Computing technique for improving the accuracy of measurements of an enclosed space

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Abstract - *Embedded systems is a widely implemented domain with Robotics as an ever growing filed. In this paper, a method for measuring and obtaining the dimensions of an enclosed space is proposed. For the purpose of measuring, a robot is built which has ultrasonic sensors mounted on it. This robot can be sent in places inaccessible under normal circumstances, and is controlled remotely using a hand mounted module operated by a controller which consists of an accelerometer. The transmission and receiving of data is done using radio frequency based modules. The data obtained from the ultrasonic sensors mounted on the robot is then ultimately mapped on the user workstation. This is done in order to get a clear view of the space without even entering it.*

Key Words: Arduino, Ultrasonic sensors, Accelerometer, Environment mapping, processing development environment.

1. INTRODUCTION

There exist many enclosed spaces around us which might be inhabited by humans or which are totally untouched. However, there are very few techniques to explore and delve into these spaces for the sake of operating in them or for whatever reasons one might want to. In this extract we present a technique to not only explore and uncover these very enclosed spaces but employ a system by making use of the contemporary technologies which measures the distances of the whole space with respect to a pivot point. The contemporary technologies used are cheap and provide an open source solution so as to allow improvements and enhancements as and when needed in the near future. The pivot point is a robot, maneuverable from a distance by a person.

As far as the technologies are concerned, we focus primarily on embedded system integrated with necessary sensors. We use a widely known and used microcontroller-based kit Arduino (different variants).The job of maneuvering the robot is accomplished by the usage of an accelerometer based Hand mounted module (HMM). The primary sensor for measuring the distance of the enclosed space is the ultrasonic sensor. Having simple trigger and echo pins and simple transmission and reception based on the reflection principle, it is not only easy to understand the working but also program it. Thus, the all crucial measurement data obtained by the ultrasonic sensors are sent to the standalone system to process. Thereafter a mapped model is prepared that effectively presents a sort of a blueprint of the whole enclosed space in front of the user.

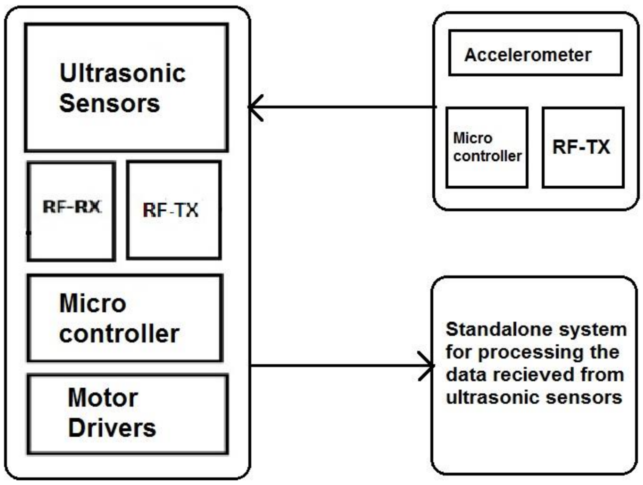

Fig -1: Overview of the proposed system

2. RELATED WORK

In the proposed system the major control which user has is maneuvering the robot to the required areas. Various navigation methods have been proposed. For example, gyroscopes have been used, but as rightly suggested by [1], when there is a tilt in the gyro, there is a change in output voltage. However, the voltage level resets back to zero if the tilt remains constant which is undesirable. Thus the gyro reports erroneous readings which are unfavorable for the robot movement. Hence to solve this problem accelerometer is preferred as it outputs steady duty cycles. It is also easier for the person to understand the movements.

The accelerometer data can be transmitted using Zigbee [2]. However, RF modules are preferred due to easy integration with Arduino and its lower cost.

3. MODULES

3.1 Hand mounted module (HMM)

The HMM is a component required to maneuver the robot. It comprises of a 3 axis accelerometer, ADXL335. The accelerometer gathers the readings from the X, Y and Z axis. However, we have considered the values of X and Y axis only due to 2 degrees of freedom. These axes record the tilt of the component (HMM) and gather corresponding readings. Hence the operability for the user becomes easy. The X-axis deals with turning the robot in right or left direction with respect to a pivot point. The pivot point is the left wheel of the robot for turning left and right wheel of the robot for turning it right. The Y-axis deals with moving the robot forward or backward. The ADXL335 is very sensitive and responds to any sorts of vibrations. Thus the values of the accelerometer have to be calibrated and the original values obtained by movements of the hand must be subtracted from a threshold value for every movement of the hand.

For X-axis values' calibration,

$$Xval = Xval - 330 \quad (1)$$

For Y-axis values' calibration,

$$Yval = Yval - 355 \quad (2)$$

Xval and Yval are variables used in order to represent original values obtained from the accelerometer for X and Y axis respectively. Based on trial and error methods, the values 330 and 355 are obtained as ideal threshold values of ADXL335 for X and Y axis respectively and are subtracted from the original values obtained from the accelerometer.

The obtained values are sent to the robot via a radio frequency transmitter-receiver module present on the robot.

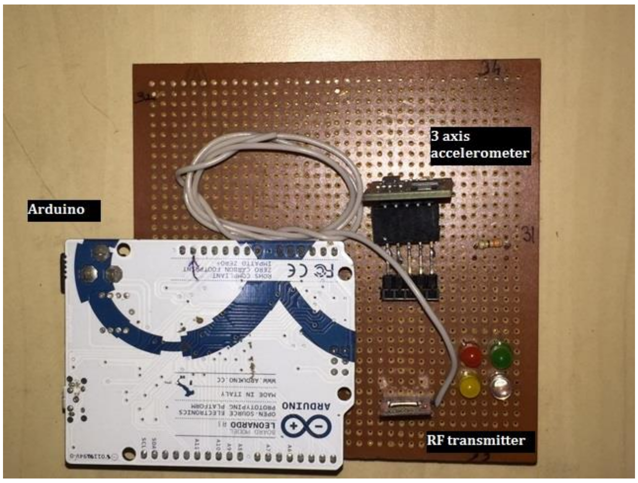

Fig -2: Hand Mounted Module(this will be put on a glove)

3.2 Robot

This is the core of the whole system. It is the maneuverable part which would enter into the inaccessible areas. The robot is fixed with various components which are responsible for data gathering and transmission.

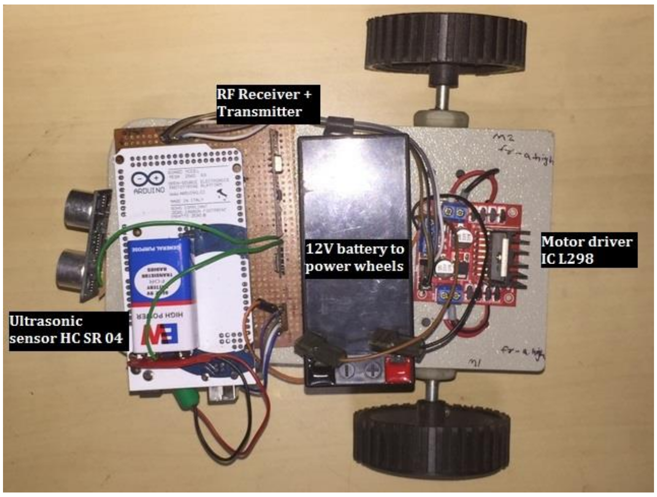

Fig -3: The actual Robot

3.2.1 Ultrasonic sensor (HC SR04)

An Ultrasonic sensor (HC-SR 04) works on the principle of SONAR. It emits an ultrasonic wave in one direction, and starts the timing when it is emitted. The ultrasonic waves spread in the air and return immediately when they encounter obstacles in the way. Then, the ultrasonic receiver stops the timing when it receives the reflected wave. As the velocity is 340m / s in the air, based on the timer record t, we can calculate the distance (s) between the obstacle and transmitter. [3]

The transmitter pin sends out eight cycle bursts of 40 kHz and detects whether there is a pulse signal back. The time for which the received signal is obtained (high level time) is measured and using the following formula the distance is calculated:

Distance = (high level time * velocity of sound (340 m/s)) / 2

The sensor has a range of 400cm. This is enough for scaled down applications in an enclosed space. This calculated distance is necessary as the mapping of whole area is done based on this very data.

3.2.2 Radio Frequency module (434 MHz)

The communication process between the modules is carried out via a RF transmitter and receiver. This RF module comprises of an RF Transmitter and an RF Receiver. The transmitter/receiver (Tx/Rx) pair operates at a frequency of 434 MHz. An RF transmitter receives serial data and transmits it wirelessly through RF through its antenna. The transmission occurs at the rate of 1Kbps - 10Kbps.The transmitted data is received by an RF receiver operating at the same frequency as that of the transmitter. [5]

The accelerometer data is transmitted via Radio waves through this module's transmitter to the Arduino on robot. On the other hand, the data collected by the ultrasonic sensors is also transmitted via another RF transmitter to the Arduino present at the user work station.

Why is RF module used over Infrared?

Wireless communication is the key for transferring the data seamlessly and in a hassle free manner. The signals propagating from the RF transmitter can travel through larger distances making it appropriate for long range applications. Also, Infrared operates in line of sight mode. Hence an obstruction causes interference in communication for Infrared modules. Next, the RF transmission is more strong and reliable than IR. The specific frequency used by RF, which unlike IR, doesn't get much interference.

3.2.3 Motor driver IC (L298)

The robot is attached to 2 DC motors which rotate two separate wheels. The microprocessors operate at low voltages and require a small amount of current. However, the motors require relatively higher voltages and current. Thus current cannot be supplied to the motors from the microprocessor. Hence an L298 motor driver IC is used. The IC also facilitates movement of the DC motor in clockwise and anticlockwise directions as it reverses the polarity.

3.3User workstation

The ultrasonic sensors present on the robot are responsible for calculating the distance of the nearest objects, obstacles, walls etc. This gathered data is then transferred to the user workstation. The user workstation is nothing but a Personal computer connected (via USB) to a module having an Arduino and a radio frequency receiver. The PC should have Processing Development Environment (PDE) installed on it. [6] This IDE is required to represent all the data obtained from ultrasonic sensors graphically

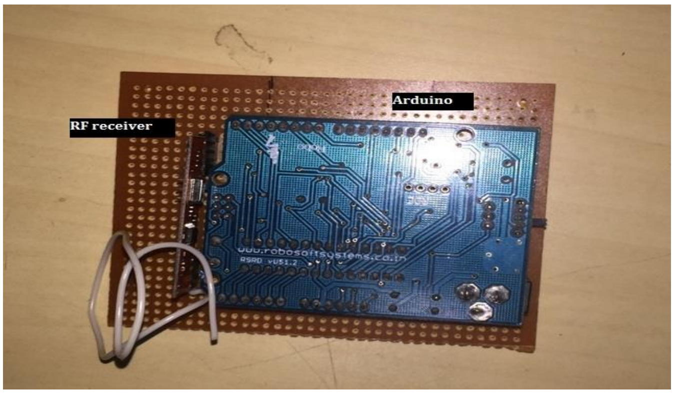

Fig -4: User workstation module

4. MAPPING

The primary input for mapping the environment is the data obtained from ultrasonic sensors. The distances obtained from these ultrasonic sensors are real time. Thus a continuous input stream is obtained and transmitted to the user workstation.

Here, serial communication ports play an important role. The obtained data is passed to the Serial monitor of the Arduino. Hence, we have to initially identify the COM port to which the Arduino is connected. This port name is passed to a sketch running on the workstation where the PDE is present. It reads all the incoming data on the Arduino. This port is the primary link between the Arduino and the PDE.

5. CONCLUSIONS

The system has been intended to be implemented in various domains of public and private sectors. Being cost effective and easy to understand it will reach out to more people. The main intention behind implementing this system is accessing the inaccessible areas to create its blueprint. The system mentioned in this paper is a scaled down concept. Using appropriate resources and enhancements it can be implemented at an industry level. Even though this is very primitive technology, it could be an effective solution for the military personnel to discover the area without risking human's lives. Enhancements like installing infrared cameras to detect life or making the robot more durable and penetrable based on the terrain, could be a step forward in this very system. Other applications could be measuring the spaces in caves or dungeons for mining purposes. This would help the miners to determine whether the area is worth mining or not and also test the soil samples (using appropriate sensors if need be) and enhance it further according to the need. This would save time and money altogether.

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