ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

Implementation of Swarm Robotics for Air Pollution Monitoring

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ABSTRACT: This paper describes a model project for determining the environmental conditions that exist in an area using an army or a swarm of robots. These robots relocate themselves independently of each other, in their own prescribed path.

This project is inspired by the extent of task that are collectively accomplished by a swarm of ants or bees, the swarm of robots find their utility in areas where environmental conditions are to be monitored. Monitoring of environmental conditions using satellite technology, stationary gas sensors have their own drawbacks. Satellite technology for monitoring fails when an area is to be monitored where signals fail to reach. Similarly, stationary gas sensors cannot be installed at every location.

KEYWORDS: Pollution Monitoring, Swarm Robots, Environmental Conditions Monitoring.

I. INTRODUCTION

Pollution and environment conditions in which we live has become a vital issue of late. Significant number of research work is being carried out on ways to monitor environmental conditions, both in normal and severe conditions, in a cost effective and efficient manner. Swarm robots are generally used for ad hoc purposes, but can be also used otherwise. Scalability is an important reason why swarm robots are deployed in monitoring air pollution [1].

Each robot is initially located at distinct position and is required to move independently from each other. It can only detect the pollution intensity within its limited path range.

The objective of this paper is found a simple & easy to implement prototype for an army of robots which would monitor air pollution. As illustrated in Figure 1, the prototype consists of 3 robots, 2 to monitor air pollution and one master to collect and map the findings of the slave robots. These findings can be represented in spatial or digital form and intended action can be taken accordingly.

II. IMPORTANCE

It this model attempts to find a way of monitoring air pollution and environmental condition with the help of robust robots. The quality of air that we live in is getting deteriorated at rapid pace and has reached a critical stage, especially in metro cities. Pollutants like iso butane, sulphur dioxide, nitrogen dioxide along with carbon dioxide which is the major greenhouse gas are at a rise, which not only have adverse effects on lives of people but also contribute to global warming.

At world level, the recently concluded COP-21 at Paris tried to address these grave concerns and India voluntarily presented its Intended nationally determined contributions - INDC’s, under which it pledged to reduce its greenhouse emissions significantly and take steps to improve the quality of air in coming years.

In such circumstances a need is felt for a system which can monitor the environmental conditions effectively in areas which are highly prone to adverse air conditions [2].

III. MOTIVATION

Nature has always enjoyed a complementary relation with innovation. The sight of swarm of bees or ants, working together in huge numbers and ultimately accomplishing a colossal task, seems inspiring, a task which is seemingly impossible for a single insect to accomplish.

If robotics is somehow coupled with the 'swarm' phenomenon, their utility is found to be maximum. With the appealing concept of 'swarm' and a dire desire to address some of the problems of air pollution which is prevailing in our cities, motivated us to design this prototype model.

Along with it, we find today that not much technology is utilized in hazardous areas like coal mines, where workers and labourers are constantly prone to adverse air conditions and even fire due to which a large number of poor people have lost their lives. Not much is done to address these issues [3].

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IV. RELATED WORKS UNDERTAKEN

Sr. no.	Research / Project topic	Refe-rence	Main features	Assumptions	Limitations	Applications	Year
1	From Swarm Intelligence to Swarm Robotics	[4]	□This paper draws analogies between swarm intelligence and swarm robotics and explains the use of swarm intelligence in swarm robotics		□ The main focus has been on multiple robots but a detailed study of efficiencyis not considered by comparing them to a single complex robot	□ This paper forms the base of almost all swarm robotic projects which include swarm intelligence. □ Such robots are used inenvironmental conditions monitoring , foraging and path finding in some specific cases.	2004
2	Dispersion of a swarm of robots based on realistic wireless intensity signals	[5]	□ Simple dispersion algorithm based on wireless signal intensities is proposed and tested in a physics based simulator of a robotic Platform.	□ It is assumed that the change in relative orientations is very small during the motion of the robots.	□ The noise is very high. Also, the bearing of other robots could not be obtained from wireless sensor Readings.	□ With improvement in dispersion algorithm and testing it in more realistic environment, this can be used in indoor environment such as office environments.	2007
3	Coverage Control of a Robotic Swarm for Pollution Monitoring	[6]	□ This paper presents a decentralized algorithm for a swarm of autonomous mobile robots to achieve area coverage for environmental pollution monitoring. □ Robots relocate themselves independently from each other according to the pollution intensity andcoveredness.	□ The algorithm which has been described in this paper assumes that the robot will remain confined to the limited sensing range.	□ As the assumption is that the robot is confined to limited sensing range, practically this will not be always the case. □ According to the algorithm, the robot might move outside their sensing range and hence a possibility is that the robot might break away from the swarm. Hence, this algorithm in certain cases is not self sufficient.	□ Algorithm is effectively in air pollution monitoring as the robots move according to their sensed data or pollution characteristics.	2011
4	Analysis of Algorithms to implement Swarm	[7]	□ This paper analyzes different algorithms that are designed for the working of a swarm robot and	□ The four algorithm which are discussed in this paper	□ Although, on paper , the advantages of swarm seem enormous, significant amount	□Hole avoidance, Chain based path formation for catching a prey.	2011

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	Bots for Effective Swarm Robotics		how they enable the multiple physical quadruped robots to diagnose and recover when placed in unanticipated situations	assumes that swarm makes the task easier and practically advantages of a single robot are very few in number.	are experiments need to be done to prove that swarm are actually effective		

Table 1: Related works undertaken, features, assumptions, limitations and their applications.

V. PROBLEM STATEMENT

Spectrum to design a prototype model for effective monitoring of air pollution and environmental conditions which Provides higher levels of robustness and flexibility. This prototype model must be able to extend to 'n' number of Robots which effectively monitors and presents its findings over a large area. The performance of the swarm of robots must be better than any single complex machinery, at the same time being cost effective and practically usable in certain situations in which conventional & commonly used systems fail.

VI. PROPOSED METHODOLOGY

For applying our methodology on a prototype of two robots we follow a three -step procedure. The same can be extended for 'n' number of swarm of robots. Initially, the second or inferior robot monitors the condition in his own path using gas sensors and the data is communicated with the first robot. This robot is higher in hierarchy than the second robot as he has data regarding area that he has monitored on his own added with the data which is collected from the second robot. We denote the robot 1 as'r1' and robot 2 as 'r2', where each robot in initially placed in the desired location. This is illustrated in Figure 1.

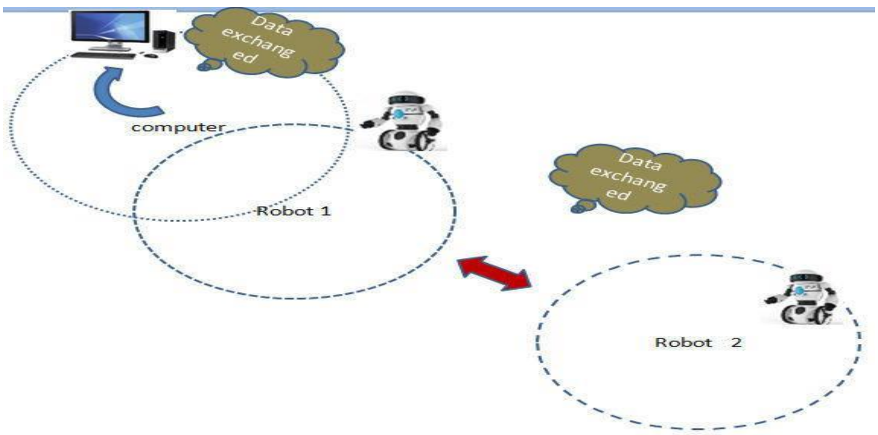

Figure 1: Swarm robots interaction model for pollution monitoring via data exchange between robots.

Robots 'r1' and 'r2' equipped with gas sensors, performs two functions. First, it displays the data collected by it in digital form on its own screen. Secondly, transmitting the data through the swarm to ultimately reach to a machine where the data can be mapped and utilized accordingly, the first robot combines the information and transmits it to Administrative robot. A large area is covered by similarly applying 'n' number of swarm of robots.The total area Covered can be sketched by various figures accordingly. One of the way in which this can be done is shown in Figure 2.

In this approach, an area which records more pollution relatively to other can be highlighted using some or the other form.

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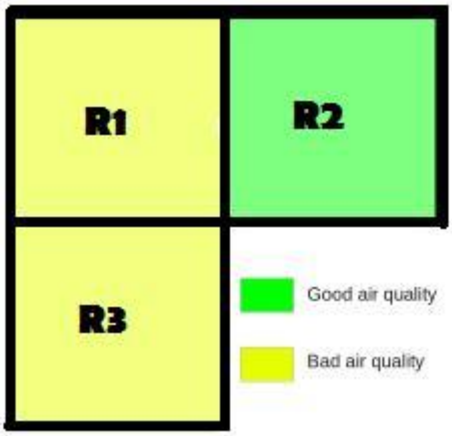

Figure 2: Three robots showing conditions of their prescribed area.

VII. BLOCK DIAGRAM

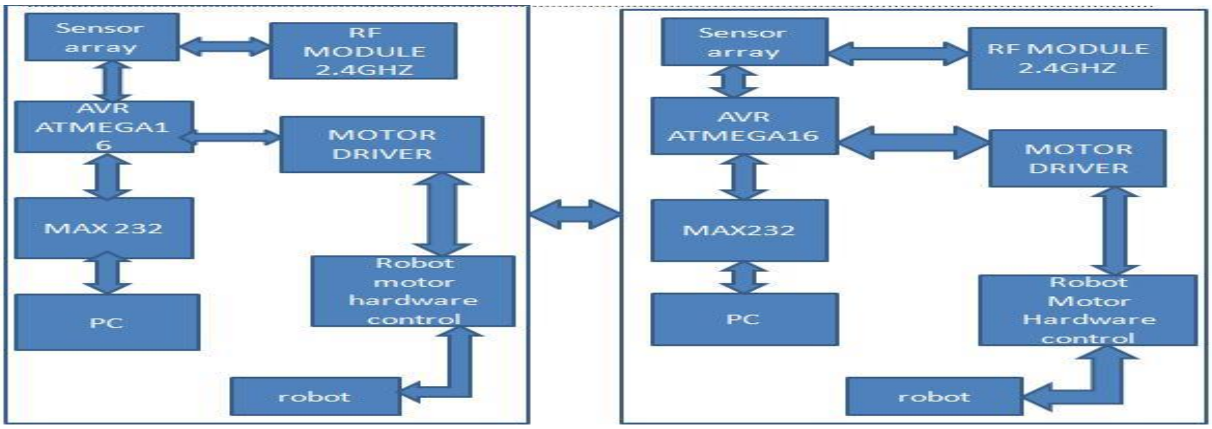

Figure 3: Prototype for the proposed system.

VIII. IMPLEMENTATION

The levels of toxic gas are continuously sensed by MQ6 and LM35 and are displayed on LCD which is refreshed every second.

Atmega16 are pre-programmed to move in a desired path. Additionally, relevant algorithms can be programmed accordingly for *ad hoc* purposes.

Robots communicate in two fold way. Firstly, with environment as discussed above and secondly, the robots communicate by means of wireless communication modules which are responsible for transfer of monitored data.

Independent data collected from individual robots is communicated to robot which is higher in hierarchy than him. Ultimately, sensed data over a larger area reaches the administrative robot where it can be displayed in multiple and detailed form, depending on the purpose it is being used for. The basic block diagram for the implementation is shown in Figure 3.

IX. CORE STUDY

9.1. AVR microcontroller

This is heart of a project being an auto mated system every unit has to be synchronized with each other via some control device. ATmega 16a serves out purpose and coordinates the entire system. The ATmega 16a is low power high performance 8 bit microcontroller with 16 Kb flash programmable memories The AVRs have 32 single-byte registers and are classified as 8-bit RISC devices. In most variants of the AVR architecture, the working registers are mapped in as the first 32 memory addresses (000016–001F16) followed by the 64 I/O registers (002016–005F16). Actual SRAM

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starts after these register sections (address 006016). (Note that the I/O register space may be larger on some more extensive devices, in which case the memory mapped I/O registers will occupy a portion of the SRAM address space.) [8].

9.2.Power system

•The power system of robot is the critical part of it's overall design. Simply stated, a robot needs power to run. Therefore, the power system must include a power source that stores enough energy for the robot to run for a predetermined time period which can recharge after a predefined time. In addition, power must be provided at a constant voltage through a particular voltage regulation scheme in order to ensure the proper operation of all circuitry and components.

• Most of the power consumption in the swarm robots results from the motors and relays. The IC chips selected for the project require far less voltage and current in comparison. Two significant practical issues to take into account regarding the selection of batteries are their size and weight. The battery type must be smaller in size to reduce the area. After considering all the batteries, we have used Lithium ion(Li-Ion) battery is the most suitable for this project since they are widely available and are considerably cheaper, their relative advantagesoutweightheirdisadvantages[9].

9.3. Gas sensorMQ6:

•MQ6 is gas sensor used for detecting the gases which are found in the atmosphere. This type of sensor can sense many types of gases.MQ6 finds its maximum utility in sensing iso-butane, a gas which is highly toxic. Also MQ6 is highly sensitivity to LPG and propane. Other than this, MQ6 is also sensitive to alcohol and smoke [10].

9.4. Temperature Sensor LM35:

• The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in° Kelvin. The LM35 does
Not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range [11].

9.5. RF Module:

• This is the basic communication module which is being used in this model, for establishing communication between the master and slave and also between the administrative PC and master robot.

• RF module works on 2.4 Ghz frequency and makes use of Amplitude shift keying (ASK).

• RF module works on 9600 baud rate and consumes a meagre current of 32 mA to 42 mA[12].

9.6. MAX 232:

•MAX 232 is used as interface between robot and the communicating computer. it provides a interface so that the particular robots shares its data with the communicating computer.Max232 is designed by Maxim Integrated Products. This IC is widely used in RS232 Communication systems in which the conversion of voltage level is required to make TTL devices to be compatible with PC serial port and vice versa. This chip contains charge pumps which pumps the voltage to the Desired Level. It can be powered by a single +5 volt power supply and its output can reach +_7.5 volts.MAX232 comes in 16 Pin Dip and many other packages and it contains Dual Drivers. It can be used as a hardware layer convertor for 2 systems to communicate simultaneously [13]

9.7. Motor Driver 293D:

• Forthismodel, weneededastandardTTL inputs and makes a standard servo our slave. Standard servos use a "Pulse Width Modulated" ("PWM") signal to tell a servo where to rotateto. PWM works by sending a rapid train of high/low signals to the servo's regular driver brains, and depending on how different the high signal is from the low signal, the servo moves to the according position. PWM is great if the rotation is much more than 180°, which is fine for actuators, but not for driving wheels [14].

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XII. RESULTS

Figure 4: Final implementation of Air pollution monitoring Swarm robots.

X. CONCLUSION AND FUTURE SCOPE

Much research has been done and numerous algorithms have been developed for efficient utilization of swarm robots. All these researches have shown the advantages that swarm robots have over conventional single robot system.

We are currently developing the prototype model for two robots using the components that have been mentioned in this paper.

This swarm can be expanded to ‘n’ number of robots, according to the requirements of the user. Along with this, the sensors which are installed must be chosen according to the application and environment for which it is used for. Further development can be done by using a variable path using self-locating or path finding algorithms such as Daystar’s algorithm.

This would have significant advantage, as the robot would only move in areas where the need for monitoring is present, instead of moving in a fixed prescribed path. But since significant resources would be needed for extending this project to multiple robots, any proposed model must be first simulated on available simulation software and should be implemented only after analysing the efficiency for that particular application.

XI. LESSONS LEARNT

Implementing swarm robots comes with plethora of challenges. Implementation becomes complex as every robot needs to monitor pollution in its area so as to give an overall picture of the environment in the whole area.

For very less number of robots, using RF module is always preferable, which was the case in our project. Although the complexity increases if less secure module is used, costs are reduced significantly. On the other hand, when large number of robots are to be implemented use of a secure protocol becomes necessity.

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Care should be taken regarding the purpose for which swarm robots are to be implemented. The numerous advantages associated with swarm technique does make it attractive, but one must analyze the application for which it is used and if single robot could be more effective. Like initially we planned on making swarm robots for a wide view of surrounding. But after comparing it with conventional technique of single robot, we found that infect a single robot if more effective for imaging purposes.

If the swarm is designed using RF module, even a non-working robot in a chain can make other robots following it useless. Hence, the communication module must be protected by covering it using some robust cover.

Software, which is used for the purpose of displaying the data must be comprehensive. Although, the robots have an LCD fitted over them e which show its findings, if they were to be used in a mine or cave like structures, monitoring is to be done only on administrative robot. Hence, the data must be represented according to the user needs.

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