

**Invisible Robotics Bumper**

**Summary and Background**

Summary:

This project for the Invisible Robotics Bumper (iRoboBumper) aims to create a SONAR-based obstacle detection system for robotics platforms that provides a full 360 degree horizontal coverage while maximizing the update rate. The self-contained unit includes a base with screw holes for mounting onto a robot chassis, is powered by four AA batteries, and communicates with the host robotics system wirelessly.



Background:

As humans we do not generally give much thought to how our brains process the data coming from our senses to provide us with information. When we walk towards a door to leave our house, we do not consciously think, “I am 10 feet from the door; now I am 6 feet from the door; now I am 2 feet from the door; stop!” However, our brains are using data from our eyes to approximate distance, as well as a learned understanding of how far we need to be from the door in order to reach the doorknob. Even this statement over simplifies the processes that are at work though, as the approximation of distance to the door includes such processes as depth perception from the parallax between our two eyes and many monocular cues that aid in estimating distance. Thus, emulating this behavior in the actual way that humans sense their surroundings is an extremely challenging problem.

If however, you want to emulate human behavior in a robotics platform, you need to employ sensors capable of providing the raw data that can be used to calculate the same type of information. Our eyes operate in the visual light spectrum (i.e. ~ 400-700nm) and our brains essentially use complex algorithms to estimate distance. Luckily, there are simpler ways to determine distance using electronics than using a camera and image processing to determine the distance to objects. One technique is with SOund Navigation And Ranging (i.e SONAR), a system that emits pulses of sound and listens for echoes as they reflect off of objects. The distance to the object can be determined by using the time it takes for these pulses to reach an object and reflect back.

**System Overview**

Ultrasonic sensors operate on the "[time of flight](http://en.wikipedia.org/wiki/Time_of_flight)" principal to determine distance. One example is the [PING)))TM Ultrasonic Distance Sensor](http://www.mouser.com/access/?pn=%20619-28015), made by [Parallax Inc.](http://www.mouser.com/parallax/)  This sensor module has all of the circuitry needed to emit 40 kHz sound waves and listen for the echoes (i.e. reflected pulses). It outputs a 5-V [Transistor-Transistor Logic](http://en.wikipedia.org/wiki/Transistor%E2%80%93transistor_logic) (TTL) signal, which has a high duration that can be used to determine the range to the object that reflected the pulses of sound. The range of the PING))) sensor extends out to approximately 3 meters, but varies based on the reflectivity of the obstacle. Figure 1 shows a depiction of the PING))) sensor and interface.

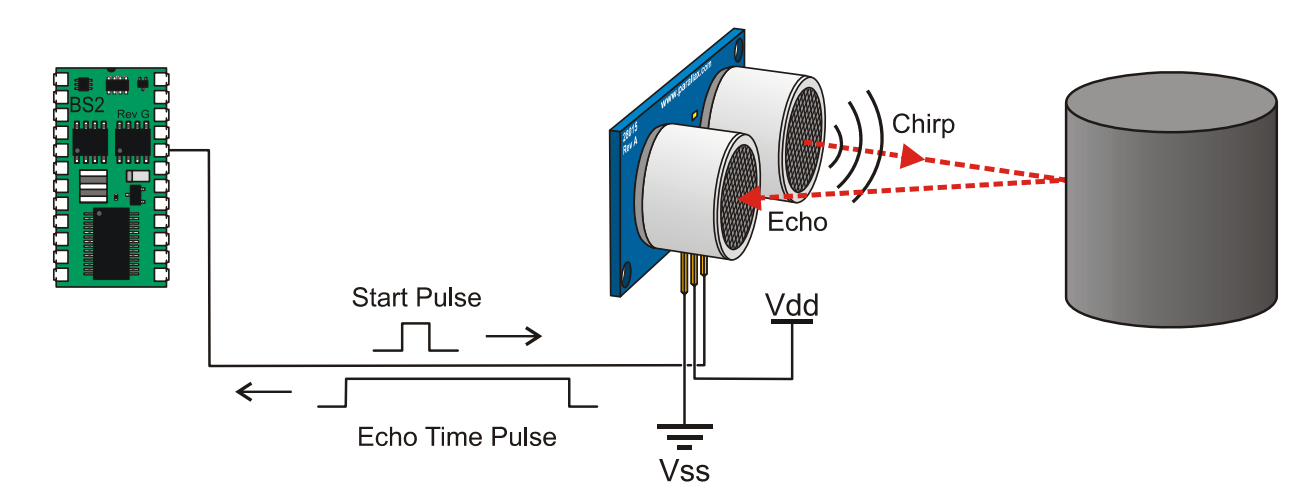


Figure 2: PING))) Sensor and interface. By measuring the echo pulse width, the distance to the target can be easily calculated. (Source: [PING))) Sensor Guide](http://www.mouser.com/ds/2/321/28015-PING-Sensor-Product-Guide-v2.0-461050.pdf))

The PING)))TM sensor has a field of view (FOV) of roughly 40 degrees (+/- 20 degrees from the direction it is facing) and is capable of 50 readings per second. Since we want a full 360 degree FOV and most ground based hobby robotic platforms do not need a 50Hz update rate, we can pan the PING)))TM sensor while continuously taking measurements to tradeoff a slower sampling rate at a given angle for increased FOV. Thus, the equations for these tradeoffs are as follows:

Same Angle Update Rate (Hz) = Pan Rate (degrees/sec) / 360 (degrees)

Sample Spacing (degrees) = Pan Rate (degrees/sec) / 50 (samples/sec)

For example, if we pan the PING)))TM sensor 360 degrees every 2 seconds this gives use a pan rate of 180 degrees per second. From the above equations, we get a Same Angle Update Rate of 0.5 Hz and a Sample Spacing of 3.6 degrees. This means, given a stationary base, we will sample the same object every 2 seconds and that the system pans 3.6 degrees between readings.

However, if we pan 360 degrees every second we obtain a same angle update rate of 1 Hz and a sample spacing of 7.2 degrees. This is a tradeoff between angular resolution and update rate. However, we could utilize multiple PING)))TM sensors pointed in opposite directions to effectively double (2 sensors), triple (3 sensors), or more the Same Angle Update Rate at a given pan rate. For this project, two PING)))TM sensors facing in opposite directions will be used to double the Same Angle Update Rate. In addition, we will also aim for a continuous pan rate in the 180-360 degrees per second range.

The distance to an obstacle from the PING)))TM sensor is calculated by multiplying the duration that the PING)))TM sensor drives the signal high by the speed of sound in air that is measurable by the sensor. The datasheet for the sensor gives the speed of sound in air as:

Cair = 331.5 + (0.6 \* TC) meter/sec

where TC is the temperature in degrees Celsius of the air. This temperature component can account for up to a 12 percent error over the 0 to 70 degree Celsius operating range of the sensor. In order to minimize this, a temperature sensor will be added to the system and used to calculate the speed of sound in air per the equation above. A Texas Instruments LMT87 temperature sensor (Figure 2) was selected as it can operate off the same 5-V supply needed by the PING)))TM sensor and it has a single analog output that varies almost linearly with respect to its temperature.

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