board and a buck converter. The robot needed high braking precision and torque enduring wheels for which it was modified by attaching cycle tires coating to produce more grip than conventional 65mm wheels. Although some problems were mastered, there are still some limitations because the robot is just a vivid idea for the future research purpose of rescue robots.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Md. Mustahsin Farhan Chowdhury proposed the idea. Tanim Ahmed and Md. Shakibul Islam modified the idea by providing additional features. The idea was developed by Tanim, Md. Shakibul, and Md. Mustahsin having equal contribution in all aspects of the robot. The project was supervised by Sk. Shariful Alam. Tanim, Md. Shakibul, and Md. Mustahsin was behind the formation of the paper. Sk. Shariful reviewed and edited the paper before sending it to the authority. All authors discussed the results and contributed to the final manuscript.

REFERENCES

[1] M. S. Shah and P. B. Borole, "Surveillance and rescue robot using Android smartphone and the Internet," in *Proc. 2016 International Conference on Communication and Signal Processing (ICCSP)*, Melmaruvathur, 2016, pp. 1526-1530.

[2] A. Sharma and M. S. Balamurgan, "Mobile robotic system for search mission," in *Proc. 2015 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS)*, Coimbatore, 2015, pp. 1-4.

[3] C. Wong, E. Yang, X. Yan, and D. Gu, "An overview of robotics and autonomous systems for harsh environments," in *Proc. 2017 23rd International Conference on Automation and Computing (ICAC)*, Huddersfield, 2017, pp. 1-6.

[4] Z. Uddin and M. Islam, "Search and rescue system for alive human detection by semi-autonomous mobile rescue robot," in *Proc. 2016 International Conference on Innovations in Science, Engineering and Technology (ICISET)*, Dhaka, Bangladesh, 2016, pp. 1-5.

[5] M. S. S. Chowdhury, M. F. Nawal, T. Rashid, and K. Rhaman, "Terminal analysis of the operations of a Rescue Robot constructed for assisting secondary disaster situations," in *Proc. 2015 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*, Cebu City, 2015, pp. 1-5.

[6] J. L. Casper, M. Micire, and R. R. Murphy, "Issues in intelligent robots for search and rescue," in *Proc. SPIE 4024, Unmanned Ground Vehicle Technology II*, 10 July 2000.

[7] R. R. Murphy, "Marsupial and shape-shifting robots for urban search and rescue," *IEEE Intelligent Systems and their Applications*, vol. 15, no. 2, pp. 14-19, March-April 2000.

[8] J. Wu et al., "An intelligent environmental monitoring system based on autonomous mobile robot," *2011 IEEE International Conference on Robotics and Biomimetics, Karon Beach, Thailand*, 2011, pp. 138-143.

[9] L. Marques, A. Martins, and A. T. de Almeida, "Environmental monitoring with mobile robots," *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Edmonton, Alta., 2005, pp. 3624-3629, doi: 10.1109/IROS.2005.1545133.FLEXChip Signal Processor (MC68175/D), Motorola, 1996.

[10] A. Ko and H. Lau, "Robot assisted emergency search and rescue system with a wireless sensor network," *International Journal of Advanced Science and Technology*, 2010, 3.

[11] S. Bahadori, L. Iocchi, D. Nardi, and G. P. Settembre, "Stereo vision based human body detection from a localized mobile robot," *IEEE Conference on Advanced Video and Signal Based Surveillance*, 2005., Como, 2005, pp. 499-504.

[12] M. F. Alvi, F. Junejo, M. W. Baloch, and A. J. Rajput, "RoboCop; A Robust Surveillance Robot," in *Proc. 2018 1st International Conference on Advanced Research in Engineering Sciences (ARES)*, Dubai, United Arab Emirates, 2018, pp. 1-8.

[13] A. Denker and M. C. İşeri, "Design and implementation of a semi-autonomous mobile search and rescue robot: SALVOR," in *Proc. 2017 International Artificial Intelligence and Data Processing Symposium (IDAP)*, Malatya, 2017, pp. 1-6.

[14] L. Huan, W. Dahu, Z. Tong, and H. Keming, "Research on a remote control vehicle," *2010 2nd International Conference on Education Technology and Computer*, Shanghai, 2010, pp. V2-263-V2-266.

[15] Y. Xiong, S. Xiao, and F. Zha, "An avoiding obstacle algorithm of mobile robot under complex unknown environments," *2011 Second International Conference on Mechanic Automation and Control Engineering*, Hohhot, 2011, pp. 1019-1022.

[16] M. N. Kiyani and M. U. M. Khan, "A prototype of search and rescue robot," *2016 2nd International Conference on Robotics and Artificial Intelligence (ICRAI)*, Rawalpindi, 2016, pp. 208-213.

[17] S. J. Moorehead, R. Simmons, and W. L. Whittaker, "Autonomous exploration using multiple sources of information," in *Proc. 2001 ICRA. IEEE International Conference on Robotics and Automation* (Cat. No.01CH37164), Seoul, South Korea, 2001, pp. 3098-3103 vol. 3.

[18] A. Joshi, C. S. Nagarjun, and R. Srinivas, "The DRASB — Disaster Response And Surveillance Bot," in *Proc. 2017 Second International Conference on Electrical, Computer and*

Communication Technologies (ICECCT), Coimbatore, 2017, pp. 1-8.

[19] D. Singh, P. Zaware, and A. Nandgaonkar, "Wi-Fi surveillance bot with real time audio & video streaming through Android mobile," in *Proc. 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, Bangalore, 2017, pp. 746-750.

[20] H. R. and M. H. Safwat Hussain, "Surveillance robot using raspberry Pi and IoT," in *Proc. 2018 International Conference on Design Innovations for 3Cs Compute Communicate Control (ICDI3C)*, Bangalore, 2018, pp. 46-51.

Sk. Shariful Alam was born in Khulna, Bangladesh, in 1979. He received the B.Sc. degree in Electrical and Electronic Engineering from the Chittagong University of Engineering and Technology, Chittagong, Bangladesh, in 2003, and the M. Sc. in Telecommunications Engineering from the University of Trento, Italy, in 2010. In 2004, he joined the Department of Electronics and Communication Engineering, Khulna University of Engineering and Technology, Bangladesh, as a Lecturer. Since January 2011, he has been with the Department of Electrical, Electronic, Telecommunications Engineering, and Naval Architecture (DITEN), University of Genoa, Italy, where he has completed his PhD. His current research interests include dynamic spectrum management, spectrum sensing for wideband cognitive radios, compressive sensing, and MAC layer for cognitive radios.

Tanim Ahmed was born in Dhaka, Bangladesh, in 1997. He is currently doing his B.Sc. degree in Electronics and Communication Engineering from Khulna University of Engineering & Technology, Khulna, Bangladesh. His current research interest includes machine learning, artificial intelligence, and image processing.

Md. Shakibul Islam was born in Faridpur, Bangladesh, in 1998. He is currently an undergraduate student in the department of Electronics and Communication Engineering at Khulna University of Engineering & Technology, Khulna, Bangladesh. Approximately it will need about half a year to complete his B.Sc. degree. His current areas of interest are IoT based medical equipment, Machine Learning, Deep Learning & Neural Networks, and Automation.

Md. Mustahsin Farhan Chowdhury was born in Rajshahi, Bangladesh, in 1998. He is pursuing his B.Sc. degree in Electronics and Communication Engineering at Khulna University of Engineering and Technology, Khulna. Along with his major, his field of study includes automation, internet of things, Cybersecurity, and IT support. Since July 2019, he has been working as a Student Lab Operator at Fab Lab, KUET.