A STATISTICAL APPROACH FOR ERROR REMOVAL FROM DATA OBTAINED USING SONARS

Ishika Roy[1], Sayana Rehman[2], G. Sravani[3], Sreedevi S. Nair[4]
[1,2,3,4]Electronics and Telecommunication Engineering Department FCRIT Vashi, Navi Mumbai
Email: roy.ishika95@gmail.com[1], arsayana4@gmail.com[2], gsravanirao35@gmail.com[3], sreedevinair24@yahoo.co.in[4]

Abstract
Obstacle avoidance or detection strategy is heavily dependent on the performance of range measurement devices like ultrasonic sensors. Therefore profiling them becomes extremely crucial and plays a pivotal role in improving the accuracy. We suggest two algorithms based on statistical approach for error removal in range measurements. As a result the profiled sonar's processor looks at the return echo signal every pulse and decides where along that pulse's return time lays the strongest return thus imparting more information about the exact distance of the object. We demonstrate this with experimental results.

Index Terms: accuracy, profiling, range, strongest return.

I. INTRODUCTION

SONAR (Sound Navigation and Ranging) is helpful for exploration and navigation on land as well as underwater. A sonar sensor emits a signal or pulse of sound. If an object is in the path of the sound pulse, the sound bounces off the object and returns an echo. The sensor is equipped with the ability to receive signals and by evaluating the time between the emission of the sound pulse and its reception, the range and orientation of the object can be determined.

In critical situations like a disaster struck region, where autonomous navigation systems encounters debris, valuables and living beings, the precise identification of an object or obstacle becomes of utmost importance. For a smooth, collision-free navigation in an unknown terrain the need for high accuracy can be met with sonars with better specifications. Another inexpensive way of tackling the same problem would be the implementation of sonar profiling. Profiled sonars use pencil shaped beams which provide an accurate cross-sectional profile of the obstacle's surface highlighting any structural differences or disturbances on it as shown in Fig. 1.

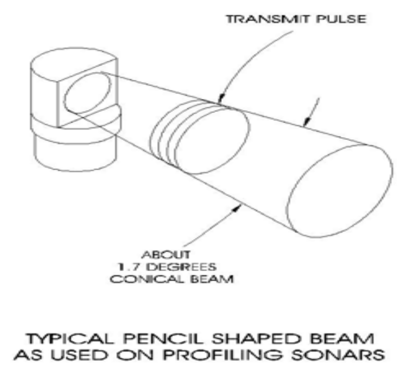

Figure 1. Profiled Sonar Beam [1]

Once an obstacle is detected, the system saves the distance of the object and either avoids the object by changing course or provides the personnel with the details for further inspection if a desirable entity is observed [2]. Thus sonar profiling saves time and money while simultaneously providing results for successful navigation aided by faithful obstacle detection and identification.

II. ERRORS IN SONARS

While finding the range of the target, the reflected sound signal introduces some random error due to temperature, noise etc. thus leading to error in distance measurements. When the sensor (placed on a robot) is in motion, it comes across objects that cause multiple reflections as shown in Fig. 2. As a result the estimated distance is different from the actual one hence gross measurement error occurs.

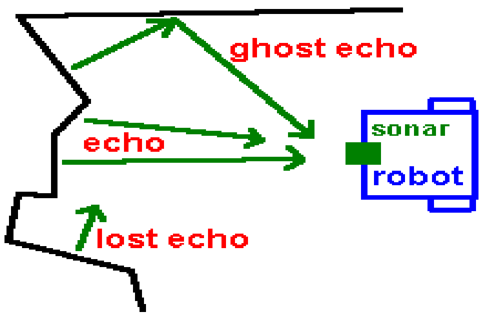

Figure 2. Reflections from surfaces with different shapes [3]

The error in the exact distance measurement from the face of the ultrasonic sensor to the target is known as the absolute accuracy whereas relative accuracy is the uncertainty in error in the new distance measurement when the target moves relative to the sensor. Resolution is the minimum change in distance that can be measured by the sensor when the target moves relative to it. Wavelength of the sound, Q factor of sonar, the reflecting characteristics of the target affect these measurements.

In order to obtain the absolute distance between the sonar sensor and the target several parameters are to be considered:
The beam angle of the transducer- As shown in Fig. 3 for the beam angle of the transducer ,wider the beam angle more is the distortion, narrow beam pattern is preferred to avoid unwanted reflections, speed of sound-it changes depending upon the environment.[4]

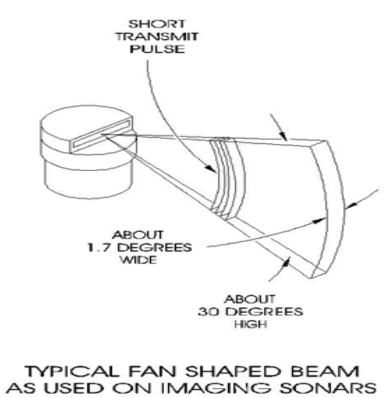

Figure 2. Beam of Imaging Sonars [5]

Target reflectivity- the reflected signal induces some amount of random error (noise)

Receiver sampling speed- faster the sampling speed, better the ability to find the leading edge of echo signal, different environmental factors etc.

III. ERROR CORRECTION

In order to profile the Sonars one must take into account the different parameters stated in previous section. The most erroneous ones that concern us are the beam angle and the target reflectivity.

Beam angle is of major concern because greater the beam angle, larger are the chances that the SONAR beam might hit surrounding objects and not the target whereas the reflected signal from the target induces some amount of noise in the internal circuitry.

IV. IMPLEMENTATION

We propose two solutions in our algorithm to profile Sonars. One is based on regression to tackle the beam angle problem and the other is a Gaussian function that eradicates noise in the target reflected signal.

A. Regression

The idea behind regression is that when there is a linear correlation a line can be used to estimate the value of dependent variable from the independent variable. The regression equation is a linear equation of the form: $\hat{y} = b_0 + b_1x$. To conduct a regression analysis, we need to solve for b_0 and b_1. Therefore to implement regression different values of theoretical distance of the target and corresponding Sonar reading (two set of readings) were tabulated. The mean value of the two set of readings were calculated and based on experimental and the actual target distance a regression formula was computed in Excel as shown in Fig. 3 and Fig. 4. This formula was then implemented in the code to generate more accurate results.

Theoretical r	Theory R^2	Experimental (d1)	Experimental (d2)	Mean (d)	Regression value
7	49	6	6	6	6.9876
9	81	8	7	7.5	8.53965
12	144	11	11	11	12.1611
20	400	18	18	18	19.404
25	625	23	24	23.5	25.09485
30	900	29	29	29	30.7857
40	1600	39	38	38.5	40.61535
50	2500	48	48	48	50.445
60	3600	57	58	57.5	60.27465
63	3969	60	59	59.5	62.34405
65	4225	63	61	62	64.9308
66	4356	64	62	63	65.9655
70	4900	67	66	66.5	69.58695
75	5625	71	72	71.5	74.76045

Figure 3. Excel sheet Table

```
=1.0347*E10+0.7794
```

Figure 4. Obtained Regression Formula

B. Gaussian Function

We know that white noise has a Gaussian pdf and hence in order to eliminate random errors in the reflected echo signal we use this function wherein we calculate the mean and variance values (for 3 set of readings of the target distance) [6]. Here the mean gives us the actual distance of the target and variance tells us about the possible deviation from the actual distance. This code was implemented using Arduino IDE and the results as displayed on the serial monitor are shown in Fig. 5.

```
Mean:10.35   Variance:0.81
Mean:10.07   Variance:0.50
Mean:9.60   Variance:0.50
Mean:10.81   Variance:0.50
Mean:11.72   Variance:0.50
Mean:5.86   Variance:4.45
Mean:2.61   Variance:0.50
Mean:4.02   Variance:2.63
Mean:22.82   Variance:3.23
Mean:11.40   Variance:22.95
Mean:18.31   Variance:0.50
```

Figure 5. Output after using Gaussian function

V. RESULT

Using the two solutions that we proposed earlier the SONARs were profiled. It was found that the SONAR readings were much more accurate and nearer to the actual target distance as shown in Fig. 6.

```
Initial Distance :2 Profiled Distance :2.22
Initial Distance :4 Profiled Distance :4.42
Initial Distance :7 Profiled Distance :7.25
Initial Distance :7 Profiled Distance :7.27
Initial Distance :6 Profiled Distance :6.32
Initial Distance :6 Profiled Distance :6.04
Initial Distance :6 Profiled Distance :6.45
```

Figure 6. Profiled Output

VI. CONCLUSION

Sonar profiling using regression and Gaussian is an affordable method to increase the accuracy in obstacle detection and identification of its orientation. We successfully implemented the same and obtained the distance values accurate to 2 decimal places. This technique when integrated with our navigation system will prove beneficial in obtaining better results for obstacle avoidance during navigation.

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