**Ultrasonic Sensor (HC-SR04) :**

For the working of ultrasonic sensors: refer to the attached manual

Pre 1st october work

Observations:

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| 1. | Range | 27 inches (2.25 feet) |
| 2. | Field of View | Vertical: 30 degrees  Horizontal: 53 degrees |
| 3. | Angle Test | Sensor starts losing signals when the angle Q shown in the figure exceeds 20 degrees .  These values hold for objects with flat surface. |
| 4. | Material Test | Test Cases:  1) Flat plastic surface:  The values given by the sensors are accurate (measured by scale). Hence error can be considered as +-1inch (least count).  2) Flat wooden surface:  Same as above.  3) Concrete pieces (with uneven surface):  The readings are accurate but precision is less compared to the first two cases. i.e fluctuations are observed in the readings. However these are sort of insignificant as they can be easily filtered out in the code.  4) Wet Sand:  More fluctuations are observed, with the mean reading remaining effectively the same (+- 2 inches error). These are mainly due to the unevenness of the surface and multiple reflections of sound waves. Again, these fluctuations and errors can be filtered out by considering the minimum value (out of 10 consecutive readings)as the actual value. This works as in this time span, the obstacle wouldn’t move much and the higher readings (meaning the wave takes more time to reach the sensor) are a direct consequence of multiple reflections and other phenomena. |
| 5. | Interference between two sensors | This happens when the sound waves sent by one sensor are received by the other sensor. Now a sensor can send a wave in one direction if and only if it can receive a wave in the same direction (principle of reversibility). This implies that if an obstacle were to cause interference between two sensors, it would be detected by both. This just adds an additional case in the code without harming performance of any other part of the system. The only issue is when there is no obstacle around and yet a sensor receives a sound wave before its timeout (obviously from some other sensors). Hence the tests are carried out with no obstacles in the field of view.    No interference is observed when the sensors are placed parallel and adjacent to each other.  Fluctuations in the readings are observed as the angle between them is decreased to 80-90 degrees. However these are insignificant.  . |
| 6. | Placing of sensors | Here three sensors are placed on each side in an orientation that maximizes the field of view. The only issue is that of interference between two adjacent sensors (which is almost zero from the previous test).  In this arrangement, less number of sensors is used but there are some regions which are out of the fields of view of all sensors. But these regions would be scanned by the sensors at some point in time owing to the fact that the bot is mobile. Appropriate tests need to be carried out before reaching any conclusions.    In the above figures, the blue arrows denote the axes of the ultrasonic sensors. |

Minimum error in observed values: +- 1 inch (least count)

**Work to be done**:

1) Make an obstacle avoiding bot using ultrasonic sensors and Rpi.

2) Research on encoding of these sensors.