# Navi-GATOR

Intelligent Machine Design Lab

Special Sensor Report

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# Introduction

Probably the most useful information in navigation is knowing the coordinate of the traversing object. However, this has been one of the biggest obstacles smaller robots have faced because the accuracy of the Global Positioning System is no greater than a few feet—and even this precision is accomplished by using the best (hence, most expensive) GPS receivers available on the market.

The problem with calculating position with wheel encoders is robot movement encounters significant slippage, which can additively amount to large errors after increased travel. When a small robot moves around, both the wheels and motors sometime uncontrollably slip—causing these inaccuracies. While this can be minimized by careful platform design and wheel placement, this will still cause inaccuracies which are far too great for practical coordinate calculation.

To attempt to solve this problem, I will be using a ground positioning system implemented with three external ultrasonic transmitters (analogous to satellites), and one local ultrasonic receiver (analogous to the GPS receiver) on board the robot. This system is based on the same principal used by the *Global Positioning System*—where time differences of pseudo-random pulses sent by each satellite are used to calculate 3-dimensional position. The special sensor that is going to be used here is 2-dimensional—simplifying the mathematics and complexity a great deal.

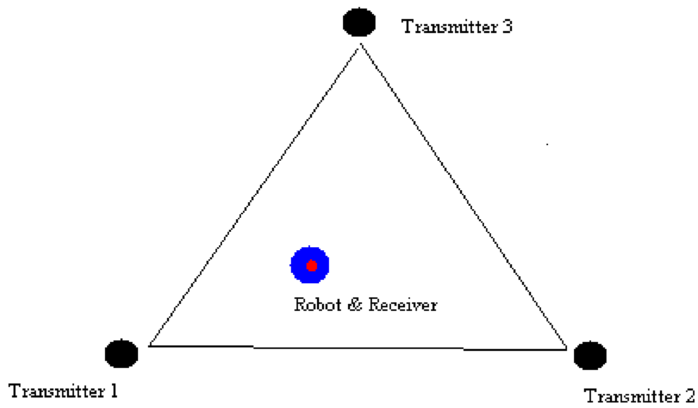
If successfully accomplished, several robots in proximity equipped with sonar receivers can use this system to accurately calculate position, because the functionality of the transmitters is robot independent.

# Availability

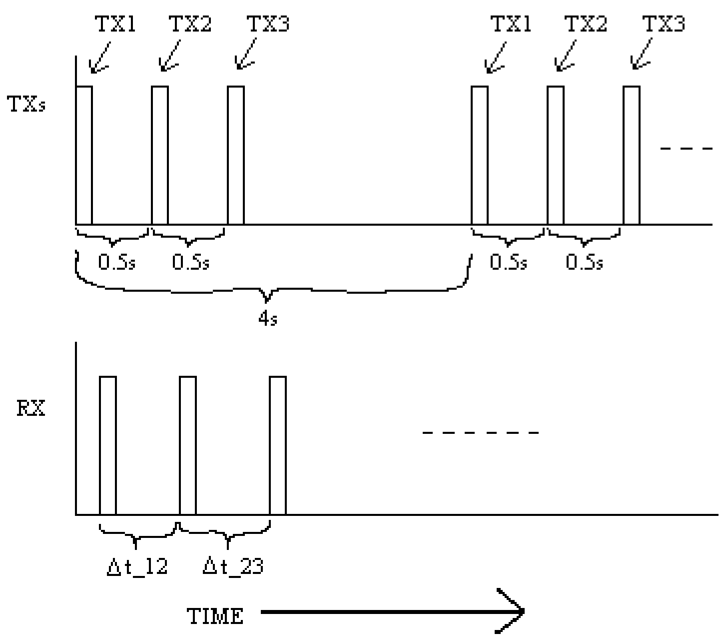
Unfortunately, I have not been able to find this complete sensor-system available for purchase. The only thing available is the schematic for the ultrasonic receiver circuit, available via the MIL website. Therefore, I have to design my own system. The core of this sensor-system is four 40kHz ultrasonic transducers—which are widely and cheaply available at surplus stores. Additionally, an Atmel microcontroller for the transmitters, and a filter and comparator for the receiver are used, which are both widely available. The filter used in the MIL circuit is a MAX266 active filter, which can only be obtained via the Maxim website at this time.

# How it Works

The following diagram shows the location of the sonar sensors, and grid-mapping technique:




The transmitters are arbitrarily placed in a equilateral triangle, with side length of 10 feet (for now). The robot will determine the distance away from each transmitter to calculate its current coordinate. Pulses by each transmitter will triggered at fixed intervals of 0.5s, with a period of 4s, as shown below.



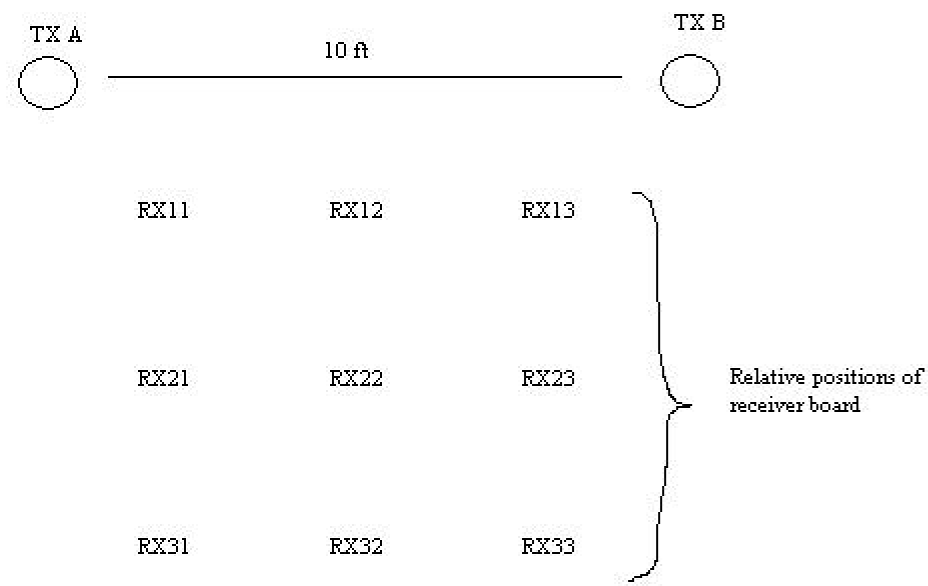

The receiver (robot) determines the time difference between each of the pulses to compute coordinate. The exact equations can be found in the Appendix of the final report.

The transmitters are generic (non-brand Taiwan manufactured) ultrasonic transducers with a frequency of 40kHz and a bandwidth of 1kHz.  The pulse generation of these transducers are done by 40kHz oscillator circuits consisting of 40kHz crystals and inverters.  Each oscillator is located at all of the transmitting stations.  The 40kHz square-waves are fed in through a high-power buffers with an enable inputs which are capable of driving ultrasonic transducers.  The enables of each transmitting station are triggered on for a small time duration separately at different known times by the master transmitting station which the controller, Atmel's ATTINY26, is located.  The previous figure shows an illustration of the RX and TX sides of the system.

## Preliminary Data

To pre-determine the accuracy of this system, two transmitting stations were placed 10 feet apart—named transmitters A and B, and a receiving station was placed at 9 different measured locations away from the transmitters, and time readings were captured via an Atmel ATMEGA8 using its input capture port and timer 1. The ATMEGA8 measured the time difference between the signals—which can be compared to the theoretical time difference for accuracy calculation.

The following figure shows the relative placement of the transmitters and the different test spots for the receiver board.

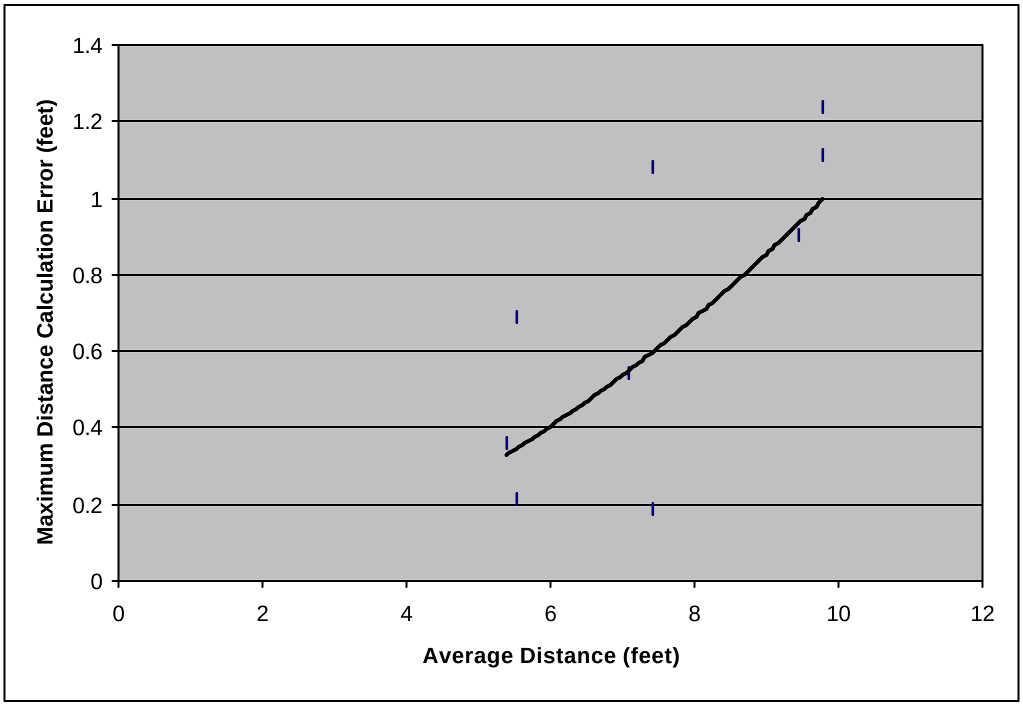



The receiver spots are located exactly at the following coordinates (taking TX A as 0,0 and y-axis inverted):

| | | |
|---|---|---|
| RX11 = (2,2) | RX12 = (5,2) | RX13 = (8,2) |
| RX21 = (2,5) | RX22 = (5,5) | RX23 = (8,5) |
| RX31 = (2,8) | RX32 = (5,8) | RX33 = (8,8) |

The speed of the ultrasonic transducer was assumed to be 1130ft/s (room temperature and humidity deviation is insignificant).

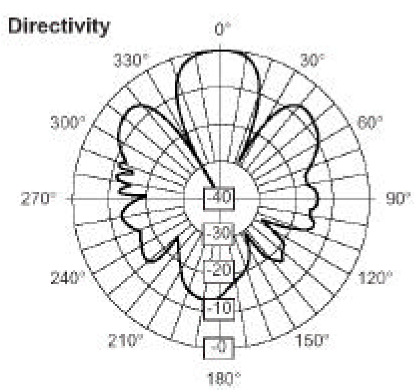
Expected time delay values were computed and were compared to experimental values. These values were then compared to determine the maximum computed distance error possible. The following table shows the relationship of average distance between transmitters and distance calculation error.

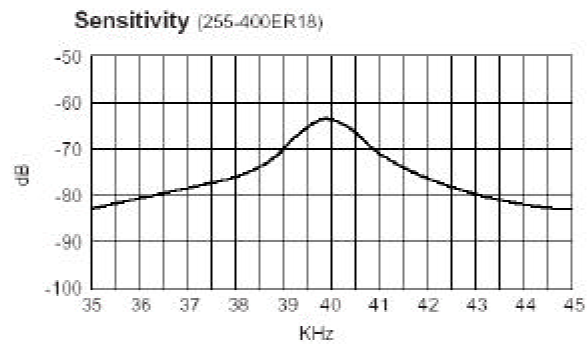



As can be viewed from the graph, the further the transmitters are from the robot, the worse the calculation will be. Thus, it is advantageous to keep the transmitting triangle small. Therefore, I am choosing to keep the side length of the equilateral transmitting to 10 feet, taking note of that fact if I plan to make it bigger in the future, it will come at the cost of less accuracy.

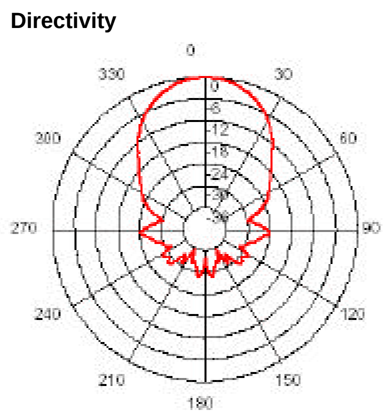
For reference purposes (perhaps for future modification of shape of actual TX-TX-TX trio), the directivity and sensitivity of the RX and TX ultrasonic transmitters are shown below (extracted from their respective data sheets)*:

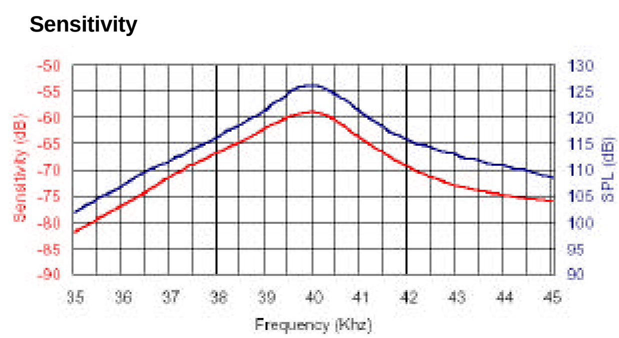
<u>Receiving Unit</u>






Transmitting Unit




Experimental Results

The following were achieved by testing one transmitter and the receiver:

Voltage: 9 V
Frequency: 40 kHz

Maximum detecting distance (TX facing directly at RX): Over 20 feet
Maximum detecting distance (TX facing 30 degrees off of RX): ~ 15 feet

These tests were done to make sure the transmitting signal will always be detectable by the receiver in the triangle. Since 15 feet is almost twice the furthest possible distance the robot can be from any transmitter, this is well within range.

# Conclusion

This sensor system seems to be a more accurate method of getting position. The robot that will attempt to use this system will demonstrate the effectiveness of knowing this information. Using coordinates to move, unlike random-movement, a robot can traverse a given area with nearly 100% efficiently. This robot will test the real-world accuracy of this system. One final note is that these tests were performed on a stationary object (with no motors connected to ground, etc.). Motors need to be optically isolated to prevent noise from disturbing signal detection. However, be cautious of directivity… this was the problem in my robot, where the receiving sonar was positioned so it was “looking” exactly upwards, while the transmitting stations were positioned looking at the robot on the same ground level as the robot—this prevented my robot from obtaining coordinates accurately.