Design and Implementation of a Multi-Robot System Based on Zigbee Network

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***Abstract* — Multi-robot system is widely used for collecting environmental data, patrolling in factories or boundaries, searching and rescuing. In this paper, a multi-robot system (MRS) was designed and implemented. The robots in this system communicate over a Zigbee network. This MRS is capable of avoiding collision; detecting light sources; getting information on temperature and humidity in its work space, as well as the position of each robot using GPS antennas. The collected data are sent to and stored in a server for further analysing and predicting environment condition. The MRS could be used in monitoring factories. A prototype system consisting of three mobile robots was developed and it has successfully detected light source in laboratory condition.**

Keywords — MRS, Zigbee, light source detection, obstacle avoidance, monitoring

I. INTRODUCTION

Wireless sensor network (WSN) is popular in environment monitoring. However, it has several shortcomings: WSNs are not flexible, not easy to reconfigure, and need a lot of nodes. Mobile wireless sensor network or muti-robot systems (MRSs) are investigated to overcome the drawbacks.

MRS consists of a number of simple robots. The robots are supposed to perform some desired collective behaviors while interacting with other robots in the system and with the environment. This approach has emerged from research on artificial swarm intelligence and studies on behaviors of insects (ants, bees, etc).

MRSs are increasingly used in repetitive, dangerous tasks or tasks that require a high level of distributed coordinations [1][2]. Some examples are: patrolling, monitoring, surveilance, detecting chemical leaks, rescuing victims after natural disasters. As the computational power and the reliability of robots are enhanced, this becomes and remains a growing trend [3].

While the underlying science of the operation of MRSs has been well developed, its technical aspects have yet to receive adequate attention, with only several papers on real implementation of MRSs and their real world application [4] [5] In this paper, we develop a system for the task of monitoring and test the system in real conditions. In this work, we address various problems, including obstacle avoidance, collective search, positioning and localization, and navigation of a robotic system.

This paper presents the first stage of our ongoing project, where a multi-robot system will be built for the purpose of monitoring and patrolling in industrial zones, as well as mitigating consequences in the aftermath of industrial disasters. In this stage, we work on a system consisting of three mobile robots communicating over Zigbee network. Each mobile robot is equipped with microcontrollers for real-time control and on-line navigation.

The paper is organized as follow. After this short introduction, the second part presents the implementation of the system. The part includes structure of each robot, system architecture, the algorithms and software of the system. The third part provides test results. The last part gives conclusions and future works.

II. DESIGN AND IMPLEMENTATION OF THE MRS

The typical infrastructure of the MRS is composed of a number of mobile robots as nodes and a server. In this work, based on the existing Zigbee network of MEMSICS, we design a system with three mobile robots which is able to communicate using Zigbee modules over I2C.

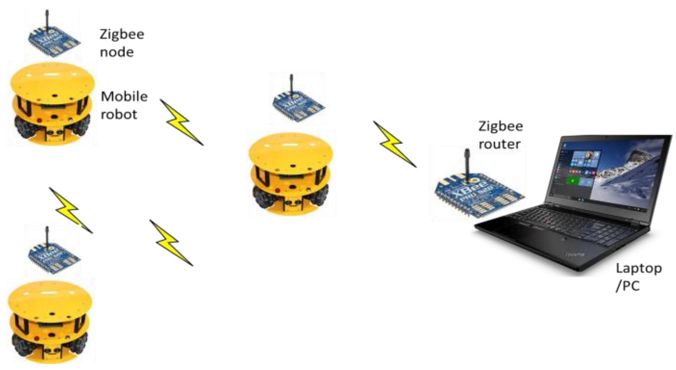


Fig 1. Infrastructure of the MRS

A. *Mobile Robot Design*

The chassis of a mobile robot is a composite filled circle. Two independent driving wheels are mounted with two DC gearbox motors, which are controlled by Atmega328P microcontroller. The heels and motors are mounted symmetrically to make the robots' motion more flexible. A metal ball caster–roller ball is used as a passive wheel.

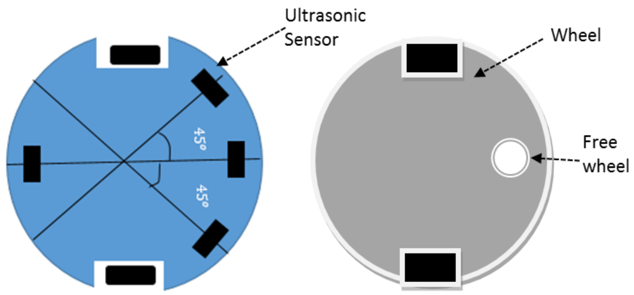


Fig 2. Design of mobile robot base (top and bottom view)

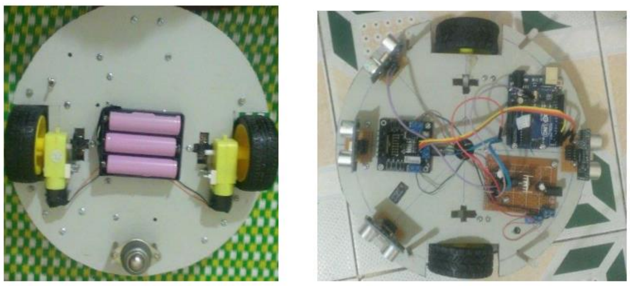


Fig 3. Base of a mobile robot (top and bottom view)

The diameter of this base is 25cm; two main wheels are 21cm apart; the roller ball is 10cm from the center; and the chassis surface is 4cm from the ground.

Each robot includes the following components:

+ Central control: Atmega 328P microcontroller on Arduino Uno R3.

+ Source module: LM2576 HVT – 5V.

+ Control motor module: L298N

+ Ultrasonic sensor module: HC-SR04

The architecture of a robot is given in Fig. 3

B. *System Design*

The block diagram of the entire system is provided in Fig. 4. Each robot (a node in a WSN) is equipped with a processor & radio platform (MPR2400CB) and an environmental sensor board (MTS420CC). This sensor board consists of five sensors/modules. In this work, we make use of only two of them, namely ambient light sensor TAOS TSL2550D and GPS module LEA-4A. The base station includes an MPR2400CB and a USB interface board (MIB520CB). This allows the system to communicate over Zigbee network and avoid collision during the course of finding a light source. The star topology of the network is shown in Fig. 5

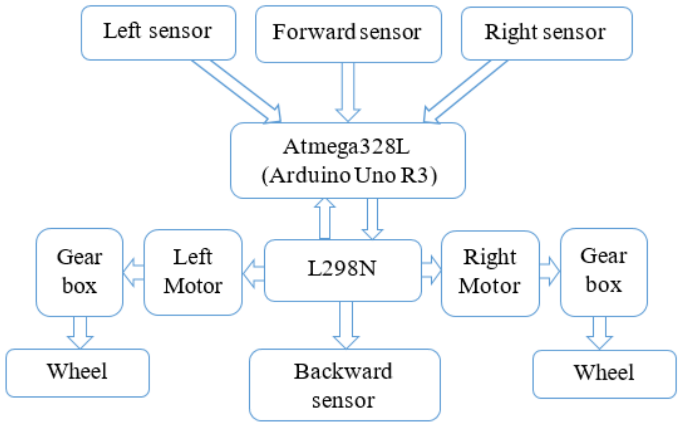


Fig 3. The architecture of a robot

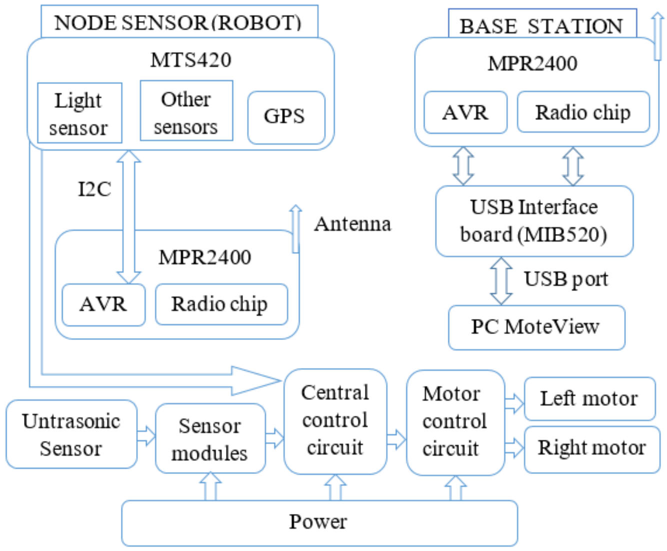


Fig 4. System block diagram

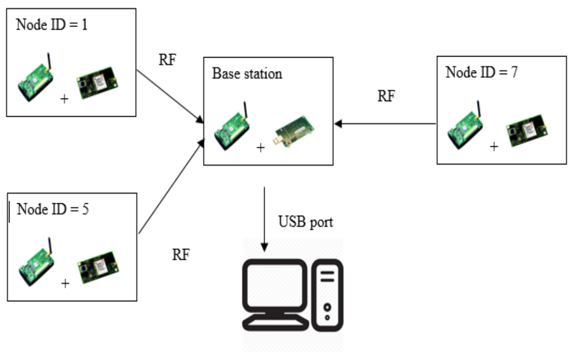


Fig 5. System topology

The final prototype of the system is given in Fig. 6.

Fig 6. The designed MRS

C. *Algorithm for avoiding obstacles and detecting light sources.*

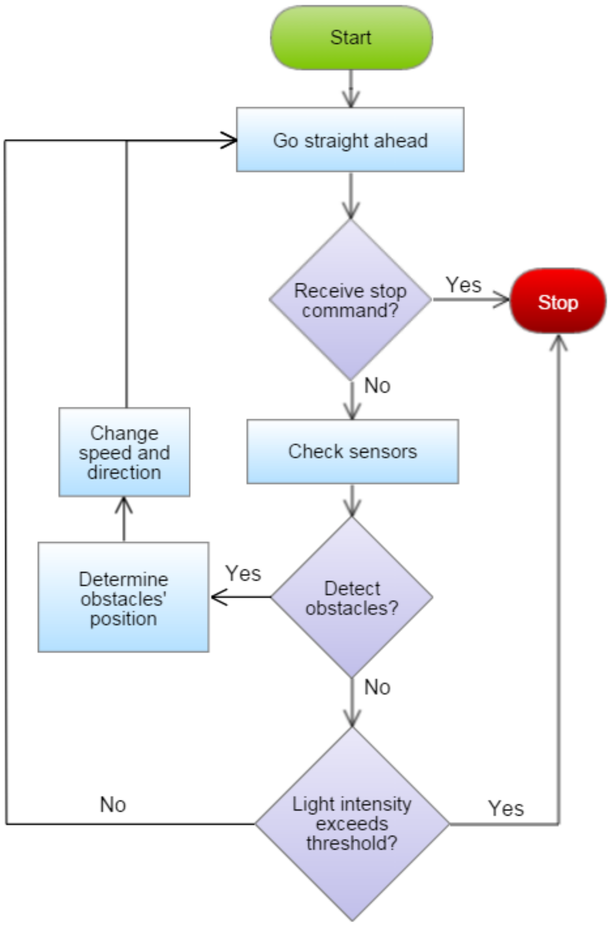


Fig 7. Flowchart of algorithm for avoiding obstacles and detecting light sources.

III. Results and Discussion

In this part we give following results:
- Calibration for straight motion of a robot
- Detecting and avoiding obstacles
- Avoiding mutual collision
- Positioning
- Detecting light sources.

A. *Straight motion calibration*

Because the actuator of the robot has no feedback signal, we need to calibrate. Initially, the two motors are controlled by PWM pulses with the same maximum duty cycle. Then we let the robot run 1.5m to get its trajectory path. The blue line in Fig. 8 shows trajectory path of a robot without calibration. After a few adjustments to the PWM pulse of right motor, the robot's trajectory path is the green line in Fig. 8. The robot's speed is about 0.3m/s.

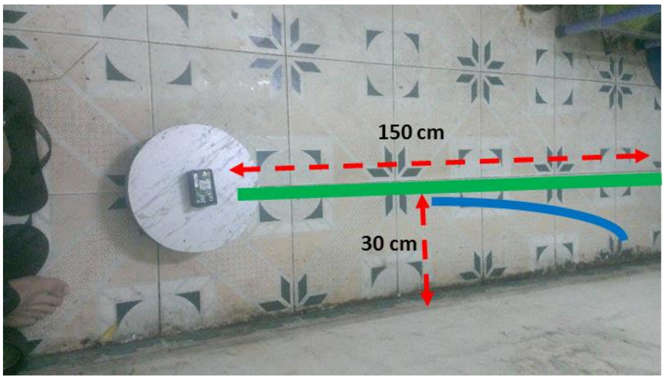


Fig 8. Motion calibration

B. *Collision avoidance*

The robots are able to detect obstacles and avoid them. In Fig. 9, a robot detects the U-shaped obstacle and moves away it. However, the robot could not avoid some small obstacles.

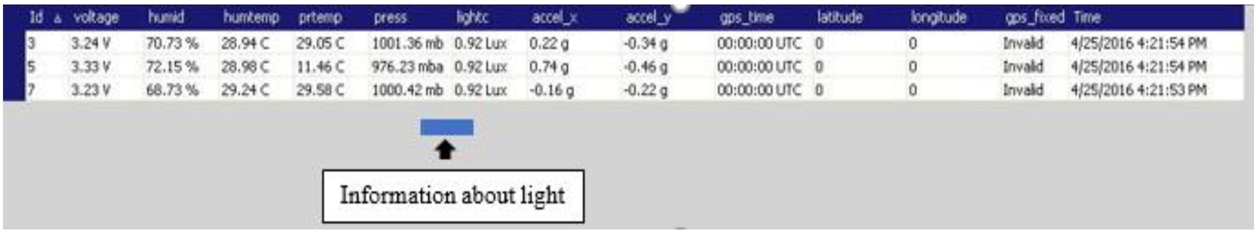
Fig 9. Avoiding obstacles

C. *Detection of light sources*

The system is tested in outdoor environment, with the absence of sunlight (test time is 11:21 pm). The light source used is flash light.

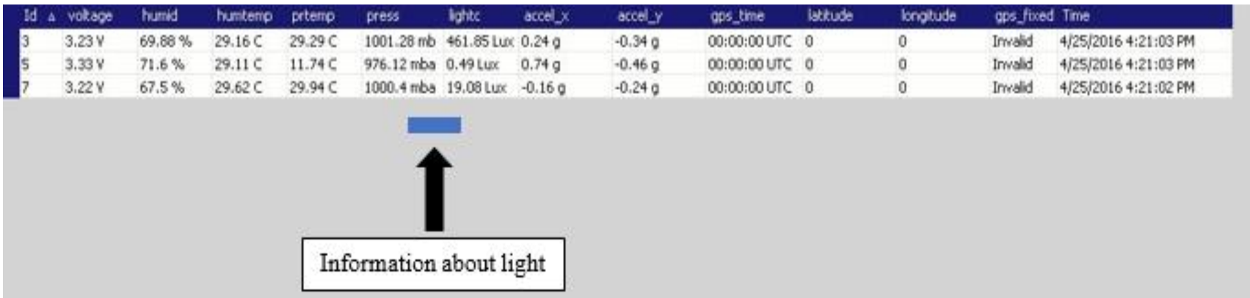
There are two test cases. In the first case there is no real light source. In the second case, the light source is flash light. In the first case, we check the behavior of the system when there is no source.

The results are presented in Fig. 10 and Fig. 11



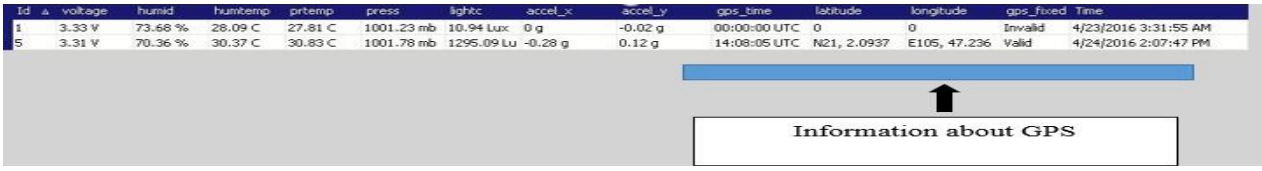
Id	voltage	humid	humtemp	prtemp	press	lightc	accel_x	accel_y	gps_time	latitude	longitude	gps_fixed	Time
3	3.24 V	70.73 %	28.94 C	29.05 C	1001.36 mb	0.92 Lux	0.22 g	-0.34 g	00:00:00 UTC	0	0	Invalid	4/25/2016 4:21:54 PM
5	3.33 V	72.15 %	28.98 C	11.46 C	976.23 mba	0.92 Lux	0.74 g	-0.46 g	00:00:00 UTC	0	0	Invalid	4/25/2016 4:21:54 PM
7	3.23 V	68.73 %	29.24 C	29.58 C	1000.42 mb	0.92 Lux	-0.16 g	-0.22 g	00:00:00 UTC	0	0	Invalid	4/25/2016 4:21:53 PM

Fig. 10. Results when light source is turned off



Id	voltage	humid	humtemp	prtemp	press	lightc	accel_x	accel_y	gps_time	latitude	longitude	gps_fixed	Time
3	3.23 V	69.88 %	29.16 C	29.29 C	1001.28 mb	461.85 Lux	0.24 g	-0.34 g	00:00:00 UTC	0	0	Invalid	4/25/2016 4:21:03 PM
5	3.33 V	71.6 %	29.11 C	11.74 C	976.12 mba	0.49 Lux	0.74 g	-0.46 g	00:00:00 UTC	0	0	Invalid	4/25/2016 4:21:03 PM
7	3.22 V	67.5 %	29.62 C	29.94 C	1000.4 mba	19.08 Lux	-0.16 g	-0.24 g	00:00:00 UTC	0	0	Invalid	4/25/2016 4:21:02 PM

Fig. 11. Result when light source is turned on



Id	voltage	humid	humtemp	prtemp	press	lightc	accel_x	accel_y	gps_time	latitude	longitude	gps_fixed	Time
1	3.33 V	73.68 %	28.09 C	27.81 C	1001.23 mb	10.94 Lux	0 g	-0.02 g	00:00:00 UTC	0	0	Invalid	4/23/2016 3:31:55 AM
5	3.31 V	70.36 %	30.37 C	30.83 C	1001.78 mb	1295.09 Lu	-0.28 g	0.12 g	14:08:05 UTC	N21, 2.0937	E105, 47.236	Valid	4/24/2016 2:07:47 PM

Fig. 12. GPS Positioning

D. Positioning using GPS

Fig. 12. shows the results of positioning using GPS in outdoor environment.

IV. CONCLUSION AND FUTURE WORK

A. Conclusion

We have designed and implemented a multi-robot system based on Zigbee network. Robots in the system are able to avoid obstacles, collectively detect light source, communicate using Zigbee network and get their positions using GPS (with big error).

B. Future Works

This work is only a beginning step in a project, where a simple multi-robot with Zigbee network (RF communication) is designed. In the future, we will build sophisticated MRSs with the ability of communicating over Zigbee network and apply swarm algorithms such as ACO, PSO on the system.

ACKNOWLEDGMENT

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