Swarm Robotic System for Mapping and Exploration of Extreme Environment

Shivam Kharje[1], Shaikh Mohd Wahaj[2], Sayyed Saba Fatma[3], Prof. Ekta Ukey[4]

[1,2,3]Department of Computer Engineering, Pillai HOC College of Engineering and Technology, Rasayni, Mumbai University, Mumbai, India
[4]Assistant Professor, Department of Computer Engineering, Pillai HOC college of Engineering and Technology, Rasayni, Maharashtra, India

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Abstract - *Swarm robotic system is a field of robotics and an emergent research area that comes under multi-robotic systems in which multiple robots work in coordination with each other even after being distributed and decentralized in nature. The purpose of using multiple simple robots is that it can perform tasks which are complex in nature in a more efficient way compared to a single robot with more functionalities, giving robustness and flexibility to the group. Swarm robots with missions such as exploration of chemical leakages, radiation, high temperatures in extreme environments that are hazardous for human workers. During Disaster, there is a need to analyze environments for detection and human bodies trapped and to find the safe passage for the rescue team to go in and conduct any other rescue operation there is a need to have a complete idea of such environments. In this paper, we focused on designing and building a swarm robotic system from scratch using open source technologies and inspiration from some previous swarm robots. The robots are small in size of 9-10 cm approx. The main application of the microbots is to map the environment in 2D using ultrasonic sensors and other cost-efficient sensors. The robots can communicate among themselves when deployed for specific missions, and send data to a centralized system creating a complete map of the environment. The robots form an IoT network for communication among themselves. The result revealed that an increase in the number of the microbots increased the performance of the mapping significantly.*

Key Words: *Swarm robot, IoT, Multi-robotic system, Extreme Environment, Exploration.*

1. INTRODUCTION

Robotics systems are the future of mankind. We have been building them and using them in industries according to their applications. The output is accurate, they are efficient, that is what makes humans more reliant on robotic systems. Currently, the robotic system which is used consists of a single robotic system that is designed to do particular and only one task. This type of system is known as a traditional system. Swarm robotics is defined as a group of robotics that is not just a group, they are bio-inspired robots working together to achieve a particular goal. The together behavior of the insects like ants, honey bees which trail behind each other while searching for food and Honey bees which collect honey can save it together. Social insects are able to send and receive information and communicate with each other the location of the resources they need. In our paper, we are focusing on building multiple robots which will be based on the swarm robotics system concept. These robots will be used for safety applications, with the developing need for safety, robotics systems are required to perform dangerous tasks like industrial work where they have to monitor chemical plants and nuclear plants where humans have to maintain a safe distance. Another important application is disaster mitigation where the response team has to act immediately and they need data for the disaster infected area. This data can be collected with the help of these swarm robots. Military applications also play a major role as an area filled land mines are hard to detect risking the life of the soldiers. Swarm robots can help in the exploration of this environment and can find and create a map of the area.

There are different methods to fulfill this above application that is by using, traditional robotics system or deploying the group of robots together also known as swarm robotic system. Building a traditional robotic system involves using multiple sensors and equipment and integrating them into one system. And this one system will do the task and only the task which it is designed to do. This type of robotic system cannot do any other job then, what they are designed to do. Building a swarm robotic system has various benefits as there are multiple robots and these robots are small in size hence building them is not costly at all. These robots can be designed in such a way that they can also share their senses that is the data from the sensor with each other, hence not all the robots in the fleet need to have expensive sensors, each robot can have different sensors and they and collectively report other robots what they have sensed.

The benefits of swarm robotics make a huge impact, such as i) The Robotic system can be easily scaled just by increasing the quantity of robots in the fleet of the existing robots. ii) The robustness of the swarm robotic system is high because the task is distributed among the robots. iii) The function for which the robotic system is designed can be easily modified by just adding a different module or sensor to that robot. There are also some disadvantages like i) Due to the large size of the robotic fleet it will be hard to accumulate the error occurred, monitoring them will require extra effort. ii) These robots need to communicate with each other so developing a communication system that is lag-free and real-time is a hard and complex task. The primary goal of this project is the implementation of its own robotic system. We intend to build a fleet of robots, in which the robots are small in size about 10 cm in height and width. This robotic system will be open source, simple, cheap and easy to build so others can use them to carry out research. Another thing we intend to achieve is mapping the area in which this fleet of the robot will be deployed. These robots can be controlled individually and also together in a group. We intend to make this robotic system autonomous so they can carry out the exploration process without any human interaction.

2 Existing systems:

I. Khepera III:

Developed by Inhouse incubation of Swiss organization K-Team, notable for its Koala, K Junior and Hemisson robots, Khepera III robot substantiated itself in numerous instructive and research ventures requiring the utilization of smaller than usual portable robots. Numerous sensors are moreover inserted on the robot, for example, there are Eight infrared telemeters with range of 30cm,there are 5 ultrasounds sensors of 20cm to 4m territory range and just 2 ground sensors for line following or bluff recognition. Numerous scholastics and specialists overall use Khepera 3 robot for different undertakings, for example, self-sufficient route, counterfeit knowledge, multi-operators frameworks, control, constant programming and much More.

The Khepera III robot includes: a control board based on a DsPIC30F5011 clocked at 60MHz and has 4Kb RAM. with 64Kb ROM. It has a battery life of approximately 8 hrs. It's height is 70mm and weight is 690 grams. Its supports matlab as a development Environment.

II. Epuck:

The Epuck robot developed for teaching purposes by EPFL by the same designers of khepera robot. The Epuck is open source hence you can have low level access even to electronic sensors.

Features of E Puck robot:

i) Neat Design: The mechanical structure is quite simple assembly is easy and the software installation is simple and easy, EPuck is an example of clean design.

ii) Flexibility: Epuck covers a wide range of sensors and extensions it is used in a wide variety of research and educational activities.

3. PROPOSED SYSTEM

Developed countries China, U.S., and India Face most problem when hit by occurrence of natural disasters, accidents. Given the large landmass each country has, these results are expected. Nearly 48,000 workers die in the country due to occupational accidents, of which the construction sector contributes 24.2% of the fatalities. In India, the rate is 20 times higher. It observed that as many as 38 fatal accidents take place every day in the construction sector in the country. The main objective of this research is to develop a robotic system that has swarm intelligence. We propose to build a multi robotic system which can perform tasks that traditional robotic systems cannot perform. Swarm robots can go on missions such as exploration and mapping of fallen debris, chemical leakages, radiation and high temperatures in extreme environments which are hazardous for human workers and rescue teams. During Disaster, there is a need to analyze environments for the detection of human bodies trapped and to find the safe passage for the rescue team to go in and conduct any other rescue operation There is a need to have and complete the idea of such environments. In our research, we will be focused on designing and building a swarm robotic system from scratch using open source technologies and from inspiration from some previous swarm robots, and mostly nature. The robots are small in size and 9-10 cm approx. The main application of the microbots is to map the environment in 2D using the camera above the head and other cost-efficient sensors for obstacle avoidance. The robots will be modular in nature making them easy to connect and a sensor according to the requirements of the mission. The robots can communicate among themselves when deployed for specific missions, and send data to a centralized system creating a complete map of the environment. Further developing an algorithm for effective distribution of tasks amongst the robots in the swarm. The robots form an IOT/ ad-hoc network for communication among themselves. Each robot will be equipped with the different sensor but the data they generate will be shared amongst all the robots in the swarm which is a unique feature compared to traditional robotic systems. The robots will be autonomous; they will mainly take actions based on the environment they are deployed in. These multiple robots can also be controlled by a single operator by just defining the objective and the goal of the mission. They will be deployed forand the robots will act accordingly.

4. METHODOLOGY

The implementation of the project is dividing into several parts

i) Developing of the robot: We intend to develop a robotic platform based on open source technology like Arduino. The robot will be 10 cm in size. The main processor is NodeMCU Esp8266 it is low-cost open-source IOT platform, it is 32bit with 128kb memory and 4mb storage,It features wifi capability, analog pin, and digital pin and serial communication protocol. It can be programmed with Arduino idle. It requires a power supply of 5v.

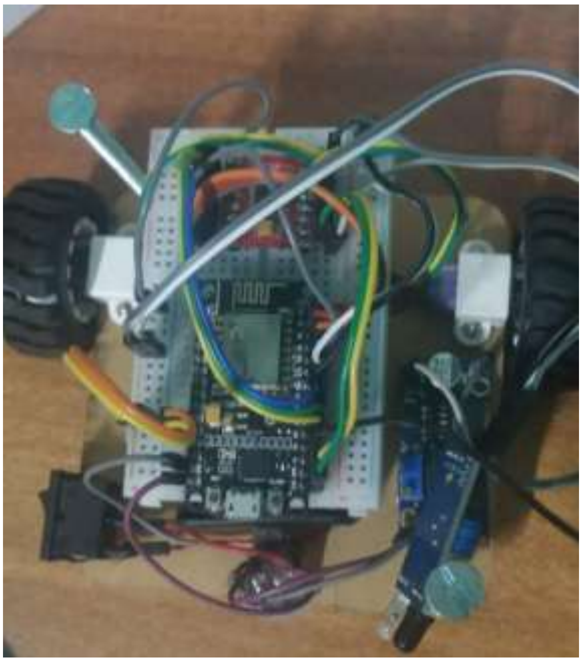
An IR sensor is connected to Esp8266, it acts as a proximity sensor that can detect obstacles, It has a range of 20 cm and input of 3.3 voltage to create logic. It consists of Ir led transmitter and a photodiode receiver, it can operate in a range of 20-60 degrees. The robot has two motors which are N20 micro gear motor with the specification of 6v and 200 rpm these two motors are controlled using a Tb6612fng motor driver it can control 2 dc motor at a constant 1.2A. The two output motors A and b can be controlled separately and the speed of each motor can be controlled using a PWM signal with a frequency. The logic supply voltage should be in range 2.7 Vdc to 5.5v dc, while the motor supply that is VM is limited to a maximum voltage of 15vdc. The robot is powered with 2 lithium-ion 18650 rechargeable cells, the cell has the charge of maximum 4.2v to 3.3v and 2200mah and maximum charging current 4200mah. The output of two cells is maximum 8.4v, this output is boosted to 12.1v using a step-up converter.

Connections:

Esp8266	**Tb6621ng**
D0	PWMA
D1	INA2
D2	INA1
D5	INB1
D6	INB2
D7	PWMB

Esp8266	**Tb6621ng**
D0	PWMA
D1	INA2
D2	INA1
D5	INB1
D6	INB2
D7	PWMB

Robot



Connections

ii) Programming the robot:

The main objective of swarm robotics is collaborative working and coordination among themself this can be achieved with communication among themselves. The nodeMCU module is an IoT development board that has built-in wifi, hence we are using the wifi as a medium for communication between the robots and the central system. We used Esp8266wifi library which allows it to connect to the wifi network which we can create temporary, all the robots in the fleet are communicated to this same wifi network, the wifi network has a limitation of connecting 8 devices this limitation can be overcome by using mesh network in which endless robots can be connected in the fleet. We create a web server thought which we can control each robot over the wifi network, the robot functions like forward, backward, right, left, brake and obstacle detection mode can be accessed. Designing in this way can be useful to debug the problem in a single robot even in the fleet. The same code can be used to control a single robot and the entire fleet at the same time.

The server uses GET and POST methods to send and receive information hence each robot task is an URL under the single robot domain. The robot can be accessed using the IP address which is assigned by the wifi network.

iii) Detection of the robot:

The robot's main objective is to create a map of an area in which they are deployed. Each robot has a color-coding, there is a 10cm color sheet placed on top of each robot. This color sheet can be detected using the camera placed overhead. We use OpenCV, an open-source computer library. The steps for color detection are:

i) Capture and store a background frame, the camera records the image where the robots are deployed, every single frame of image is captured and then converted into a video by patching them together, the noise can be reduced using an average over multiple frames.

ii) Blurring is another effective way of reducing noise. Gaussian blur is also known as gaussian smoothing. Mathematically it is the same as convolving the image with gaussian function. Gaussian blur is a low pass filter.it is ideal to exploit the Gaussian haze's distinguishable property by isolating the procedure into two passes. In the primary pass, a one-dimensional portion is utilized to obscure the picture in just the level or vertical course.

iii) Converting to HSV, HSV stands for Hue, saturation, the value is an alternative representation of the RGB model. The blurred output from the Gaussian blur is given as an input to the HSV filter which converts it to the HSV model.

iv) Color detection is the next and for most important, the HSV output from HSV filter represent three values. The value channel encodes the brightness of the color the shading and the gloss of the image can be controlled through this channel. HSV is the way in which humans perceive color information.

v) Contouring is the by which we can find the boundary of the color sheet, the contour is simply the boundary of an object in an image. Steps in contour finding are converting to grayscale, then converting to a binary image. And then finding the contour. The properties of contours are finding area and perimeter.

vi) Finding the centroid points and then saving them in the array. The array is the coordinate of the movement of the robot which can be mapped on the frame. In this, we can create a map of the safe route through which navigation can be done.

5. ALGORITHM

Step 1: Deploying swarm robots into the field.

Step 2: The robot navigates and detects obstacles.

i) Move forward

ii) If Ir.analog == 1:

ii) Turn left.

Step 3: Color detection using an overhead camera.

i) Capture frame.

ii) Apply Gaussian Blur.

iii) Converting RGB to HSV.

iv) Color Detection.

v) Contouring.

vi) Finding the centroid.

Step 4: Tracing the points.

i) Logging all the coordinates of the centroid into an array.

ii) Averaging them.

Step 5: Plotting the coordinate array onto live feed.

Step 6: Saving the image of the map.

6. EXPERIMENTAL SETUP

The size of the robot is 10 cm each, we deployed them into an arena which we created in order to test the result. The area is the arena was 6*6 m long. There is an overhead camera placed which covers the entire arena. It had a fence of 12 cm long. There are some blocks of 5cm spread across the arena which act as an obstacle for the robot. The goal of this experiment is to find all the path avoiding the obstacle and making a 2d map of all the routes.

7. RESULT

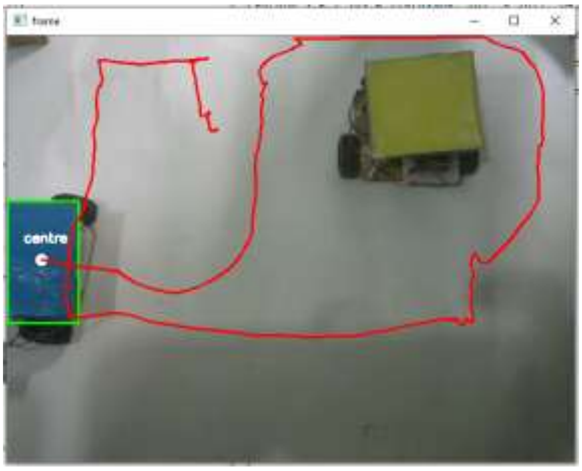
On deploying the robot they created the 2d map as expected. The variation in the result was seen after they were deployed separately from different sides of the arena. Deploying from different sides made a huge impact as the mapping process was distributed. Deploying all the robots from the same side in the same direction took more time for the result. The speed of the robot can be increase depending on the size of the arena. We also notice some lag while detecting more than 6-7 robots, this might be due to the no synchronization between the process.

LiveCam

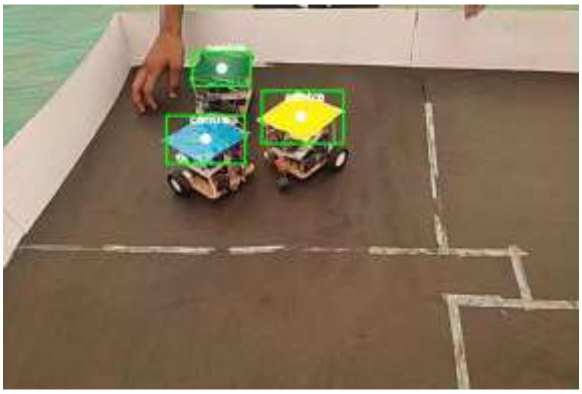
HSV Feed

Detecting contour

Centre detection



2D Map



Robot Fleet

7. CONCLUSION

In this paper, we focused on building an open-source swarm robotic platform that can be used for the exploration and mapping of extreme environments. We are successful in building it. The work is distributed among all the robot which was the goal and it was achieved. We predict an increase in throughput of up to 60 to 70%. Using cost-efficient material was the main goal of the project, though the sensors are not much accurate they did perform well. The 2D map did not have a scale ratio, but adding a scale ratio would help in navigation and increase the accuracy of the output map.

The future scope of the project will be increasing the strength of the robots so they can move objects together, Using lidar in a distributed architecture to create 3d maps.

8. REFERENCES

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