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Swarm Intelligence based Fire Fighting Robot

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***Keywords*— SIFFR, Swarm Robotics, Temperature Sensor**

***Abstract*— *The swarm robotics inspired from nature is a combination of swarm intelligence and robotics, which shows a great potential in several aspects. Swarm robotics is a relatively new and rapidly developing field which draws inspiration from swarm intelligence. It is an interesting alternative to classical approaches to robotics because of some properties of problem solving present in social insects, which is flexible, robust, decentralized and self-organized. Fire detection and extinguishment are the hazardous job that invariably put the life of a fire fighter in danger. By putting a robot to perform this task in a fire-prone area, it can aid to avoid annoying incidents or the loss of lives. This paper describes the development of Swarm Intelligence Fire Fighting Robot using (SIFFR) that is equipped with the basic fighting equipment that can round through the hazardous site via a guiding track with the aim of early detection for fire. When the fire source is being identified, the temperature will be promptly extinguished using the fire extinguishing system that is mounted on receiving robots platform. To detect for fire source, the input from temperature sensors were finely-tuned in relation to the surrounding area, external interference and the mobility of the SIFFR prior the deployment of the platform.*

I. INTRODUCTION

Fire-Fighting is an extremely dangerous task but still often being carried out by human operators, thus putting human life, invaluable as it is, in a very wobbly situation [1]. Swarm robotics is a relatively new technology that is being explored for its potential use in a variety of different applications and environments. In particular, swarms of robots potentially employ different types of communication channels; have special concepts of identity; and exhibit adaptive emergent behavior which could be modified by an intruder [4]. Addressing these issues now will prevent undesirable consequences for many applications of this type of technology.

This robot will detect any obstacle comes in his way. IR sensors are mounted on this robot which will operate on 5v input and emits infrared signals continuously. Sensor will sense and manipulate the signal reflected by the obstacle. Sensor output will have main role for the movement of robot. Slowly when the robot will reach to the obstacle, the intensity of reflected light will increase and at a particular value the robot will stop and will change its path automatically. The IR output will give to the microcontroller, which will set the relay ON or OFF position. DC motor driver L298 is used for driving the motor. Here the first robot start working then it senses light or fire with the help of temperature or light sensor. Which building floor is suffered with fire is detect with sensors and send data to second robot. Then the second robot receives that data with the help of RF transceiver and start working on same path. After reached destination point the robot will start sprinkling water on that floor.

This paper presents the design, implementation and experimental demonstrations of the SIFFR. The contents are organized as follows. Section 2 introduces the concept of swarm robotics. Section 3 shows the system specification and block schematic of SIFFR module. Hardware design is described in Section 4. The software design and algorithm is explained in Section 5. Test setup and testing procedure is interpreted in Section 6. Meanwhile results and analysis are shown in Section 7. Finally, Section 8 summarizes the research conclusions and sheds some light on the future work.

II. SWARM ROBOTICS

Swarm intelligence embodied by many species such as ants and bees has inspired scholars in swarm robotic researches. Nature always gives humankind knowledge and inspirations. Through distributed collaboration or assembling themselves into different collective structures, insects like ants and bees get able to transport objects that are too large for any single one of them or to bridge gaps that will stop them separately as individuals. Swarm intelligence personified by these social insects when they cooperate with one another in a large scale has been brought into robotic research by scholars and become an attractive topic in the robotic community [2].

Non-communicative swarming has to be achieved without central or on-line control. In non-communicative mode the swarm consists of homogeneous but anonymous robots, the latter means that the robots are able to recognize another robot as a robot but they cannot identify other robots as a particular individual with a unique name. The advantages of this approach are that the swarming behavior is relatively independent of the number of robots that are active, making the swarm robust to failures of individuals and its size may vary considerably. A drawback is that as the swarm behavior depends on many parameters and is inherently complex, it is hard to fully predict the behavior. Swarm research therefore usually aims at behavior types of a general nature. The basic behaviors that can be generated in the non-communicative mode are [3], [5]:

1. Obstacle and Robot avoidance.

2. Wall/Track/. Gradient following

3. Aggregation/Dispersal/Gathering/Clustering

4. Area Coverage

5. Basic Search/Exploration Behavior

6. Acquisition/Maintenance of Geometric Formations

7. Autonomous Navigation

III. SYSTEM SPECIFICATION AND BLOCK SCHEMATIC

A. Specifications

- MLX 90614 Infra Red Sensor: - It is low noise amplifier, 17-bit ADC and powerful DSP unit, a high accuracy and resolution of the thermometer is achieved.
- Microcontrollers (AVR-ATMEGA 16), display units (LCD) are used to perform the coordination between various blocks.
- Motor driver LM298 is used to drive DC motors in both the master and slave robot.
- CC2500 low-cost, low-power 2.4 GHz, SPI interface RF Transreceiver is used communication between transmitter and receiver robot.

B. Block Diagram

Transmitter side block diagram

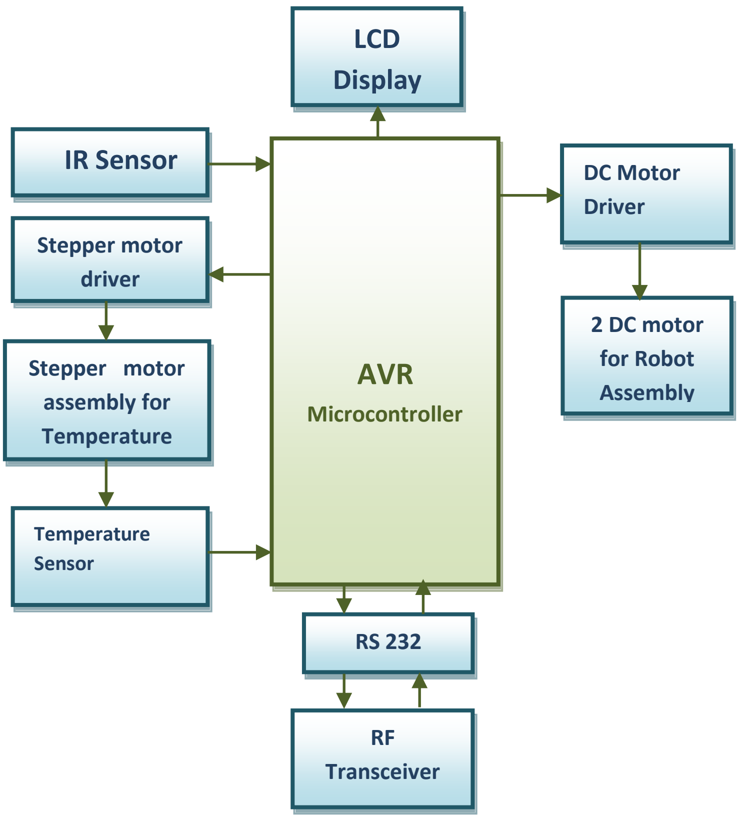

Fig.1: Schematic diagram for Transmitter block.

Working: - MLX 90614 Infra Red Sensor will sense the change in temperature and give signal to the AVR-ATMEGA 16 microcontroller. Microcontroller will check temperature at different degrees with the help of stepper motor. If it will find any change in temperature it will send command to the receiver via CC2500 RF Transreceiver.

Receiver side block diagram:-

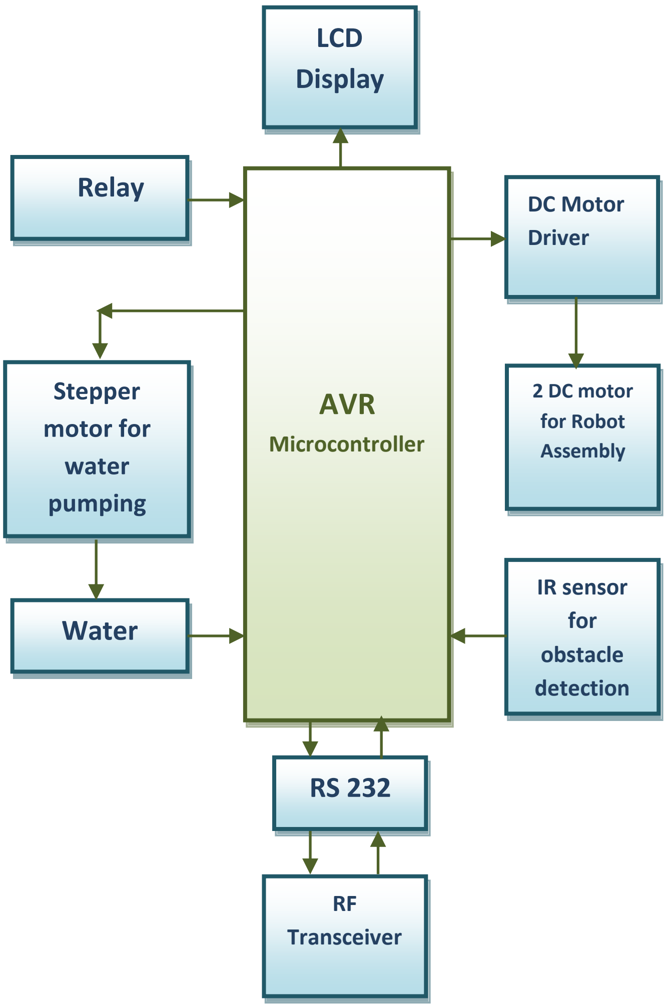

Fig.2: Schematic diagram for Receiver block.

Working: -The receiver side block is also having an IR sensor for obstacle detection in its path. After getting signal from the transmitter through RF transreceiver it will follow its path to reach upto the desired location with the help of DC motors provided to it. After reaching to the required location it will start sprinkling water at the fire place with the help of water pump which it fitted on the stepper motor so that it will sprinkle water in all directions.

IV. HARDWARE DESIGN

Hardware design begins with selection of proper equipment required to do the various jobs. Selection is mainly on the basis of current and voltage ratings, IC packages, clock rate and cost. Power supply is designed for the various components according to their ratings.

A. Microcontroller

Two microcontrollers are required one for transmitter and other for receiver robot. AVR is preferred over PIC and 8051, as it takes only one machine cycle to execute one instruction as against 12 for 8051 and 4 for PIC [11].

Specifications:

Advanced RISC Architecture

- 131 Powerful Instructions – Most Single-clock Cycle Execution
- 32 × 8 General Purpose Working Registers – Fully Static Operation
- Up to 16 MIPS Throughput at 16 MHz
- On-chip 2-cycle Multiplier

High Endurance Non-volatile Memory segments

- 16 Kbytes of In-System Self-programmable Flash program memory
- 512 Bytes EEPROM, 1 Kbyte Internal SRAM
- 10,000 Flash/100,000 EEPROM
- Data retention: 20 years at 85°C/100 years at 25°C
- Optional Boot Code Section with Independent Lock Bits
- In-System Programming by On-chip Boot Program
- True Read-While-W

B. Sensors

Using MLX 90614 Infra Red Sensor for temperature detection and it is fitted on stepper motor so that it will sense temperature at different step angles.IR sensors on both transmitter and receiver for obstacle detection.

- Melexis' MLX90614ESF-BAA is an infrared thermometer designed for non-contact temperature sensing. An internal 17-bit ADC and a powerful DSP contribute to the MLX90614's high accuracy and resolution. It has a huge number of applications including body temperature measurement and movement detection.
- The MLX90614 provides two methods of output: PWM and SMBus . The 10-bit PWM output provides a resolution of 0.14°C, while the TWI interface has a resolution of 0.02°C. The MLX90614 is factory calibrated in wide temperature ranges: -40 to 85°C for the ambient temperature and -70 to 382.2°C for the object temperature. The measured value is the average temperature of all objects in the Field Of View of the sensor. The MLX90614 offers a standard accuracy of 0.5°C around room temperatures [10].

C. Motor driver LM298

LM L298 is an integrated monolithic circuit in a 15- lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver de-signed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the in-put signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

D. CC2500 low-cost, low-power 2.4 GHz, SPI interface RF Transreceiver

The CC2500 is a low cost 2.4 GHz transceiver designed for very low power wireless applications. The circuit is intended for the 2400-2483.5 MHz ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) frequency band. The RF transceiver is integrated with a highly configurable baseband modem. The modem supports various modulation formats and has a configurable data rate up to 500 kBaud.

E. ULN2003 driver is used to drive relay and stepper motor.

The ULN2003 is a monolithic high voltage and high current Darlington transistor arrays. It consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diode for switching inductive loads. The collector-current rating of a single Darlington pair is 500mA. The Darlington pairs may be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED gas discharge),line drivers, and logic buffers. The ULN2003 has a 2.7kΩ series base resistor for each Darlington pair for operation directly with TTL or 5V CMOS Devices. The main features are 500mA rated collector current(Single output), High-voltage outputs: 50V, Inputs compatible with various types of logic, Relay driver application

F. Power supply design

An ideal regulated power supply is an electronic circuit designed to provide a predetermined voltage Vo, which is independent of load current, temperature and also of any variations is line voltage. The power supply consists of Step-down transformer, Bridge Rectifier, Filter, IC Regulator. Power supply is a vital part of all electronic systems. This circuit is required to drive the various components on the board. It is normal voltage regulator built with ubiquitous Transformer-Bridge Rectifier-Filter-Regulator assembly. We required a 5v supply for digital IC's.

V. SOFTWARE DESIGN

Codes were written in AVR Studio. Part by part circuit simulation was carried out on Proteus Design Suit. Complete interfacing diagram was prepared on EAGLE.

Algorithm:

1. The transmitting robot which consists of Infrared sensor enters a lane with multi storey and single storey residential Houses and buildings.
2. As the transmitting robot moves from one house to other it checks the temperature of that floor or house using IR sensor.
3. If the temperature is less than threshold voltage the robot moves on to the other house.
4. If the temperature is more than threshold voltage the robot sends a signal using RF trans receiver to receiving robot.
5. The receiving robot follows up the signal and goes to the house of which the transmitting robot had send in the signal and sprays water using water jet [5].
6. The Receiving robot also gives audio and visual signal to nearby people.
7. The Transmitting robot keeps checking the Temperature of affected region as the Temperature comes below the threshold voltage the Receiving robot stops spraying water.
8. The Transmitting robot moves on to the other house.

VI. TEST SETUP AND TESTING PROCEDURE

Once the PCB along with the peripheral devices, it is necessary to verify that, the design is correct & the prototype is built to the design drawing. This verification of the design is done by writing several small programs, beginning with the most basic program & building on the demonstrated success of each. It is important to test and troubleshoot the hardware in the following steps:

- Physically check all the connections.
- Check whether power supply wires are firmly connected to all boards.
- Check for any dry solders.
- Check if IC's are physically in place.
- Check whether all components are correctly mounted.
- Check whether VCC and ground are shorted.
- The PCB has a single main VCC and ground track on it. It is necessary to ensure that neither of these tracks is shorted or open at times a short circuit may occur

and IC's would be in danger of being shorted. This can be checked by a multi-meter at various points of tracks carrying necessary VCC. Ground has '0'V across it.

- Check IC's VCC and ground:
- Once the above step is performed check individual IC's to see that correct pins are connected to VCC and Ground. This can be achieved by checking the voltage levels on multi-meter at each VCC and Ground pins of all IC's.

In the figure 3 the transmitter robot is checking each house on its path for any rise in temperature and the receiver robot is following the path of the transmitter. In this setup authors showed the transmitter in the check mode and the receiver in the receiving mode.

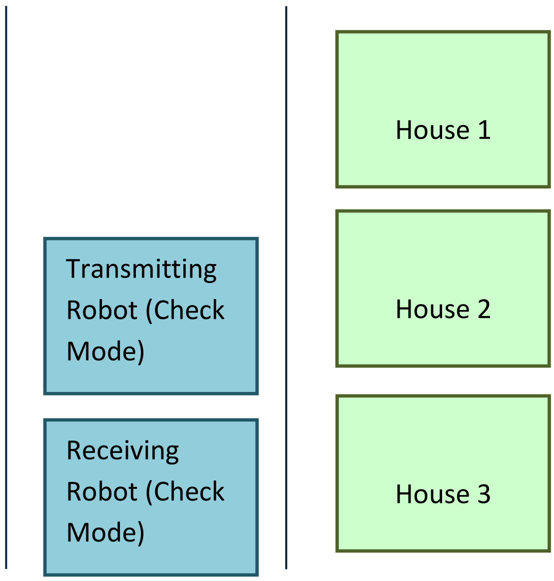

Fig.3: Setup of check mode at transmitting side

In figure 4 setup, the transmitter has detected the origin of fire at house 1 and called the receiver to the required location. The transmitter itself has gone in wait mode while the receiver in the spraying mode is spraying the water at the fire place.

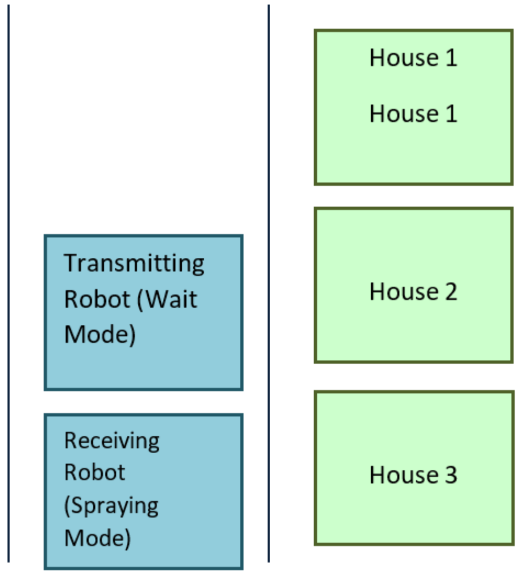

Fig.4 Setup of check mode at receiving side

VII. RESULT AND ANALYSIS

This paper served two purposes. First it helps to find the origin of fire in multi-storied buildings. Since it is very difficult to control fire in multi-storied buildings because the newly constructed buildings have fire safety system installed in it but what about the old tall buildings, they don't have such kind of system installed in it. For such buildings this project will play important role to detect the origin of fire and its control. Second, it continuously checks any rise in temperature in all directions in densely infra structured areas and as soon as it finds any rise in temperature(chances of fire occurrence) it will send signal to slave robot. Slave robot will come to the fire place and sprinkle water to extinguish fire.

Results-Output:

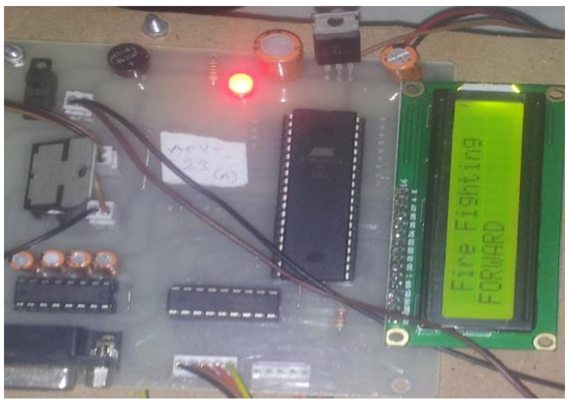

Fig.5: Transmitter robot moving forward

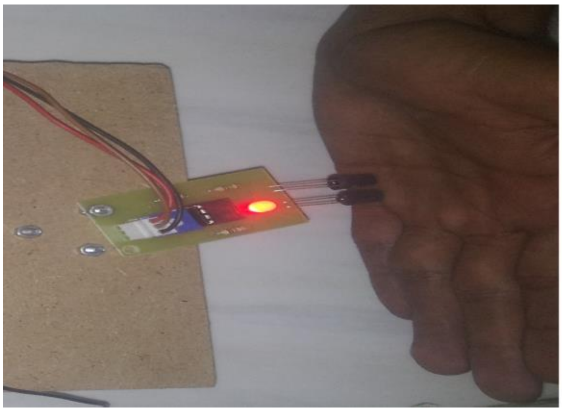

Fig.6: Transmitting Robot detecting Obstacle.

In Figure 5, the transmitter robot is moving forward while checking the surrounding temperature and the same will be displayed on 16X2 LCD.

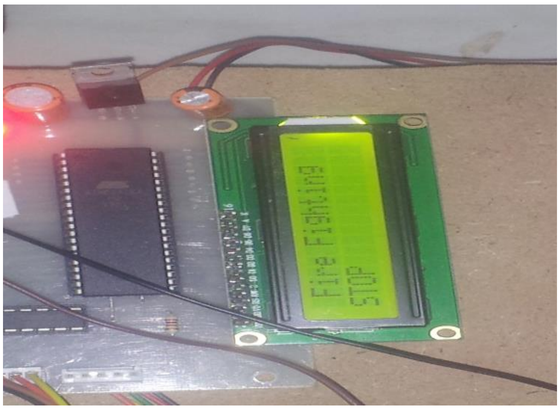

Fig.7: Transmitting Robot stops.

In Fig 7,when the transmitter comes across any obstacle in its path it will stop the moment it senses the obstacle and the same is displayed on LCD.

VIII. CONCLUSION

From this paper, it is evident that the Swarm intelligence can be used for the Fire-fighting purpose. The transmitter (master) robot will sense the rise in temperature in multi-storied as well as densely infrastructure areas with the help of Infrared temperature sensor fitted on it. It will send signal the moment it will come in contact with the rise in temperature using RF Transreceiver to the receiver robot. Receiver(Slave) robot will follow its path and reach up to the fire place and start sprinkling the water until the fire extinguishers using water pump and relay fitted on it. Design of multiple fling robots is proposed in future studies.

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