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Acoustic Source Localization and Navigation Robot

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Abstract: ***There are many areas of using acoustic localization technique. This technique is not only to locate a person, who is talking, but also could find them when they are in need. This can also be implemented in wild life photography, to locate the animals. In this technique, three microphones have been employed in the form of equilateral triangular pattern ,in which all these microphones detects the same sound .Using this information and trigonometric formula, the direction of sound has been calculated .The main objective of this project is calculate how precisely the position of sound source can be calculated using the technique mentioned above, while varying the distance and angle of the source .In order to explore the capabilities of TDOA and test the obtainable accuracy, a demonstrator was built. On a complete car chassis, three microphones were mounted and used to determine the direction towards the sound source. Thereafter, the robot rotated towards the sound source with an accelerator, keeping track of how much it had rotated. After this movement a comparison was made between the robot's direction and the actual direction of the sound source. Finally an ultrasonic sensor was placed on the robot for obstacle detection whilst tracking the sound. The vehicle travelled straight forward until the ultrasonic sensor deemed that an object was too close. The results show that an increased distance yields a more accurate sound localization and that there are some angles in which the sound localization functioned better.***

Keywords: TDOA, Two Dimension, Integrated Development Environment, Inertial Measurement Unit, Pulse Width Modulation.

I. INTRODUCTION

Nowadays sound localization is used in various sorts of applications. For instance, sound localization is used in humanoid robots to determine where a person is located when assistance is required. The sound localization concept can also be used to get the direction of an animal's position while hunting and wild life photography. The focus of this study will lay in how an Arduino microcontroller and three microphones can be used to locate the source of a sound. Difference in arrival time of the sound to the microphones placed in different locations on the vehicle, the direction to the sound source can be calculated. This sound localization concept is called Time Difference Of Arrival (TDOA).

The objective of this project is to investigate whether an Arduino microcontroller can sufficiently interpret a sound source, calculate the data and exhibit the correct output to the motors so that a vehicle can steer and go to the position of the sound source. This will be analyzed while distances and angles towards the sound source are varied. The reason for using an Arduino microcontroller is due to its simplicity and that it has sufficient amount of pins for this project.

The scope of this project is be to construct a land robot that can track the direction of a sound source with three microphones. Thereafter the robot will move towards the sound source and travel forward. There are several different factors taken into account. One of these factors is that there is an ultrasonic sensor that will detect objects that lay in the path of the robot, when it travels forward towards the sound source. The robot avoids the object and adjust its path accordingly to continue its route towards the sound source, instead of slowing down to a halt in front of the object. In addition, the demonstrator is able to locate sounds in a 360°section. This area is defined as the whole right side of the demonstrator. On a complete two wheel chassis, three microphones are mounted. These microphones were placed in triangular shape. The reasoning behind the placements of the microphones will be described further in the chapter. Initially, let us assume that one microphones is placed on front and the rest of microphones are placed on rear.

When arduino is given with power supply, the arduino timer begins. When sound is made, and detected by these microphones, the time of arrival is recorded and the difference in time of arrival is calculated on basis of arduino timing. As already mentioned about the use of ultrasonic sensor, which is meant for obstacle detection and navigation, an accelerometer is also used to detect the direction of the sound source and compare the direction of the sound source to the robot's direction of turn in degree. The motor cannot be directly connected to the arduino, as motor requires minimum of 2A of power, whereas the arduino can only sufficiently produce 0.2A of power. Thus, the motor is connected to the arduino through ICLM293d Motor Driven Module. Instead of ICLM293d Motor Driven Module, High side driver and Power MOSFET Motor Driver which produces

a power of 80A could have also been employed, but a four wheel chassis requires eight transistor modules, the IC LM293d Motor Driven Module has been employed. Thus on detecting the direction of sound, the robot moves accordingly. A microphone array, consists of three microphones, is used to receive sound signals.

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If that signal is received, the Time Delay Of Arrival (TDOA) among various microphones is used to estimate the direction of the sound source.

II. BASIC TDOA CONCEPT

Sound localization refers to a listener's or system's ability to identify the location the origin of a detected sound in direction and distance from the receivers. The design of accurate Sound Source Localization (SSL) systems is an active research area. An accurate SSL system estimates the direction of the sound source based on signals received by array of microphone receivers,. The direction of the sound source can be obtained by estimating the time delay of arrival between the signals captured by individual microphones. In this research, time and spectral domains analysis of the each signals received by each microphone, is used to calculate the time delay between these signals.

SSL systems have been used in defence purposes to localize gunfire, bombs' sounds, jet sounds and military vehicle tracking. They can also be used by police departments for gunfire localization and object movement tracking

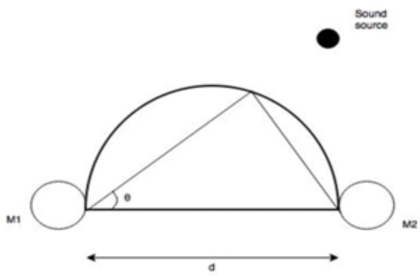

Fig.1 TDOA Diagram

In this project, TDOA is used to calculate the angle of origination of sound as seen from the demonstrator's perspective. Locating a sound source can be done by recording the different times with which a sound wave reaches the microphones. If the distance between the microphones is known as well as the TDOA between them, the angle which the sound came from can be calculated with trigonometry assuming sound propagates through space in a spherical manner with constant speed.

the angle θ can be calculated as ,

$$\theta = \arccos(\Delta t * v / d)$$

Where,

(i) Δt = the time difference,
(ii) v = the speed of sound, and
(iii) d = the distance between the microphones

Here, the microphone that captures sound at last is kept as reference to find the direction of sound, where it is considered that the sound source is opposite to the direction of the reference microphone. The "d", is the distance between the rests of the microphone, apart from the reference microphone and "Δt" is the difference in time delay between the two microphones that excludes the reference microphone. "v" is the velocity of the sound in air, that is approximately 343 m/s.

III. RESEARCH METHODOLOGY AND RESULT DISCUSSION

In this paper, the microphones arrays used are in numbers of three. The foremost important thing is to achieve localization in 360°,and this is the reason for reducing the number of microphones arrays. The waves are assumed to be in spherical shape. As already mentioned, the sound is captured initially, by microphones arrays. The time of arrival of sound, to the individual microphone varies. Thus, the Time Difference Of Arrival(TDOA) is calculated, and given to the arduino, where the datum are further processed and given to navigation part, which is includes ICLM 293d Driver module, Ultrasonic sensor, MPU 6050 Accelerometer and gyro scope, and DC Motor.

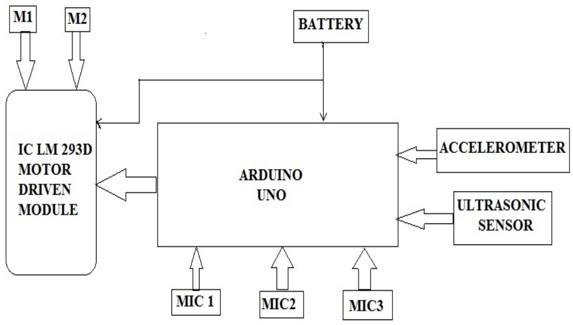

Fig.2 Functional Diagram

Arduino: In this section the hardware used to build the demonstrator will be described further. All of the electronic components used in this study are connected to the Arduino UNO. The Arduino UNO is a 8-bit microcontroller that has the ATmega328P as microprocessor which can be seen as the brain of the Arduino. It has 6 analog input pins for conversion to digital signal and 14 digital input output pins, out of which 6 enable a PWM signal. The Arduino IDE, or integrated development environment, is the software used to program the Arduino. This is an included software that is based on C/C++. Uploading of the program is done from the computer's USB port to the Arduino's USB B-type port. The Arduino UNO is an open source hardware and was used in this project based on its simplicity and the fact that it had sufficient amount of pins for the requirements. All of the controlled devices and microphones were connected to the Arduino.

Fig.3 Arduino UNO

Microphone: In the demonstrator two different types of microphones were used due to problems with ordering of parts. In total three microphones were mounted on the chassis in which one of these microphones was of model SEN-12642 with a built in amplifier. The threshold for when the first mentioned microphone detects sound can be adjusted by the usage of a resistor. A higher resistance implicates a lower threshold and lower resistance indicates a high threshold.

Fig.4 Microphone module

Wheel Chassis Castor: A two wheel metallic chassis with a caster wheel is used in this project for navigation part. The entire hardware parts used in this project are mounted on this chassis .12v DC motor each is used in the wheels. A 12v dry cell is used to power the chassis as well as to other components mounted on the chassis. To make the chassis move forward or backward, both the wheels has to rotate in the same direction. When the chassis has to make a turn, then only one of the wheels should rotate .To make a sharp turn, and then both should rotate at the opposite direction.

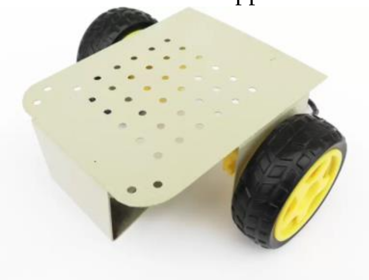

Fig.5 Two -wheel chassis with caster wheel

H-bridge: An H-bridge allows currents to go through components in either direction, allowing motors to be run in both ways. The use of an H-bridge also allows the use of an external power supply to the motors.The H-bridge used in the demonstrator is of model L293d Dual H-Bridge Motor Driven module. The H-bridge is designed for running two different motors simultaneously. Since the demonstrator will have 4 motors in total, one for each wheel, and only one H-bridge is used, it is necessary to connect two DC-motors parallel on each side of the H-bridge.

DC Motor: The acronym DC in DC motor stands for direct current. This implicates that a direct current is used to supply the motor with electricity. Commonly a DC motor consists of an odd number of poles and the ingoing current direction is what determines the rotational direction of the motor. To reverse the direction of the motor an H-bridge can be used. The smaller variants of DC motors usually comprises of a permanent magnet and poles. The poles are connected to the rotor that is made up of a coil to create a magnetic field when the motor rotates. This magnetic field changes direction when the motor rotates one cycle.

For propulsion of the demonstrator four DC motors with built-in gearboxes will be used, one for each of the four wheels. The DC motor used in this project is the DADG02S.

Fig.6 DC Motor

Ultrasonic Sensor: An optical sensor has a transmitter and receiver, whereas an ultrasonic sensor uses a single ultrasonic element for both emission and reception. In a reflective model ultrasonic sensor, a single oscillator emits and receives ultrasonic waves alternately. This enables miniaturization of the sensor head.

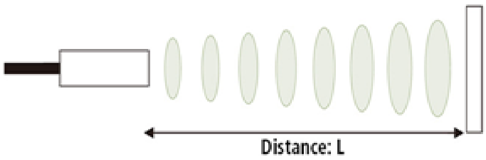

Fig.7 Distance measurement

The distance can be calculated with the following formula:

$$\text{Distance } L = 1/2 \times T \times C$$

Where L is the distance, T is the time between the emission and reception, and C is the speed of sound.

MPU6050: The MPU6050 is a Micro Electro-Mechanical Systems (MEMS) which consists of a 3-axis Accelerometer and 3-axis Gyroscope inside it. Here the yaw is considered for horizontal direction angle detection and movement.

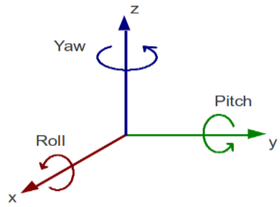

Fig.8 Yaw-Roll-Pitch diagram

IV. CONCLUSION

In this research, a microphone array based system has been designed and built to estimate the direction of sound sources of interest in the full scale of the horizontal plane and its accuracy was evaluated over the full range taking several parameters into consideration. The assumption of having sound waves parallel to each other when received by the microphones did not affect system accuracy except for very close sound sources to the microphone array. The designed system has an accuracy that increases as the distances among the microphones increase because the error estimation of TDOA is decreased. The change in sensitivity of the cosine-inverse function has been taken into consideration to always depend on the pair of microphones in the microphone array and that gives better accuracy for the system and it is one of the major points that resulted in the outstanding performance of the built system. In general, accuracy tends to increase as the sound source distance from the microphone array increases because the assumption of having parallel sound waves coming from sound source to microphone array will be closer to real directions. Improving the system to estimate the distance of sound source in addition to the direction to get a full scale accurate sound source localization system is one of the essential challenges.

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