DESIGN AND DEVELOPMENT OF RF BASED MODULAR ROBOTS WITH LOCAL AND GLOBAL COMMUNICATION

K. Jagadeesh Babu, B. Kiran Kumar, G.Vyshnavi Devi, K. Pramodh Kumar, and V. Rama Krishna

Department of ECE, St.Ann's College of Engineering and Technology,
Chirala, Andhra Pradesh, India.

ABSTRACT

The main objective of the proposed research work is to establish communication between different modules in modular robots. In this paper, a 7 module modular robot system capable of achieving both local and global communication is presented. The proposed work present, how RF communication between various modules in a modular robot can be effected by changing the operating frequency and distance between the modules. The RF based modular robots are highly useful in the applications like space exploration, where the scenarios are highly unpredictable.

KEYWORDS

RF, Modular Robot, Zig Bee, Local communication and Global Communication

1. INTRODUCTION

The design and construction of modular robots is one of the latest paradigms, where researchers and engineers are working to open the new gateways in robotic technology [1]-[3]. The modular robots consists of group of modules that contain sensors or actuators or motors, which are required to communicate continuously to perform a specific task. The main functionality of a modular robot depends on the ability of having good communication between all its interconnected modules.

Currently, communication between different modules in a modular robot is based on infrared (IR), Zigbee or wired links. However, the use of these technologies has several issues. The main problem of Infrared links is the need of proper alignment and orientation between the modules to achieve communication. Also, in some cases the environmental impact like dust can obstruct the optics and effect electrical connections. Bluetooth suffers from limited range, and it needs the presence of a central node to operate the entire robot topology. Wire links limit the movements of modules and also makes the system complex.

One of the apt solutions to get rid of these problems and establish good communication between various modules is the implementation of RF (Radio Frequency) Communication. The benefits of using RF solutions are that they do not require precise module alignment and can provide global and local communication [4]-[5].

The main challenge in the design of RF based Modular Robots is the establishment of both local and global communication. The antenna used in modular robot must be carefully designed performing both local and global communication based on the required operation of the modular robot [6]-[7]. A team of robots, which are capable of self-organize into multi-hop ad-hoc network allowing for the completion of a given task are designed and developed [8]. Xuefeng Dai et al.

have mentioned the problems that are encountered, when the multi robots are operated in multitasking environments [9]. The method of multi-robot formation, where the robots adjust themselves to alter various parameters like size, direction of path, orientation etc. was clearly presented in [10]. Based on the operation of the robot, a specific module is required to communicate only with another specific neighbor module, which is known as local communication. Similarly, in other case the module is required to communicate with all other modules at a time performing a specific task, which is known as global communication. In a modular robot, achieving both local and global communication is a challenging task as various important parameters like power, distance, size and orientation of the modules are to be taken into consideration. In the proposed research work, a 7 element modular robot that is capable of establishing both local and global communication is developed and successfully tested.

2. DESIGN

To establish communication in robots, mostly IR or Zig bee or wires are used. However, these techniques are not preferable in the design of advanced robotic structures like self-reconfigurable and modular robots. The alternate and the most efficient technology to establish communication is the use of RF. The main benefit of using RF communication is that there is no stringent requirement of alignment between transmitter and receiver and the operation mainly depends the capability of the antenna. This important feature of RF communication is highly advantageous in establishing communication between various modules of a modular robot, where getting alignment between different modules is a difficult task.

2.1 Development of Modular Robotic System:

The prototype of a modular robot mainly consists of two parts. One is General board and second one is communication board. The general board consists of a powerful Atmel ATMEGA 1280, 32-bits microcontroller with 8 KB of RAM and 128 KB of flash program memory. The specified microcontroller has very low power usage. The second one is communication board, which is used to establish the communication between different modules of a robot. The communication board was developed by using an RF radio chip. The module is supposed to have a set of important services and abstractions, such as sensing, communication, storage, and timers. The radio chip provides extensive hardware support for packet handling, data buffering, burst transmissions, data encryption, data authentication, clear channel assessment (CCA), link quality indication, and packet timing information. The general board and communication board are linked establishing a modular robot. The entire arrangement is fixed on a robot chassis.

The modules in a robot communicate both locally and globally. The main purpose of the local communication is to communicate with a neighbor module and perform a specific task. Global communication allows modules in different parts of the system to communicate with each other directly. Global communication can also be established using local communication i.e. passing the information from module to module. However, it takes lot of time and even some data may be lost. These issues can be easily solved by using RF communication between different modules.

2.2 Procedure:

For the proposed wireless communication system, the modules are required to communicate either locally or globally among its neighbors. In the proposed research project, seven modules are arranged as shown in Fig.1. Each module has a transceiver, which can transmit and receive signals from the other modules over the allotted radio channel.

Here module (1) is configured as a transmitter, which operates at dual band of frequencies 2.4 GHz and 433 MHz band. These bands are chosen as they are license free in our country. Modules (2), (3), (4) and (5) are selected as receivers and operate at 2.4 GHz frequency band. Modules (6)

and (7) are also selected as receivers, but to operate at dual band 2.4 GHz and 433 MHz. The transmitter module (1) is designed such that it can change its operating frequency and power level at specified intervals of time.

The procedure for achieving both local and global communication is planned to do in three steps.

Step 1: In step 1, the module (1) communicates in the 2.4 GHz band, thus communicating with module (2), (3), (4) and (5). As shown in Fig.1, the distance from module (1) to (6) and (7) is larger compared to the remaining modules. The power level of module (1) is adjusted so that it can't communicate with modules (6) and (7). This is nothing but local communication

Step 2: In step 2, the power level of antenna in module (1) is raised so that, it communicates with all other modules, thus achieving global communication.

Step 3: In step 3, the operating frequency of the antenna is changed to 433 MHz band, so that module (1) is able to communicate only with module (6) and (7) and not with module (2), (3), (4) and (5) as they are tuned to 2.4 GHz band. This is nothing but establishing local communication between modules (1) to (6) and (7).

The E-field and H-field values from Master to slave for various distances are measured using radiation meter. Table 1 shows the obtained radiation values for various distances, when the master is operating at 2.4 GHz. Similarly, Table 2 gives the radiation values, when the Master is operating at 433 MHz. From the values given in both the Tables, it is obvious that the signal levels received by any Module decreases with increase in the distance.

Table 1. Radiation values when Master (Module 1) is operating at 2.4 GHz

Module No.	Distance from Module 1 (cm)	E-Field (V/m)	H-Field (µT)
1	0	230	1.96
2	20	25	1.96
3	40	18	1.96
4	60	15	1.86
5	80	10	1.86
6	100	8	1.76
7	120	5	1.66

Table 2. Radiation values when Master (Module 1) is operating at 433 MHz

Module No.	Distance from Module 1 (cm)	E-Field (V/m)	H-Field (µT)
1	0	200	1.86
6	100	7	1.66
7	120	4	1.66

This procedure can be applied to any number of modules to achieve both local and global communication. In the current proposed work, when a particular module receives signal, LED glows and it can be made to move using motor arrangement. The developed prototype of the proposed modular robot system capable of establishing both local and global communication is shown in Fig.2. The significant contribution of the presented work is understanding how to establish local and global communication between various modules of a modular robot by changing the operating frequency and power levels. The master module is capable of achieving global communication at two different frequencies up to a distance of 120 cm.

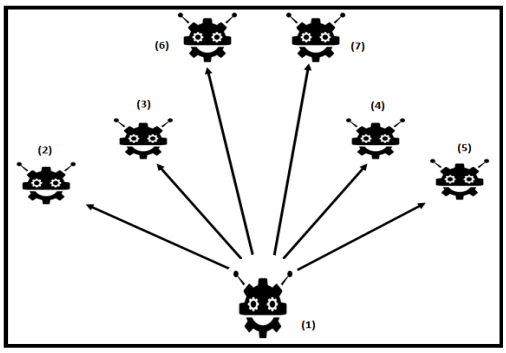

Fig.1.Schematic Representation of Modular Robots to achieve Local and Global Communication

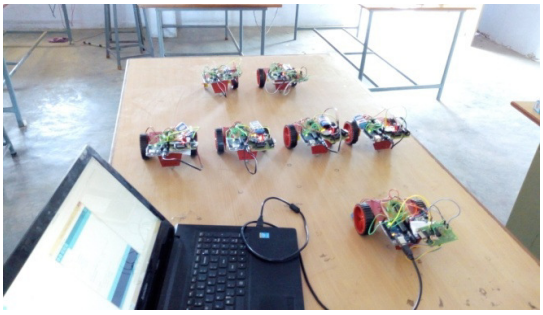

Fig. 2. Developed Modular Robot system with local and global communication

3. CONCLUSIONS

The RF based modular robots are designed and developed at two different frequencies i.e., 2.4 GHZ and 433 MHZ. In the design approach, seven robots were used where one module is used as master and remaining as slaves. In the local mode, the master will be able to communicate with only specified robots, based on the distance and operating frequency. In the global mode, the master can communicate with all modules irrespective of the operating frequency. The developed 7 module system helps in establishing the RF communication between various modules of a Modular Robot, which are useful for various applications like space exploration, disaster management etc. The prototypes are developed and tested successfully in the laboratory.

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REFERENCES

[1] Kasper Stoy, David Brandt and David J. Christensen. Self-Reconfigurable Robots: An introduction (Intelligent Robotics and Autonomous Agents series). s.l. : The MIT Press, 2010. 0262013711; Pages 27-49 and 86-89.

[2] itch, Victor Kuo and Robert Charles. A Multi-Radio Architecture for Neighborto-Neighbor Communication in Modular Robots. University of Sydney, NSW, Australia : 2011 IEEE International Conference on Robotics and Automation, 2011

[3] Nielsen, Jacob. User-Configurable Modular Robotics. Design and use. Odense : The Maersk Mc-Kinney Moller Institute. University of Southern Denmark, December 2008.

[4] Fitch, V.Kuo and R. Towards a parallel wireless radio communication architecture for modular robots. s.l. : in Proc. of ARAA Australasian Conference on Robotics and Automation (ACRA), 2009

[5] David Johan Christensen, David Brandt, Ulrik Pagh Schultz and Kasper Stoy. Neighbor Detection and Crosstalk Elimination in Self-Reconfigurable Robots. University of Southern Denmark, Odense, Denmark : Proc. of RoboComm, 2007. Pages 1-8

[6] Guillem Arimany, Radio Frequency communication for Modular Robots, Master thesis, University of Southern Denmark, 2011

[7] K Jagadeesh Babu, K Sri Rama Krishna, L Pratap Reddy. A review on the design of MIMO antennas for upcoming 4G Communications. International Journal of Applied Engineering Research Dindigul, Vol.1, No.4, 2011.

[8] James Stephan, Jonathan Fink, Alejandro Ribiero. System Architecture for communication aware multi-robot navigation. IEEE International Conference on Acoustics, speech and signal Processing, China, 2016.

[9] Xuefeng Dai, Qi Fan and Dahui Li. Research status of operational environment partitioning and path planning for multi - robot systems. Journal of Physics: Conf. Series 887, pp-1-6, 2017.

[10] Javier Alonso-Mora1,, Stuart Baker and Daniela Rus. Multi-robot formation control and object transport in dynamic environments via constrained optimization. The International Journal of Robotics Research 36(9), pp-1000-1021, 2017.

AUTHORS

K Jagadeesh Babu is working as Professor & HOD in E.C.E Department, at St. Ann's College of Engineering & Technology, Chirala, India. He obtained his Ph.D. degree from JNTUH Hyderabad, India in 2013. His areas of interest include design of Microstrip and Dielectric Resonator Antennas for MIMO applications and UWB antennas for wireless applications and Robotics. He published more than 40 research papers in referred journals and Conferences. He is currently a reviewer for many journals such as IET Electronics Letters, International Journal of Electronics Letters (Taylor & Francis), IEEE Open Access etc. He is a Member IE (India) and Senior Member of IEEE.

Bandi Kiran Kumar is working as Professor at St. Ann's College of Engineering & Technology, India. His areas of interests include Robotics, Antenna design and RF Circuit design. He is a member of IE (India) and IEEE.

G. Vyshnavi Devi completed her B.Tech at St. Ann's College of Engineering & Technology, India in 2018. Her areas of interest include Robotics, Antenna design and RF

K.Pramodh Kumar completed his B.Tech at St. Ann's College of Engineering & Technology, India in 2018. His areas of interest include Robotics, Antenna design and RF.

V.Ramakrishna completed his B.Tech at St. Ann's College of Engineering & Technology, India in 2018. His areas of interest include Robotics, Antenna design and RF.