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IOT Based Human Search and Rescue Robot using Swarm Robotics.

Machaiah M.D, Akshay S

Abstract-- Natural calamities and disasters such as building collapse, post-tsunami, earthquakes are some of the most disastrous situation mankind faces and, in such situations, rescuing of survivors is the most critical job. This paper discusses the design and development of swarm robotics, which can be used in such disasters in order to search for survivors and several other research purposes. The swarm robots in the current project are controlled by a centralized system where all the bots connect to a common IOT cloud. Through which they communicate and store all the accumulated data. The bots also use several sensors such as GPS location tracker, an ultrasonic sensor for obstacle and edge detection for maneuvering purposes, LM35 temperature sensor. The current system also is developed with a unique novel hybrid 6-wheel design which will help in easy maneuvering over rough terrain.

Keywords-- Camera, Disaster, Edge avoidance, IOT, LM35 temperature, Obstacle avoidance, robotics, swarm robotics, search and rescue, solar powered, 3D printing.

I.INTRODUCTION

Swarm robotics is a part of multi-robotics where n number of robots coordinate and communicate with each other in a distributed and decentralized way to accomplish a common goal. It works based on the habit of local rules, A large number of simple robots are used considering the complexity of the task to be accomplished, they are developed and designed by imitating behaviors of insects such as birds, bees and ants. Simple swarm robots can perform complex tasks fareffectiveway than a solecomplex robot, giving robustness to the swarm. Accomplishing the search and reporting of survivors in the least amount of time is the major task in search and rescue which can easily be accomplished by swarm robotics. [1]As it can cover, border area by the increasing number of bots in the affected area, it can also help each other in case of a breakdown and is more reliable. These multiple robots communicate via the cloud.As a first stepthe current paper discusses and implements on best suitable hardware and software to be included on a swarm robot our second step is to develop several robots with similar configurations and apply swarm algorithms and test its effectiveness.[1]This paper discusses about swarm robots using an ad-hoc network to follow firefighters, they help in finding humans and robots. The robots move in the lower area of the building which has low smoke and lower temperature in case of fire and this can help guide firefighters. [2]This robot moves on small rocks and wreckage its equipped with a robotic arm to help lift objects, the robots are controlled via Bluetooth in a mobile device. [3]Major focus of the blue swarm 2.5 is on an inexpensive swarm where the rescue team need not worry about the cost of the robot in case of damage. It had various sensors such as a Devantech SRF04 ultrasonic rangefinder for obstacle detection, infrared range finders and emitters for collision avoidance and Melexis MLX90601 infrared temperature used to detect heat signatures from survivors, CMUCam for color blob detection. [4]Proposes an all-terrain robot with a robotic arm which could carry out 'n' number of tasks on its own. The installed Cameras, CMUcam, and FLIR Thermal Camera are used to serve the sole purpose of surveillance in different manners. CMUcam carries out vision, image processing and signature detection whereas Thermal Camera used for night vision and life detection. Apart from these there's an array of Ultrasonic Sensor on the bottom of the chassis for terrain mapping and directly uploading it to the web server also used in collision detection the robot also performs terrain mapping. The issue of area coverage can be overcome by the usage of swarm robotics, this system also doesn't have an edge detection system which can lead to disasters if there are huge steep during the search mission. [5]Proposes rescue operation system that can be carried out after receiving the location of live humans tracked by GPS which is sent to the receiver (PC, Mobile etc.) using IOT. Ultrasonic sensors are used in this paper for the obstacle detection and for autonomous movement of the robot. A GPS module is used, which can connect to numerous satellites and determine the exact location. Any motion is detected by PIR sensor it sends the location to the particular IP address. The PIR sensor used here can send irrelevant data to the rescue team as PIR sensors detect any kind of movements in front of it. This issue can be overcome by using infrared thermal cameras and a face detection system. There is no set path or destination to which this robot moves. Random traversal can lead to repeated search area and waste of time.[6]implements rescue robot with thermostat for temperature detection, an end effecter to lift objects weighing 200-300grams, also includes a RF pro for communications, and they have used Viola-jones face detection algorithm to detect survivors.[7]This robot is built with pallets which will prevent tipping and falling while moving, its equipped with RF pro for communication, Bluetooth for GPS communication, arm with wrist and elbow and robot is entirely controlled by an android app.[8]This paper offers a mobile robot based on Wireless Sensor Network, which is designed for human existence & detection in an unmanned location.

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***** Correspondence Author (s)
Machaiah M.D, Department of Computer Science, Amrita School of Arts and Sciences, Amrita University, Mysuru, India.
Akshay S, Department of Computer Science, Amrita School of Arts and Sciences, Amrita University, Mysuru, India.

Also includes a module to record, analyze conditions of the human body and communicate data, PIR detector, Gas sensor and a bomb sensor, temperature sensor.[9]wireless sensor network structure is designed for locating.
Robots navigate autonomously into search areas and locate humansurvivor's body heat using thermal array sensor.It also uses autonomous navigation and Thermal array sensor to find survivors, Location tracking is done using signal strength. Which can be inaccurate.[10]Is designed for autonomous exploration and mapping task, the robot explores areas where probability of locating victims is high, and focus on resource allocation and minimizing conflicts during exploration.[11]Focuses on robots that can carry heavy weights, using a wheel-legged system. This novel legged system can implement real time transformation in the field which will help in maneuvering in rough terrains.[12]Designed a wheel-legged design which can transform into three different state rotation center lift, leg motion, normal wheel state. This system was developed to prove the feasibility of the legged wheel in several applications. [13]Uses a 4*4 high power wheel system and a robotic arm made of 8 motors. The system communicates using Intel 89c59 IC. Robot pics and moves obstacles instead of avoiding them.[14]Implements a method where fixed temperature sensors in the industry environment can be moved using a robot and detect temperature in several different locations.[15]Describes a method to control and communicate sensor data and devices using DTMF technology. And processing of data done by Arduino UNO. [16]Developed an IOT robot which will help coal mine workers in alerting about the live condition inside the mine by sensing the toxic gas levels and the temperature inside it.[17]Discusses and implements an IOT robot which will help old age people in performing basic tasks such as reading, recording face detection, live streaming home surveillance, using raspberry pi3, which is controlled by Bluetooth remote and WebIOPi.[18]Describes how a better swarm robot can be built using data from several swarm robot built and presented at the AAAI/RoboCup challenge. Few key points to be noted were the environmental conditions, building the robots at low cost, and as small as possible.[19]Conducted a survey on existing swarm robot methodology and conducted experiment on five most advanced algorithms used for explorations the test results prove that theRobotic Darwinian Particle Swarm Optimization (RDPSO) algorithm is the best compared to several other algorithms.[20]Describes the potential that swarm robotic has over search and rescue for first responders in a disaster. And describes how blue swarm has evolved and about scout, scout walker II Beam, crawler robot.

II.PROPOSED WORK

In the current system as shown in figure 1 the system will be operated by the control unit and the search and rescue team. Both these controlling entities will be connected to the firebase cloud and retrieving live data sent by the swarm robots. n number of swarm robots are deployed and will work together on the search operation. Each robot will have similar configuration of hardware and software as mentioned in figure 1. Each robot will be connected to the firebase cloud and will upload Realtime data collected and processed by the processor. The swarm robots work autonomously without any human interaction once the area perimeter is provided. The areaperimeter needs to be provided by the operations team to the robots via the cloud. The given area will then be divided among the robots equally and the search operation will begin, the higher the number of robots the faster the search process will happen.Suppose one of the robots stops working the damaged robot stops sending data to the cloud. As soon as a damaged robot is detected, the nearest robot can be assigned the job of the damaged robot.

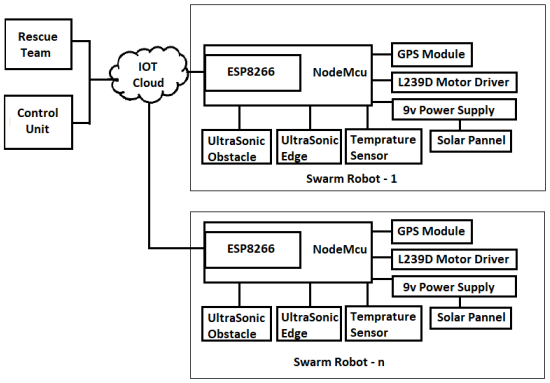

Fig.1:Architecture diagram

III.HARDWARE IMPLEMENTATION

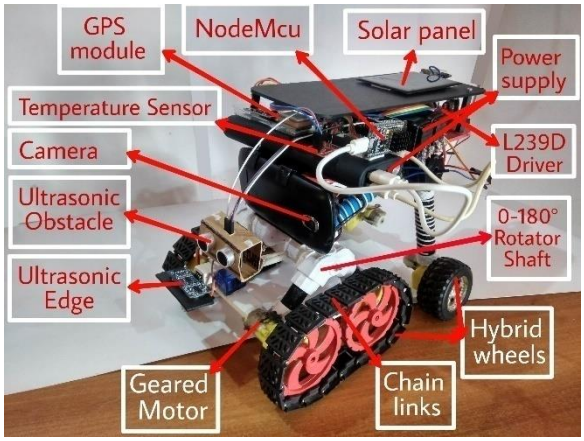

Fig.2: Hardware Implementation

Body The body of the robot is CAD designed using the Autodesk Fusion 360 software. And 3D printed using a biodegradable poly lactic acid (PLA) 3D printing filament. The 3D printed parts are then assembled together.

NodeMcu is used as the processor of the swarm robots as it is smaller in size inexpensive and has the capability of connecting to the internet via the inbuilt ESP8266 Wi-Fi module. Shown in image 3.It has several GPIO pins and has storage of 4MB runs on XTOS and it isenergy efficient, which isessentialin swarm technology. All the sensors and IO devices such as Ultrasonic sensor, GPS module,L239D, and temperature sensor is connected to the NodeMcu and the IO is processed. Two NodeMcu is used due to lower number of IO pins. The CPU has 80Mhz frequency.

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Power supply for the entire project is drawn from three different sources one 13000mah power bank for NodeMcu, sensors.
And a separate9V power supply for the L239D driver and 6 300RPM geared motors robot movement as it requires 9 volts. A 6v solar panel is installed on top of the robot which recharges the rechargeable batteries during the search operation, power from the solar panel ensures that the robots will sustain in the field of operation for a longer period of time.

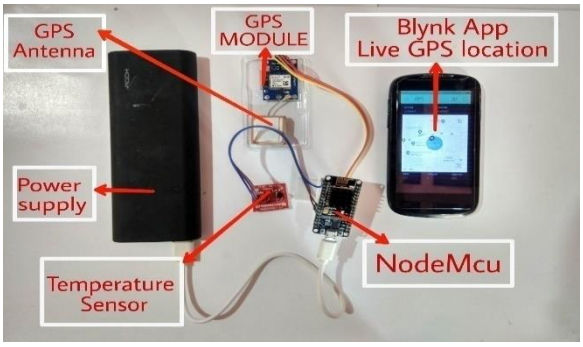

Fig.3: GPS module and temperature sensor

GY-GPS6MV2 GPS module is used for location tracking. The module has a Ceramic antenna which can connect to several satellites to determine the exact location and also has EEPROM to save configuration data when there is no power supply. This module is used in this project to track the location of the robot in the search area, and also to identify the survivor's location. These location data are sent to the cloud for analysis purposes.depicted in figure 3.

Temperature sensor LM35 temperature sensor is attached to the NodeMcu in order to accumulatelive temperature data. This sensor can detect temperatures from -55 degree 150 degrees. The raw input data is collected from the IO pin. The formula below is used to convert raw data to accurate temperature value.

Temperature = (5.0 * input data * 100.0) / 1024

This data can be used by the rescue team duringa search operation to check if the temperature is too high inside buildings if anyfire explosion has occurred.
Shown in figure 3.

Ultrasonicsensor HC-SR04 used in this project is capable of emitting 40000Hz ultrasound. As shown in the figure 4 the trigger pin in the sensor will emit ultrasound and the waves will reflect back when it strikes an object and the reflected waves is received back by the echo pin and the time duration of sent wave and received wave is calculated and the time is converted to distance, Formula used to calculate distance is distance = (duration/2) / 28.5 where distance and duration are initialized to 0 initially.
the threshold is set to 30cm distance and area of propagation is above 5-6 cm above ground level.Obstacles that are 5-6cm in height from ground level is moved over by the hybrid wheel system.This data is used to detect objects in front of the robot while moving. The robot makes use of the ultrasonic sensor data to avoid obstacles and continue searching operation without crashing into any objects.The robot moves around the obstacle instead of taking a random path as designed in[5], thisoptimizes the search process and reduces the time to search and excludes redundant search. A second ultrasonic sensor with same configuration is used to detect edges in the search area. The same principle is used as the obstacle avoidance, but the sensor will be facing the floor and as soon as the distance measured is greater than 7cm the robot detects it as an edge. And the robot will change its path avoiding the edge.

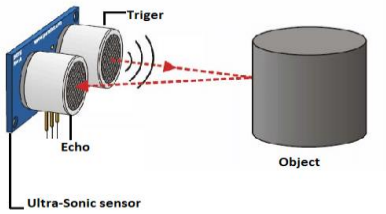

Fig.4: Obstacle detection& Edge detection

L239D motor driver: an L239D H-Bridge motor driver is used to drive the geared motors. Shown in figure 2. The H-bridge will allow the DC current to flow in both directions.Which will allow the motors to rotate in both the directions, this mechanism is used to make the robot move left, right and straight back. The left row of three wheels are connected as one connection to the L239D and similar to the right row of wheels, the robot moves forward when the H-Bridge powers both left and right as high, it moves back when it's powered low, to move left only the right set of wheels are powered high, for right all left wheels are powered high, As shown in the table 1.

TABLE 1. Digital control signals for L239D driver

Commands	Input (Right wheels)	Input (Left wheels)
Front	1	1
Back	0	0
Left	1	0
Right	0	1

Hybrid wheel systemtheunique novel 6 wheel is design shown in figure 5 is designed in such a way that the front section wheels are capable of swinging from 0 to 180 degrees with the help of a rotator shaft,helping in climbing small rocks and obstacles while the back wheels provide support.6 300RPM geared motors are used for movement.Front two wheels are connected with each other using chain links which makes the robot hybrid of both tanker wheel system and normal rovers, the hybrid wheels can maneuver over obstacles which are at the height of 5-6 cm, and the obstacles that are higher than 5-6 cm is detected by the obstacle sensor and ensures the robot takes a different path.The rotator shaftis also equipped with two suspension springs which will help in moving and reduce damages on the electronics, also will ensure the robot is stable while climbing over small objects. Depicted in figure 5.

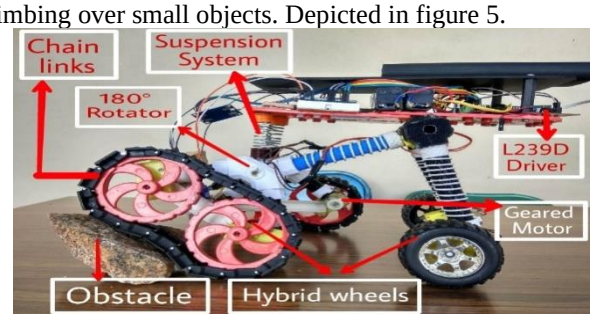

Fig.5: Hybrid wheel system

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IV.SOFTWARE IMPLEMENTATION

Arduino IDE is usedto program the swarm robot using embedded cpp language.

Google firebase cloud service is used to store and view all the data sent by the NodeMcu and sensors. To connect to the Google firebase host connection link and secure authentication id is included in the code which is provided by the firebase cloud. And to communicate with the cloud the NodeMcu ESP8266 needs to be connected to a WIFI network.The robots use the firebase cloud as a platform to communicate with each other and to receive the area to be searched and dived the area among them self. In the receiving end, both rescue team and the operation team can view the results provided by the swarm robots.

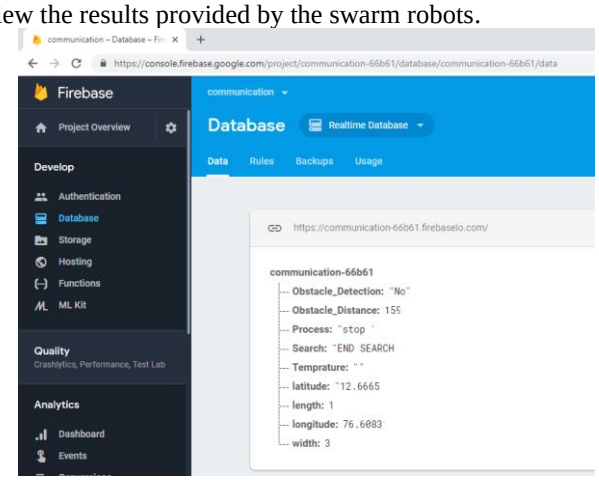

Fig.6:Google Firebase

Blynkanandroid app called Blynk is used to view the live GPS data provided by the swarm robot,Location can also be viewed in the google cloud live database. Shown in figure 6. Using the data sent by GY-GPS6MV2 GPS module, the blynk app will also show the direction in which the robot is moving and the number of satellites it is connected to provide the GPS data and also it provides the live location of the robot in a map. Depicted in figure 7.

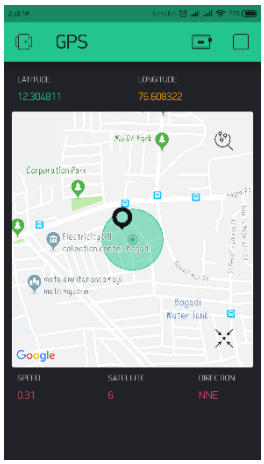

Fig.7:GPS live tracking using Blynk App

Camera to view the live scenario and to locate the survivors of the disaster-prone area, an old android mobile with an IP webcam mobile app is used for the viewing purpose. The live feed can be viewed by a computer, mobile or tabs by entering the IP address provided by the app. Both the rescue team and the operations team can view this live feed from the camera. The operations team can also toggle the led flash remotely by the IP camera web interface. Shown In figure 8. The process of detecting survivors is to be done by the operations team by looking into the live feed of the camera.

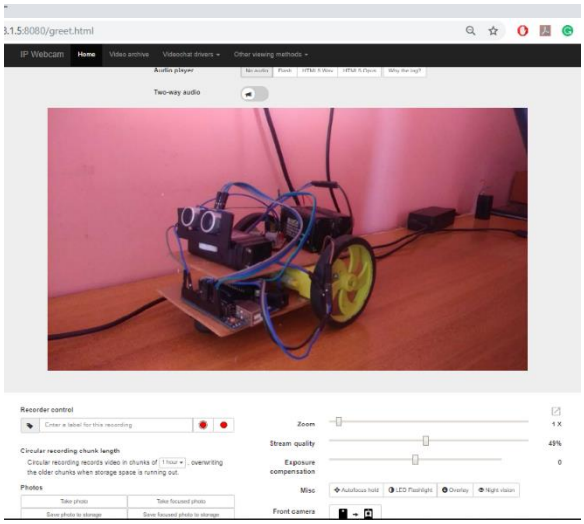

Fig.8:View from IP camera web interface

V.ALGORITHM

Step 1: Input area perimeter to the swarm robot
Step 2: Robot divides the area and start searching
Step 3: If obstacle detected change direction
Step 4: If edge detected change direction
Step 5: Find temperature of area and transmitit to the firebase cloud database.
Step 6: Find live location of robot and transmitlocation to the firebase cloud database.
Step 7: If robot damaged assign nearest robot the task of damaged robot.
Step 8: If human survivor found in camera retrieve live tracking location.

VI.RESULT

As mentioned in the proposed method the swarm robot managed to move in rough terrain the hybrid wheel system helped in climbing over small objects such as medium size stones, sand, grass and other terrain. The ultrasonic sensor accurately detected objects within the 30cm threshold and robots could calculate the best optimum path to travel by taking in the data given by the sensor sweep operation, thus prevented robot crashing into objects in the path and searching the entire area foe survivors. The second ultrasonic sensor also managed to detect edges within the given 7cm threshold, but the drawback here is that the robot was high powered and moved at a higher speed. The sensor detection was not fast enough to detect the edge and make sure the robot stops and takes another direction. The robot's power had to be reduced in order to ensure that the edge detection had to work. Reducing the RPM was not possible as prefixed geared motors were used in this project. The temperature sensor provided accurate data which will help in the search operation.

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The camera module had a video capture rate at 30fps and high-quality VGA (640*480) resolution through which live feed of the disaster area was viewed since the robot was constantly moving there was disturbance and the frame rate was not acceptable, higher quality cameras with better resolution and fps rate is recommended to be used.

VII.CONCLUSION AND FUTURE WORK

The swarm robot was successfully implemented and worked accordingly, As the area, perimeter was given to the robots, they started the search operation by avoiding objects and detecting victims was done by the rescue team by viewing the live feed from the camera. This technique of search and rescue will help in saving time of search operation which is the most crucial part of a search operation. Higher the number of swarm robots used in the field the faster the execution. Due to the hybrid wheel system, it was very easy for the robot to maneuver over several small objects and terrain. For future work the robots can be interconnected via RF pro for better communication when there is no Wi-Fi connectivity in the disaster area, the robots can send data to one another and closest robot to the rescue team or operations team can send the report to the team. Thermal cameras can be utilized to detect survivors instead of detecting it manually.

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AUTHORS PROFILE

Mr. Machaiah M.D a student of Amrita School of Arts & Sciences, Mysuru. Heis a BCA graduate from Amrita Vishwa Vidyapeetham University (2017) and is currently pursuing his Masters in Computer Applications. His area of research includes swarm robotics, embedded systems, 3D printing, IOT. Published patent on A self-aligning apparatus for eye drop application with see through window and a view point.

Mr. Akshay S did his MS in computer science from University of Mysore in 2012. He is currently pursuing his PhD. He is working as an assistant professor in Amrita Vishwa Vidyapeetham, Mysuru Campus. His research interests include computer vision, digital image processing, embedded systems, algorithms and pattern recognition.

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