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USAGE OF PARALLAX ULTRASONIC SENSORS IN DISTANCE MEASUREMNTS

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***Abstract* —** In this paper it is presented one model of distance measuring to some objects using an ultrasonic sensor. The objects have different shapes and are displayed on some presets distances over the sensor. For the measurements it was use a Parallax 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* —** environment, sensor, robot, ultrasonic.

I. INTRODUCTION

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. Sonar 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. 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).

$$d = \frac{c \cdot t}{2} \tag{1}$$

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:

$$c = 331.5 + 0.61 \cdot T \tag{2}$$

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.

II. DEVICES USED FOR MEASUREMENTS

For measurements it was used an ultrasonic sensor (Parallax PING), a microcontroller board (Arduino), a notepad and obstacles (objects) of different shapes.

The Parallax PING sensor detects objects by emitting a short ultrasonic burst and then receiving the echo. Under control of a host microcontroller (trigger pulse), the sensor emits a short ultrasonic burst (40 kHz). This burst travels through the air, hits an object and then bounces back to the sensor. The sensor provides an output pulse to the host that will terminate when the echo is detected, and the width of this pulse corresponds to the distance to the target**.** The Parallax PING sensor has a male 3-pin header used to supply power (5V), ground (GND), and signal [3].

Fig. 1. The ultrasonic sensor Parallax PING

Specifications of ultrasonic sensor Parallax PING:

- Supply Voltage – 5 V;
- Supply Current – 35 mA max;
- Range – 2 cm to 3 m;
- Input Trigger – positive TTL pulse, 5 µs;
- Echo Pulse – positive TTL pulse, 115 µs to 18.5 ms;
- Echo Hold-off – 750 µs from fall of Trigger pulse;
- Burst Frequency – 40 kHz for 200 µs;
- Delay before next measurement – 200 µs;
- Size – 22 mm x 46 mm x 16 mm.

For sensor data acquisition it was used an Arduino board. Arduino is a microcontroller board based on the ATmega328 (datasheet) [4]. That data board has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC/DC adapter or battery to get started [4].

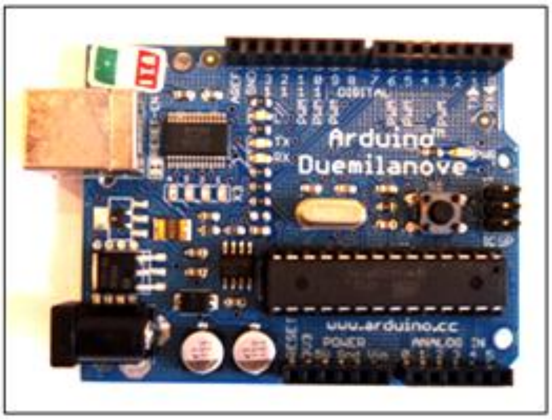

Fig. 2. Arduino data acquisition board.

Specifications of Arduino board:

- Microcontroller – ATmega328;
- Operating Voltage – 5V;
- Input Voltage – 7-12V;
- Digital I/O Pins – 14;
- Analog Input Pins – 6;
- DC Current per I/O Pin – 40 mA;
- DC Current for 3.3V Pin – 50 mA;
- Flash Memory – 32 KB.
- Clock Speed – 16 MHz

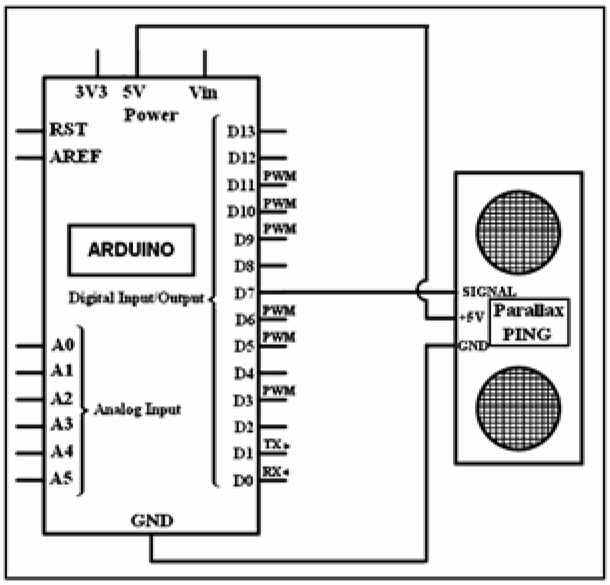

Fig. 3. Sensor connection to the data acquisition board.

The Arduino board has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board [4].

III. MEASUREMENTS

For distance measurements it was used plane obstacles with different widths, and obstacles with triangular and circular cross-sections. The measurements were made with ultrasonic sensor placed at different presets distances accountable to used obstacles. With measured distance was computed the values of sensor response time.

Fig. 4. Ultrasonic sensor attached to data acquisition board and notepad

The plane obstacle (aluminum) has widths of 20 mm, 40 mm and 60 mm. In following tables are shown the values of response time *t*(s), in function of preset distances (real distances) d_r (mm) and measured distances with Parallax PING ultrasonic sensor d_m (mm). The obstacles was placed at 20, 40, 60, 80, 100, 120, 140, 160, 180 and 200 millimeters over the ultrasonic sensor, and measurements was made at 714,5 mmHg atmospheric pressure and 24,8 ^oC (297,95 K) temperature [5].

TABLE I
VALUES FOR PLANE OBSTACLE WITH 20 MM WIDTH

Real distance	Measured distance	Response time for plane obstacle (20 mm width) detection
d_r (mm)	d_m (mm)	t (μs)
20	20,102	116,2
40	40,065	231,6
60	60,112	347,5
80	80,106	463,0
100	100,139	578,8
120	120,154	694,5
140	140,206	810,4
160	160,199	926,0
180	180,243	1041,9
200	200,255	1157,5

In tables I, II and III are showed the values of measured distance and response time in function of real preset distance for the plane obstacles with different widths.

TABLE II
VALUES FOR PLANE OBSTACLE WITH 40 MM WIDTH

Real distance	Measured distance	Response time for plane obstacle (40 mm width) detection
d_r (mm)	d_m (mm)	t (µs)
20	20,092	116,1
40	40,082	231,7
60	60,106	347,4
80	80,112	463,1
100	100,149	578,9
120	120,143	694,4
140	140,191	810,3
160	160,220	926,1
180	180,235	1041,8
200	200,248	1157,5

TABLE III
VALUES FOR PLANE OBSTACLE WITH 60 MM WIDTH

Real distance	Measured distance	Response time for plane obstacle (60 mm width) detection
d_r (mm)	d_m (mm)	t (µs)
20	20,042	115,8
40	40,081	231,6
60	60,125	347,5
80	80,120	463,1
100	100,137	578,8
120	120,133	694,4
140	140,177	810,2
160	160,195	925,9
180	180,212	1041,7
200	200,238	1157,4

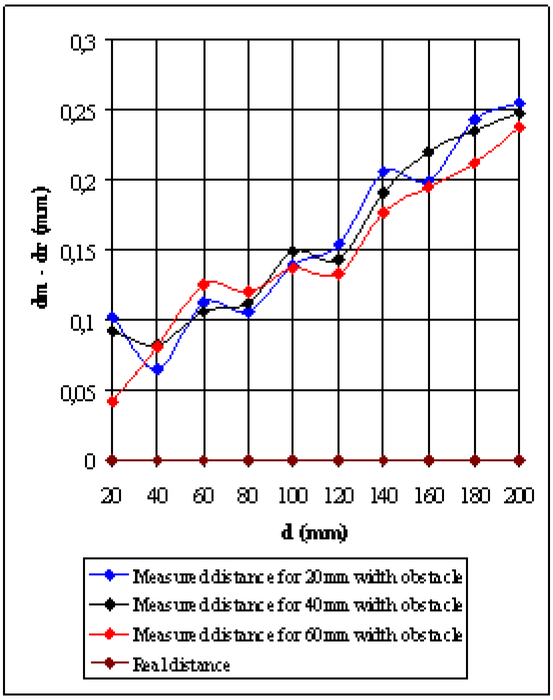

Fig. 5. Difference between the real distance and the measured distances for obstacles with different widths

In fig. 5 is showed difference between the values of real sensor-obstacle distance and the measured distances. The gaps are small, that shows the ultrasonic sensor signal it's not influenced of the obstacle width [6].

The values of measurements effectuated with triangular and circular cross-section obstacles are showed in tables IV and V. The triangular section it's an equilateral triangle with side of 30 mm length and the circular section it's a circle with diameter of 50 mm.

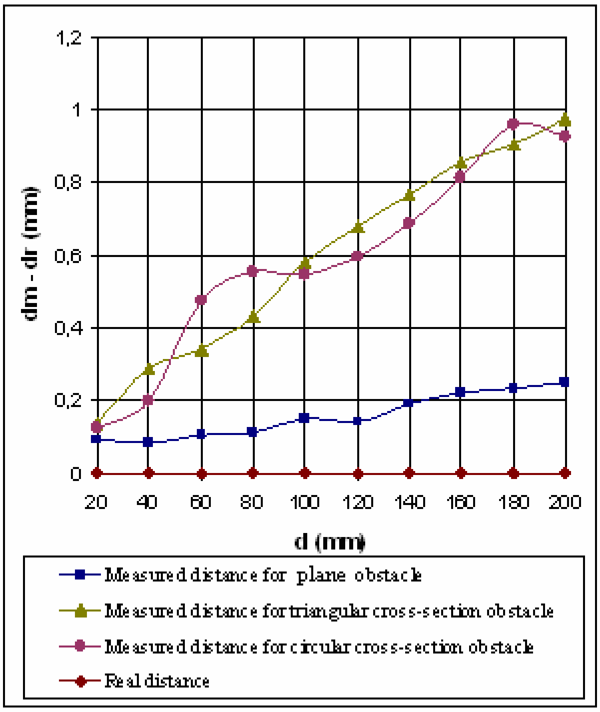

Fig. 6. Difference between the real distance and the measured distances for obstacles with different shapes

In fig. 6 is showed difference between the values of real sensor-obstacle distance and the measured distances for plane, triangular and circular cross-section obstacles. The gaps are more significant for triangular and circular section that shows the ultrasonic sensor signal it's influenced of the obstacle shape.

TABLE IV
VALUES FOR TRIANGULAR CROSS-SECTION OBSTACLE

Real distance	Measured distance	Response time for triangular cross-section obstacle detection
d_r (mm)	d_m (mm)	t (µs)
20	20,137	116,4
40	40,287	232,9
60	60,340	348,8
80	80,434	464,9
100	100,579	581,4
120	120,681	697,6
140	140,766	813,7
160	160,856	929,8
180	180,903	1045,7
200	200,977	1161,7

TABLE V
VALUES FOR CIRCULAR CROSS-SECTION OBSTACLE

Real distance	Measured distance	Response time for circular cross-section obstacle detection
d_r (mm)	d_m (mm)	t (μs)
20	20,126	116,3
40	40,201	232,4
60	60,477	348,5
80	80,554	465,6
100	100,547	581,1
120	120,596	697,1
140	140,689	813,2
160	160,812	929,5
180	180,959	1046,0
200	200,923	1161,4

To get dependence equations between the sensor response time and the real distance, it was made an approximation of obtained trajectories, using a linear regression.

For plane obstacle (40 mm width) the dependence equations are:

$$d = \left(\frac{t - 0{,}1569}{5{,}7866}\right) \cdot 10^{-3} \quad (3)$$

$$t = (5{,}7866 \cdot d + 0{,}1569) \cdot 10^{-6} \quad (4)$$

For plane triangular cross-section obstacle the dependence equations are:

$$d = \left(\frac{t - 0{,}447}{5{,}8081}\right) \cdot 10^{-3} \quad (5)$$

$$t = (5{,}8081 \cdot d + 0{,}447) \cdot 10^{-6} \quad (6)$$

For plane obstacle circular cross-section the dependence equations are:

$$d = \left(\frac{t - 0{,}387}{5{,}8073}\right) \cdot 10^{-3} \quad (7)$$

$$t = (5{,}8073 \cdot d + 0{,}387) \cdot 10^{-6} \quad (8)$$

IV. CONCLUSION

No major differences had been observed for different surface shapes and widths of the due to the values of the measurements. The ultrasonic sensor Parallax PING can be successfully used for mobile robots orientation in the working space. This type of sensor can be used on the mobile robot Pro-Bot 128 like in fig. 7.

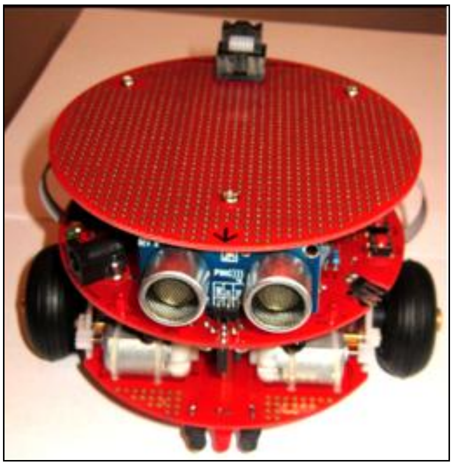

Fig. 7. Pro-Bot 128 mobile robot, equipped with a Parallax ultrasonic sensor

Pro-Bot 128 is already equipped with a programmable microcomputer, has two motors, an optical line tracing unit, an optical collision detector, two rotary speed sensors for the wheels, an acoustic sensor, two light sensors, and the possibility to measure and control its own operating voltage [7].

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.

REFERENCES

[1] A. Dumitriu, C. Bucşan, T. Demian, “Sensorial systems for robots”, Edit Medro, Brasov, 1996.
[2] J.J. Leonard, H. Durrant–Whyte, “Directed sonar sensing for mobile robot navigation”, Kluwer Academic Publishers, Boston, 1992
[3] Catalog PING)))™ Ultrasonic Distance Sensor (#28015)
[4] J. Oxer, H. Blemings, Practical Arduino – “Cool Projects for Open Source Hardware”, ISBN-13 (electronic): 978-1-4302-2478-5, 2009;
[5] R. Tarulescu, S. Tarulescu, “Distance measurements with ultrasonic sensor DT020-1”, Editura Universitatii din Oradea, ISSN 1583-0691, ANNALS of the ORADEA UNIVERSITY, 2012;
[6] U. Nehmzow, ‘Mobile Robotics: A Practical Introduction’, ISBN 978-1852337261, June 11, 2003;
[7] Pro Bot 128 Operating manual, 2011 by Conrad Electronic SE.