Design and Development of Sonar Based Autonomous Robot for Localization and Mapping for Potentially Unsafe Areas

Sukhada Lathkar[1] Prof. S.P. Karmore[2]
[1]Student [2]Assistant Professor
[1,2]Department of Computer Science & Engineering
[1,2]G. H. Raisoni College of Engineering Nagpur

Abstract— Designing of autonomous robot for exploration of unknown areas requires study of various branches, such as giving intelligence to robot, to make itself organizing embedded system. This paper proposes design of intelligent autonomous robot for inspection of potentially unsafe areas. The important function for exploration of area is dimension measurement and mapping. Also, considering safety, there is need of inspection of some places like caves for mining applications, without intervention of human workers. It also aims at graphical representation of scaled down outline model of actual space in which robot is allowed to move. The serial interface with the central system, allows central system to control robot. This system can also be used for multiple objectives such as displaying exact dimensions of any enclosure. The significant component used to implement the autonomous robot is ultrasonic sensor.

Key words: UART/Serial Communication, Ultrasonic Sensor, Mapping

I. Introduction

Some locations are difficult to imagine, because of issues related to safety, instability. E.g. caves. In applications such as mining, inspection of area is needed and most of the locations are not known priori. Some of the locations may contain toxic gases, which make it hazardous for human beings to go and inspect. This paper proposes to develop an autonomous robot for exploration of such areas. The autonomous robot is allowed to move freely in space like tunnel. It is advantaged with path finding and edge detection. Ultrasonic sensors are used to take dimensions of space surrounding a robot. Ultrasonic sensors are of major importance in distance measurement. Although the use of camera for area inspection is easier, insufficient light conditions in many areas make it ineffective. Hence sensors are used. Ultrasonic sensors measure distance of entity straight ahead by using time of flight between transmission and reception.

An autonomous robot based device is develop\ed, which will be tracked and mapped by the PC, which will run control software that operates this device, and graphical modeling software that creates an approximate scaled down graphical representation. Representation of the environment in real time, is possible due to the interface with central system, with the help of which good quality map is built. This helps to better understand and study unknown locations especially for potentially unsafe (un-stable) locations. The device is also be capable of calculating areas of closed encloses like, rectangular shaped object or room etc.

II. Basic Sonar

SONAR is the short form or acronym for Sound Navigation and Ranging. Sonar technology is similar to other technologies such as: RADAR which stands for Radio Detection and Ranging or LIDAR for Light Detection and Ranging. In that light was used to sense the other object, also in radar radio waves are used but in sonar instead of light or radio waves ultrasound or ultrasonic waves are used. The word Sonar is an American term first used in World War II; which is an abbreviation for Sound, Navigation and Ranging. The British call Sonar, ASDICS, which means Anti-Submarine Detection Investigation Committee. Later developments of Sonar include the echo sounder, depth detection etc.

Sonar is a system that uses transmitted and reflected waves to measure the distances of underwater objects and features. It has been used for submarine and mine detection, communication at ocean. The Sonar device sends out a sound wave and then waits for returning echoes, the sound data is processed by the human operators or being displayed on a monitor. And all these things are possible just because of ultrasound.

There are two types of Sonar:

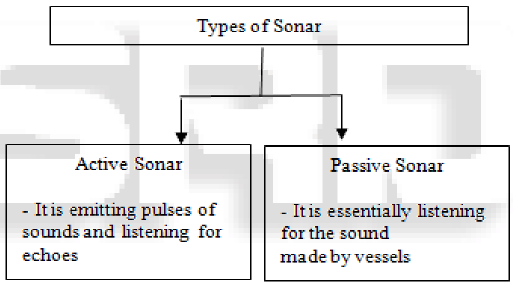

Fig. 1: Types of Sonar

III. Literature Survey

The very first Sonar type listening device was invented by Lewis Nixon in 1906, as a way of detecting icebergs. By the year 1918, both the countries Britain and the U.S. had constructed active systems, in active Sonar first ultrasonic wave is sent with the help of transmitter then this wave strikes to the desired object reflects from that object come to receiver and then decision is made according to the received waves. In 1915, the first sonar type device for detecting submarines was invented by Paul Langévin which was called "echo location to detect submarines", and used the piezoelectric properties of the quartz.

Kok Seng Chong[2] proposed Sonar Based Map Building for a Mobile Robot. It describes a robot equipped with sonar sensor array, called Werrimbi. The robot maps its position with respect to its environment. It is developed for the purpose of identifying indoor landmarks, or corners etc. It uses distinct sonar observations and geometric calculations for clear identification of planes. Geometric approach used here, is Julier-Uhlmann Kalman Filter (JUKF). It avoids calculation of Jacobian matrix for covariance, a method used for edge detection.

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Jong-Hwan Lim, Wonpil Yu, Yu-Cheol Lee, Dong-Woo Cho and Wan-Kyun Chung [3] have proposed localization of mobile robot using grid method. They have proposed to find position of a mobile robot with respect to its environment and have suggested use of Extended Kalman Filter. It does not depend on exact geometric representation of environment and hence emphasis is given on reduction of computer resources. The grids themselves are used as marker. The mobile robot is able to guess its position continuously, but the landmark is obtained by identification of grids that are obtained by intersection of two footprint beams from sensors. Extensive vector and geometric calculations are presented in this paper, for robot localization.

Xuelian Xu, Shigang Cui, Genghuang Yang, Bingfeng Wang and Li Zhao[4] [3]have proposed probabilistic grid arrangement for mobile robot map building. Efficiency along with accuracy is achieved by Baysian probability used for position estimate and map building. It is dependent on probability that a particular grid is occupied by position of robot. Probabilities of empty space around robot and occupied space are used to decide grid arrangement. This paper proposes simulation for grid based map building.

Kyoungmin Lee, Se-Jin Lee and Jae-Bok [5] Song have proposed a way for a robot to trace itself in indoor locality. According to this paper, ultrasonic sensors lack in representing a realistic representation of space around robot and hence collaborating their information with sonar data makes it more rational. This paper uses the sonar sensors to avoid specular reflections caused by firing of ultrasonic waves. The frequency of incorrect readings of distances using ultrasonic sensors is significantly high; to avoids this use of multiple sonar data sets and geometric reliability is suggested in this paper.

Pattern Anal machine intell discussed about differentiation of sonar reflections from corners and planes by employing an intelligent sensor. A system is explained which contains multi pulse/echo-ranging system that gives difference between corner and plane reflectors by exploring the physical attributes propagation of sound. The amplitudes and ranges of signals reflected from corners, for the different pairs of transmitter and receiver are processed to decide whether the object is a plane or a 90 degree corner. Also, the angle between the reflector and transducer can be measured. Amplitude of reflected signal using as functions angle of inclination n can be helpful for the differentiation algorithm. A system that uses two Polaroid transducers is explained that correctly differentiates between corners and planes for angles of inclinations within ±10° of the orientation of transducer. This system is extended to a multi transducer array that lets the system to operate over wide range. An analysis is performed to estimate comparing processing effort accuracy.

IV. PROPOSED PLAN

This paper proposes use of ultrasonic sensors for space measurement. The basic idea of distance measurement using sonar technique is used here for dimension measurement of any enclosure and exploration of unknown places. Ultrasonic sensors use time of flight as a parameter for measuring exact distance between transmitter and receiver. Multi-mode ultrasonic sensors have transmitter and receiver at the same end. In this system, these sensors are placed on motors so that they can be rotated and will be able to take multiple readings across any enclosure. By application of geometric methods, dimensions of any enclosure can be calculated and displayed on screen.

Ultrasonic SONAR module computes distance of the entity straight ahead. It is planned to fix this ultrasonic module on a panning capable fixture. Hence allows the device to rotate 360 degrees around the room or enclosure. While doing so, the ultrasonic waves are fired multiple times at consistent periodic intervals, thus collecting multiple readings of the walls or obstacles of the room or caves. This data is used for graphical modeling of the area.

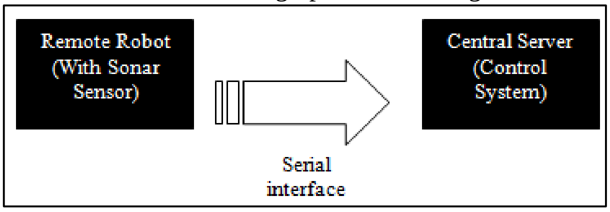

Fig. 2: Proposed System Model

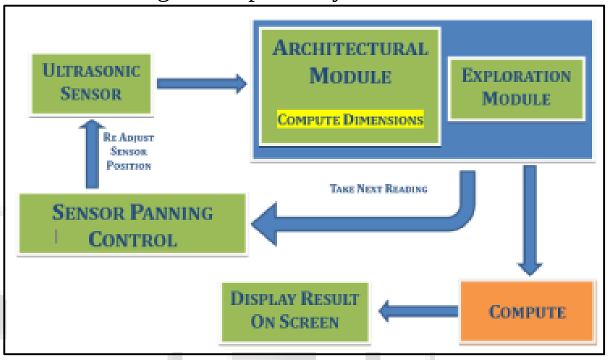

Fig. 3: Block Diagram

V. METHODOLOGY

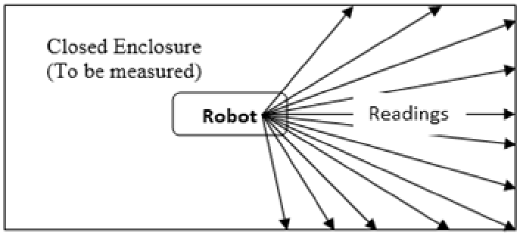

Fig. 4: System working principal (architectural)

The operation can be explained in two modes: 1. Architectural mode. 2. Exploration mode. In architectural mode, shown in fig 4, ultrasonic sensors are allowed to rotate through 360 degrees, with step angles of either of 10, 15 or 20 degrees. The readings thus collected are then processed to compute the length and breadth of the enclosure. The system is intended to perform multiple tasks so that it can be used to fulfill multiple objectives, like to compute area of enclosed area like room etc. Along with the device, a control software module can be created that runs on the PC and controls i.e. operates the device. This is the software that commands the module to fire up, rotate and take the multiple readings. This information is then used by the graphical modeling software to create an approximate representation of the room, or to virtually create 2D model with minimum error. and also for unknown location exploration.

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In case of unknown places like mines or caves, exploration mode is active. This device is allowed to move freely in space estimating path on its own and provide calculated information to a central system. Ultrasonic sensor is used for obstacle detection i.e. if it detects obstacle within its range which is 10cm, it turns left or right, determining its own path based on distance calculated, to avoid collision, otherwise it continues its straight path. This is interfaced to central system serially, which can also be replaced by wireless module. UART i.e. serial communication is used to interface module to central system. This calculated information is processed at the central system and scaled down version of the physical environment is displayed. Real time representation of navigation of robot is performed, in this mode.

VI. HARDWARE IMPLEMENTATION

Components Used for Implementation:

- Ultrasonic Sensor : CR4400
- Motor Driver : L293d
- 16*2 Lcd Display
- Atmel 89S52

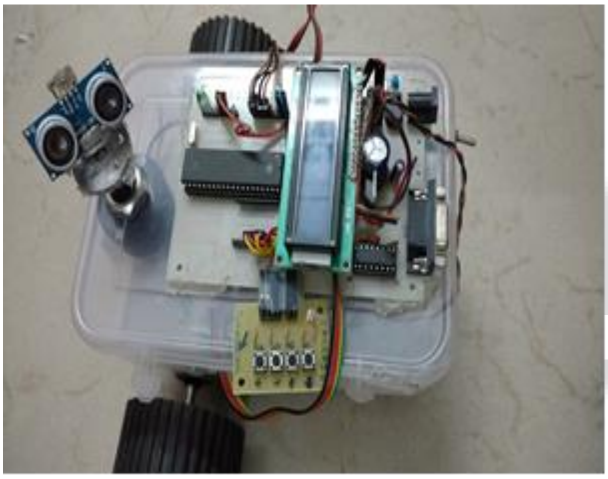

Fig. 5: Robot equipped with ultrasonic sensor

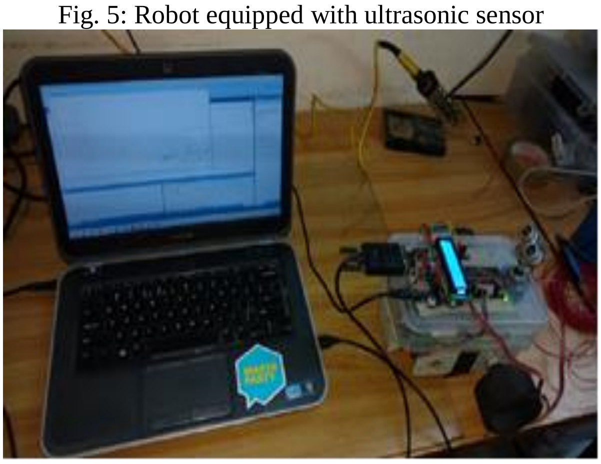

Fig. 6: Robot interfaced with central system

A. *Flowchart:*

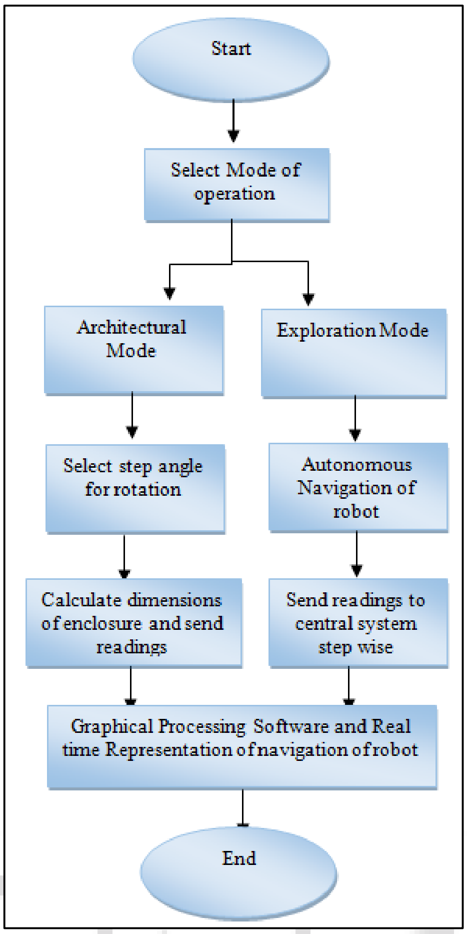

Fig. 7: Flowchart

VII. RESULTS

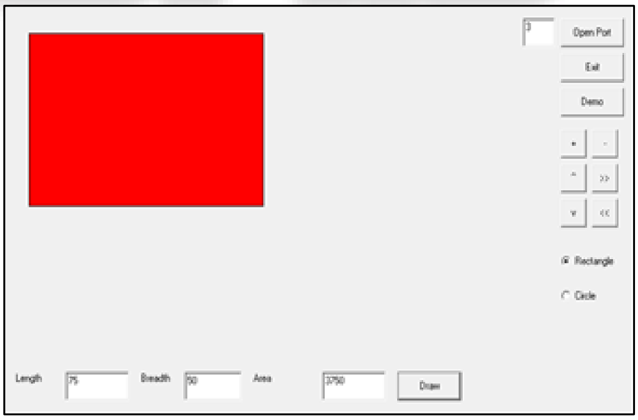

Fig 8: application of proposed algorithm

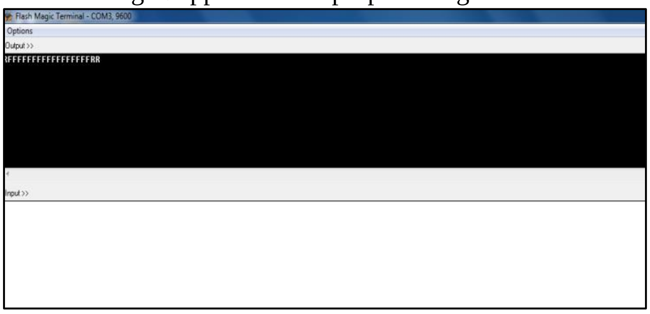

Fig. 9: Readings received after autonomous navigation

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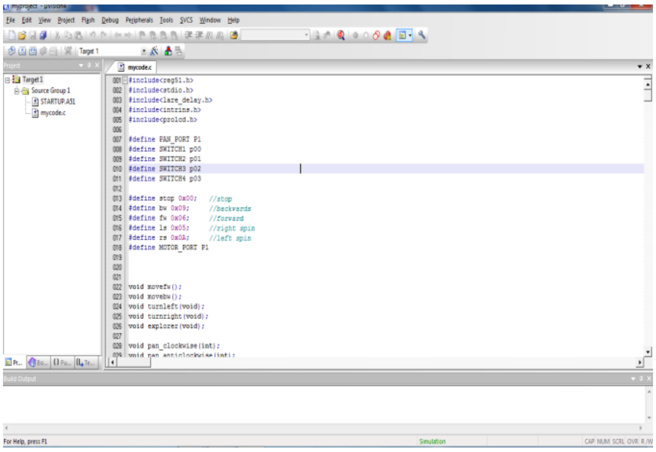

Fig. 10: Embedded C code

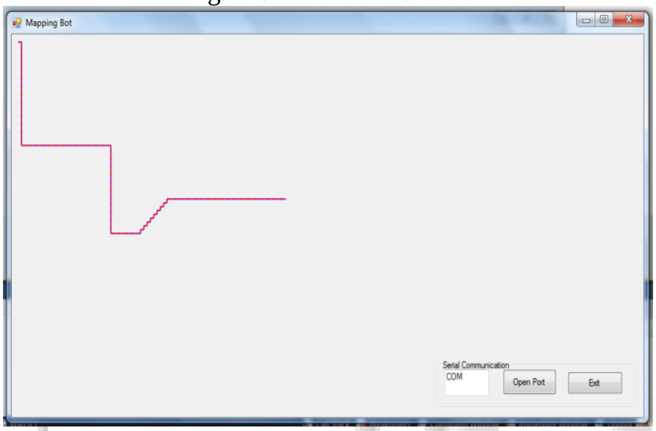

Fig. 11: graphical processing software (Real time mapping of Robot)

VIII. CONCLUSION

It is found that ultrasonic sensors are preferred mostly for grid mapping techniques, although their frequency of correct distance measurement is not that high. It can be reduced by various methods. Most of the work in mapping is done for finding current position of mobile robot with respect to its indoor environment.

Ultrasonic sensors can be used to estimate environment around autonomous robot and this information can be used for generating scaled down version of it. It will be useful for areas which are unsafe and inspection of such areas can be made possible without intervention of human beings.

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