ANNALS OF THE ORADEA UNIVERSITY
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2014, http://www.imtuoradea.ro/auo.fmte/

TEXTURE OF MATERIAL INFLUENCE AT ULTRASONIC DETECTION

Radu TARULESCU[1], Ciprian OLTEANU[2], Stelian TARULESCU[3]
[1]TRANSILVANIA University of Brasov, radu.tarulescu@unitbv.ro
[2]TRANSILVANIA University of Brasov, oltcip@unitbv.ro
[3]TRANSILVANIA University of Brasov, s.tarulescu@unitbv.ro

Abstract**—** In this paper it is presented one model of distance measuring to some using an ultrasonic sensor. The objects are made from materials with different texture and are displayed on some presets distances over the sensor. For the measurements it was use a DT020-1 ultrasonic sensor. The operational principle of an ultrasonic sensor is based on the generation of acoustic waves and their detection when reflected by an object. The measurements results are used to improve the mobile robots navigation.

Keywords**—** material, sensor, robot, ultrasonic.

I. Introduction

A real problem in ultrasonic sensors detection is the material type and texture of objects subject to measurement. Ultrasonic sensors are useful under poor lighting conditions or when there are many transparent objects such as windows or glass doorways, as this is where infrared or vision-based sensors fail. The sensor operation uses the principle of echo location. Ultrasonic sensors transmitter sends out a short pulse within a specific direction. When the pulse hits an object, which does not absorb the pulse, it bounces back, after which the echo can be picked up by a receiver [1]. Some sensors have separate transmitter and receiver components, while another sensor combines both in a single piezoelectric transceiver. Most ultrasonic sensors use a single transducer to both transmit the sound pulse and receive the reflected echo, typically operating at frequencies between 40 kHz and 250 kHz. However, the basic operation is the same in both devices.

The distance to the object can be determined by measuring the time between sending the pulse and detecting the echo.

By multiplying the time between pulse and echo t (in seconds) with speed of sound c, you will get twice the distance d to the object in meters (since the sound traveled the distance twice to get to the object and bounce back).

$$\mathbf{d = \frac{c \cdot t}{2}} \qquad (1)$$

The accuracy of the distance measurement is directly proportional to the accuracy of the speed of sound used in the calculation [2]. The speed of sound in air varies as a function of temperature T by the relation:

$$\mathbf{c = 331.5 + 0.607 \cdot T} \qquad (2)$$

II. Devices Used For Measurements

For measurements it was used an ultrasonic sensor DT020-1, an acquisition system MultiLogPRO, a software for data processing named MultiLab and obstacles (objects) made from materials with different texture.

The DT020-1sensor measures the distance between the sensor and an object in the range of 0.2 to 10 meters. The sensor can sample data at up to 50 times per second, making it excellent for motion and movement experiments [3].

Fig. 1. The ultrasonic sensor DT020-1

Specifications of ultrasonic sensor DT020-1:
- Range – 0,2 m to 3 m;
- Accuracy – 2% over entire range;
- Resolution (12-bit) – 2.44 mm;
- Receiver Viewing Angle – ± 15° to ± 20°;
- Data Logger Input Type – digital;
- Features – reports position, velocity and acceleration;

For sensor data acquisition it was used a

MultiLogPRO system. The MultiLogPRO system is a standalone 12-bit data logger with a clear LCD graphic display and a 128K internal memory. Recorded data are displayed in the form of graphs, tables, meters or digital displays, and can be analyzed with a number of pre-programmed analysis functions. This system internal memory stores experiment notes and instructions for carrying out the experiment, which can be edited or expanded at any time. MultiLogPRO can record data from up to 8 sensors simultaneously and it's capable of recording at rates of up to 21,000 samples per second, and of collecting up to 100,000 samples in its internal memory. [4].

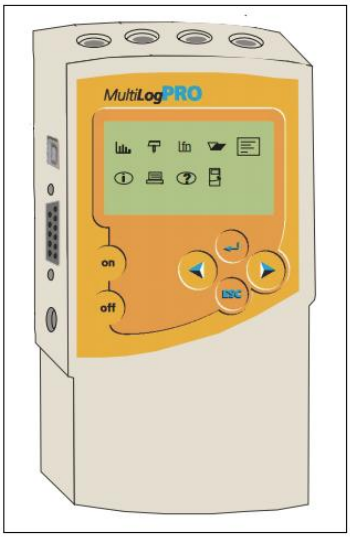

Fig. 2. MultiLogPRO data acquisition system.

The MultiLogPRO system combines with the MultiLab software. MultiLab includes a video motion analyzer module that enables to capture position and time from video movies and analyze the data with many analysis tools.

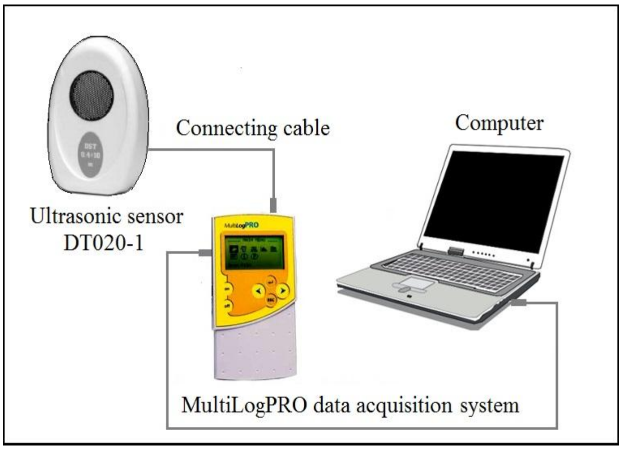

Fig. 3. Sensor connections to the data acquisition system.

The used materials were: stainless steel, aluminum, copper, cardboard, rubber and plastic.

Stainless steel is a steel alloy with a minimum of 11.5% chromium content by mass. Stainless steel does not stain, corrode or rust as easily as ordinary steel, but it is not stain-proof. Stainless steel differs from carbon steel by amount of chromium present. Carbon steel rusts when exposed to air and moisture. This iron oxide film is active and accelerates corrosion by forming more iron oxide. Stainless steels have sufficient amount of chromium present so that a passive film of chromium oxide forms which prevents further corrosion.

Fig. 4. Obstacles of different type of materials

Aluminum is a soft, durable, lightweight, malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. Aluminum is nontoxic, nonmagnetic, and non-sparking. It is also insoluble in alcohol, though it can be soluble in water in certain forms. Aluminum resist to corrosion (due to the phenomenon of passivity) and its low density.

Copper is a ductile metal with excellent electrical conductivity and is rather supple in its pure state and has a pinkish luster which is (beside gold) unusual for metals which are normally silvery white. It finds use as a heat conductor, an electrical conductor, as a building material, and as a constituent of various metal alloys [5].

Cardboard is a paper-like material, a carton. The term cardboard is a general term that is descriptive of products which are 0.30 millimeter or more in thickness, made of fibrous materials on paper machines. Cardboard is commonly made from wood pulp, straw, wastepaper, or a combination of these materials.

Rubber is a polymer of isoprene units, a hydrocarbon dine monomer. Synthetic rubber can be made as a polymer of isoprene or various other monomers.

Plastic is the general common term for a wide range of synthetic or semi-synthetic organic solid materials suitable for the manufacture of industrial products. Plastic is a typically polymer of high molecular weight, and has the capability of being molded or shaped, usually by the application of heat and pressure [6].

III. MEASUREMENTS

For distance measurements it was used three metal obstacles (stainless steel, aluminum and copper) and three obstacles made from different materials (cardboard, rubber and plastic). The measurements were made with ultrasonic sensor placed at different presets distances accountable to used obstacles. The obstacles have the same shapes.

Fig. 5. Ultrasonic sensor attached to data acquisition system and notepad

The obstacles was placed at 50, 100, 150, 200, and 250 millimeters over the ultrasonic sensor, and measurements was made at 705,6 mmHg atmospheric pressure and 21,3 ^{o}C (294,45 K) temperature. In this case, the value of speed of sound in air is 344,43 m/s.

There have been made five measurements at the same distance d_r determining the values of the measured distance d_m. The theoretical time of flight it was computed with equation:

$$\mathbf{t_0 = \frac{2 \cdot d_r}{c_{air}}} \tag{3}$$

and the real value of time of flyght was computed with equation:

$$\mathbf{t = \frac{2 \cdot d_m}{c_{air}}} \tag{4}$$

The absolute and relative errors was determined with next relations [7]:

$$\mathbf{\Delta d = \left| d_m - d_r \right|} \tag{5}$$

$$\mathbf{\varepsilon = \frac{\Delta d}{d_r} \cdot 100} \tag{6}$$

TABLE I
VALUES FOR STAINLESS STEEL, ALUMINUM AND COPPER OBSTACLES

Real dist.	Theoretical time of flight	Measured distance	Time of flight	Absolute error	Relative error
d_r	**t_0**	**d_m**	**t**	**Δd**	**ε**
[mm]	[μs]	[mm]	[μs]	[mm]	[%]
		Stainless steel			
50	290,33	50,52	293,35	0,52	1,04
100	580,67	100,68	584,62	0,68	0,68
150	871,01	151,23	878,15	1,23	0,82
200	1161,34	200,87	1166,39	0,87	0,44
250	1451,67	252,18	1464,33	2,18	0,87
		Aluminum			
50	290,33	49,82	289.28	0,18	0,36
100	580,67	99,45	577,48	0,55	0,55
150	871,01	149,31	866,99	0,69	0,46
200	1161,34	199,49	1158,38	0,51	0,26
250	1451,67	249,46	1448,53	0,64	0,25
		Copper			
50	290,33	50,31	292,13	0,31	0,62
100	580,67	100,65	584,44	0,65	0,65
150	871,01	150,87	876,05	0,87	0,58
200	1161,34	200,93	1166,74	0,93	0,47
250	1451,67	251,48	1460,27	1,48	0,59

In TABLE I are showed the values of measured distance, response time, absolute and relative errors in function of real preset distance for the obstacles made from stainless steel, aluminum and copper and in TABLE II are showed the values of the same parameters for the obstacles made from cardboard, plastic and rubber.

TABLE II
VALUES FOR CARDBOARD, PLASTIC AND RUBBER OBSTACLES

Real dist.	Theoretical time of flight	Measured distance	Time of flight	Absolute error	Relative error
d_r	**t_0**	**d_m**	**t**	**Δd**	**ε**
(mm)	(μs)	(mm)	(μs)	(mm)	(%)
		Cardboard			
50	290,33	49,32	286,38	0,68	1,36
100	580,67	98,91	574,34	1,09	1,09
150	871,01	148,73	863,63	1,27	0,85
200	1161,34	199,15	1156,40	0,85	0,43
250	1451,67	248,55	1443,25	1,45	0,58
		Plastic			
50	290,33	50,18	291,38	0,18	0,36
100	580,67	100,33	582,58	0,33	0,33
150	871,01	150,79	875,59	0,79	0,53
200	1161,34	201,18	1168,19	1,18	0,59
250	1451,67	251,88	1462,59	1,88	0,75
		Rubber			
50	290,33	49,58	287,89	0,42	0,84
100	580,67	99,15	575,73	0,85	0,85
150	871,01	149,09	865,72	0,91	0,61
200	1161,34	198,83	1154,55	1,17	0,78
250	1451,67	248,82	1444,82	1,18	0,47

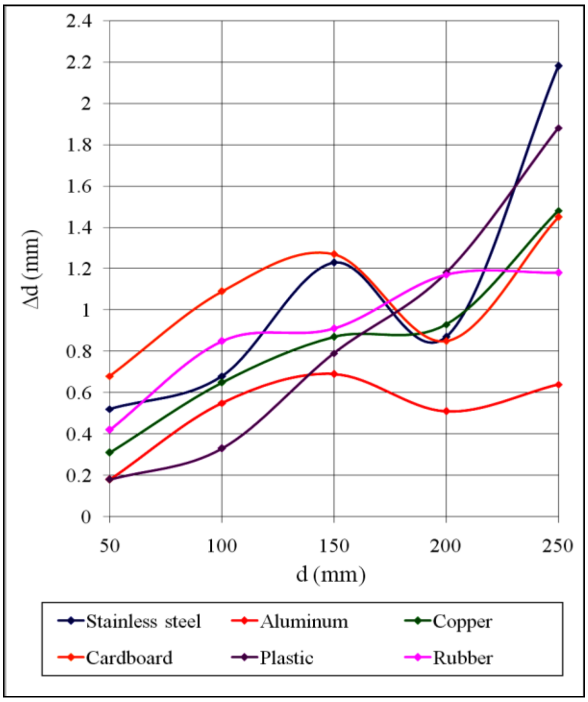

Fig. 6. Absolute error in function with real distance

In Fig. 6 is showed difference between the values of real sensor-obstacle distance and the measured distances. The gaps are relative small, which shows the ultrasonic sensor signal it's not much influenced of the obstacle texture.

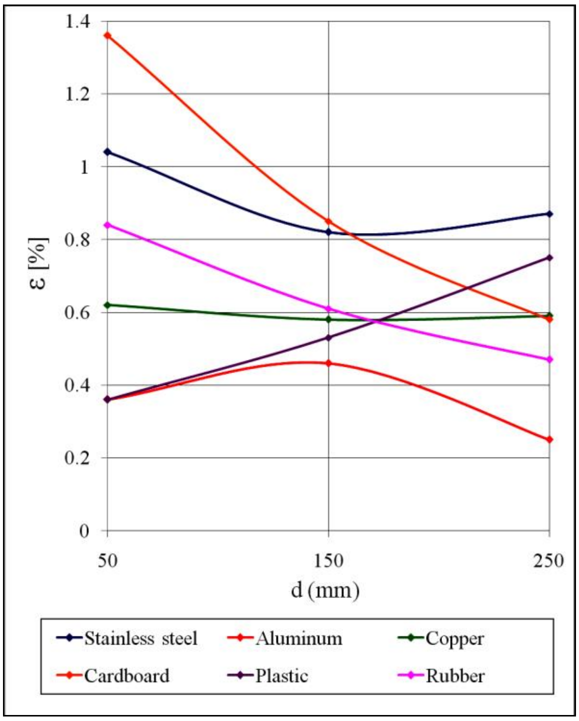

Fig. 7. Relative error in function with real distance

In Fig. 7 is showed the relative error in function with real distance, which decrease inversely with distance between sensor and obstacle.

IV. Conclusion

The object to be detected can be made of a wide range of materials. Shape, color or material type, has little effect on detection. No major differences had been observed for ultrasonic detection when are used different textures of material. The ultrasonic sensor DT020-1 can be successfully used for autonomous vehicle orientation in the working space like in Fig. 8.

Fig. 8. Vehicle, equipped with a DT020-1 ultrasonic sensor

Anyway, the sonar and ultrasonic sensor are used in different types of applications due to the low cost and high precision compared with other distance sensors.

Acknowledgment

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), ID134378 financed from the European Social Fund and by the Romanian Government.

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