# THE INFLUENCE OF WIND SPEED AND DIRECTION OVER THE ULTRASONIC DETECTION

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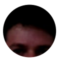

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# THE INFLUENCE OF WIND SPEED AND DIRECTION OVER THE ULTRASONIC DETECTION

**Stelian ȚÂRULESCU, Radu ȚÂRULESCU**

***Abstract:*** *This paper presents one model of distance measuring at different direction and speed of wind using an ultrasonic 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 autonomous vehicles navigation.* ***Keywords:*** *wind, sensor, ultrasonic, environment, obstacles.*

## 1. 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* with speed of sound *c*, you will get twice the distance *d* to the object (since the sound traveled the distance twice to get to the object and bounce back).

The accuracy of the distance measurement is directly proportional to the accuracy of the speed of sound used in the calculation [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.

## 2. EQUIPMENTS AND DEVICES USED FOR MEASUREMENTS

For measurements it was used an ultrasonic sensor (Parallax PING), a microcontroller board (Arduino), a notepad and a centrifugal fan to simulate wind.

The Parallax PING sensor (Fig. 1) detects objects by emitting a short ultrasonic burst and then receiving the echo.

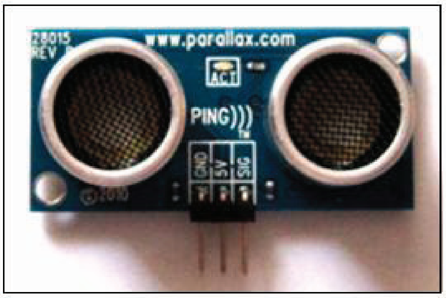


**Fig. 1.** The ultrasonic sensor Parallax PING

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].

For sensor data acquisition it was used an Arduino board. Arduino is a microcontroller board based on the ATmega328 (Fig.2).

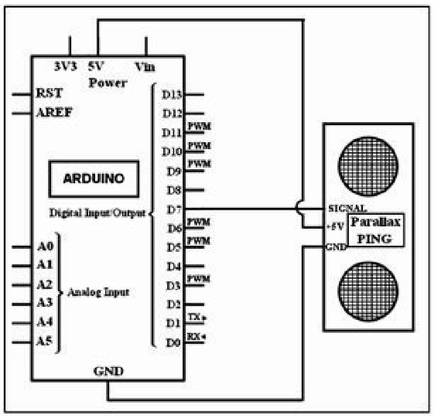


**Fig. 2.** Sensor connection to the data acquisition board

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]. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board [4].

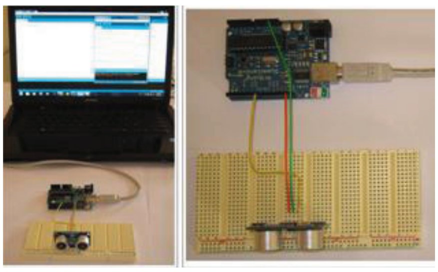

**Fig. 3.** Ultrasonic sensor attached to data acquisition board and notepad

To simulate wind it was used a centrifugal fan with a flow control flap, to obtain various speeds of the air [5].

The system has three sections, an input section (circular) of the suction nozzle surface $A_1$=0,03m$^2$ a rectangular surface $A_2$=0,025m$^2$ downstream fan which coincides with the placement of a static pressure tap and a rectangular sectional area at the outlet $A_3$=0,0185m$^2$.

## 3. MEASUREMENTS

In order to observe the influence of air currents, were made measurements of the distance between the Parallax ultrasonic sensor and a obstacle with flat surface, at three speeds of the different distribution of the air flow, a speed perpendicular to the sensor wave, a speed oriented at 45° to the sensor wave and one parallel to the sensor wave having direction of emitted signal.

Speed is adjusted to the desired values following relation:

$$v = \sqrt{2 \cdot g \cdot \left( \frac{\rho_{lp}}{\rho_{air}} - 1 \right) \cdot h_d} \quad , \qquad (1)$$

Where $g$ is the acceleration due to gravity, $\rho_{lp}$ is piezometric fluid density, $\rho_{air}$ is the air density and $h_d$ is the piezometer indication (level difference of the liquid in the piezometer columns) [5].

$$\rho_{air} = \rho_{0\,air} \cdot \frac{T_0}{T_{air}} \cdot \frac{p_{air}}{p_0} \qquad (2)$$

$$\rho_{air} = 1,293 \cdot \frac{273,15}{298,45} \cdot \frac{715}{760} = 1,133215 [\,kg/m^3\,]$$

From equation (1) is writing $h_d$ in function of speed:

$$h_d = \frac{v^2}{2 \cdot g \cdot \left( \frac{\rho_{lp}}{\rho_{air}} - 1 \right)} \qquad (3)$$

$$h_d = \frac{v^2}{2 \cdot 9,81 \cdot \left( \frac{1000}{1,133215} - 1 \right)} = \frac{v^2}{13831,24}$$

Values of $h_d$ are adjusted using adjustable damper of the used system. The speed was so adjusted to values between 1 and 12 m/s. Airflow was distributed differently in order to observe the influence over the ultrasonic waves (Fig. 4) [6].

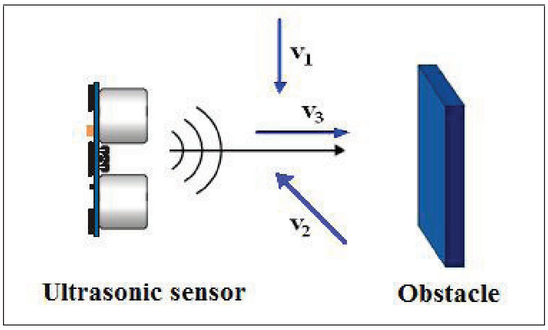


**Fig. 4.** The wind speed application on ultrasonic wave

Were $v_1$, $v_2$ and $v_3$ are:

$v_1$ – speed perpendicular on ultrasonic wave;

$v_2$ – speed oriented at 45° to the ultrasonic wave;

$v_3$ – speed parallel to the ultrasonic wave having direction of emitted signal.

At atmospheric pressure of 715 mmHg and a temperature of 25,3°C (298,45 K), the speed of sound has the value $c_{air}$ = 346,86 [m/s].

There have been made ten measurements at the same distance $d_r$=0,5 m, determining the values of the measured distance $d_m$. The theoretical time of flight it was computed with equation:

$$t_0 = \frac{2 \cdot d_r}{c_{air}} \quad (3)$$

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

$$t = \frac{2 \cdot d_m}{c_{air}} \quad 4)$$

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

$$\Delta d = |d_m - d_r| \quad (5)$$

$$\varepsilon = \frac{\Delta d}{d_r} \cdot 100 \quad (6)$$

In Table 1 are showed the values of measured distance, response time, absolute and relative errors in function of real preset distance for the applied speeds of air.

*Table 1*

**The values determined for simulated speeds**

| Speed | Measured distance | Time of flight | Absolute error | Relative error |
|---|---|---|---|---|
| v | $d_m$ | t | Δd | |
| [m/s] | [mm] | [μs] | [mm] | [%] |
| Speed perpendicular on ultrasonic wave | | | | |
| 3 | 501,7 | 2889,93 | 1,7 | 0,34 |
| 4 | 501,9 | 2893,96 | 1,9 | 0,38 |
| 5 | 502,8 | 2899,15 | 2,8 | 0,56 |
| 6 | 502,8 | 2899,15 | 2,8 | 0,56 |
| 7 | 503,1 | 2900,88 | 3,1 | 0,62 |
| 8 | 503,5 | 2903,19 | 3,5 | 0,70 |
| 9 | 504,2 | 2907,22 | 4,2 | 0,84 |
| 10 | 504,4 | 2908,38 | 4,4 | 0,88 |
| 11 | 505,6 | 2915,29 | 5,6 | 1,12 |
| 12 | 506,9 | 2922,79 | 6,9 | 1,38 |
| Speed oriented at 45° to the ultrasonic wave | | | | |
| 3 | 501,4 | 2891,08 | 1,4 | 0,28 |
| 4 | 501,5 | 2891,66 | 1,5 | 0,30 |
| 5 | 502,1 | 2895,12 | 2,1 | 0,42 |
| 6 | 502,4 | 2896,84 | 2,1 | 0,42 |
| 7 | 502,8 | 2899,15 | 2,8 | 0,56 |
| 8 | 503,2 | 2901,45 | 3,2 | 0,64 |
| 9 | 503,6 | 2903,77 | 3,6 | 0,72 |
| 10 | 503,9 | 2905,49 | 3,9 | 0,78 |
| 11 | 504,5 | 2908,95 | 4,5 | 0,90 |
| 12 | 505,8 | 2916,45 | 5,8 | 1,16 |
| Speed parallel to the ultrasonic wave | | | | |
| 3 | 499,9 | 2882,43 | 0,1 | 0,02 |
| 4 | 499,6 | 2880,70 | 0,4 | 0,08 |
| 5 | 499,7 | 2881,27 | 0,3 | 0,06 |
| 6 | 499,3 | 2878,97 | 0,7 | 0,14 |
| 7 | 498,6 | 2874,94 | 1,4 | 0,28 |
| 8 | 498,6 | 2874,94 | 1,4 | 0,28 |
| 9 | 498,4 | 2873,78 | 1,6 | 0,32 |
| 10 | 498,2 | 2872,63 | 1,8 | 0,36 |
| 11 | 498,2 | 2872,63 | 1,8 | 0,36 |
| 12 | 498,1 | 2872,05 | 1,9 | 0,38 |

When measuring the distance to an obstacle placed at 500 mm from the sensor in different atmospheric conditions (three different directions of air currents), it is noted that the distance measured values are higher than the actual distance for perpendicular speed on the ultrasonic wave and for speed oriented at 45°

and the values are lower for parallel speed on the ultrasonic wave [6].

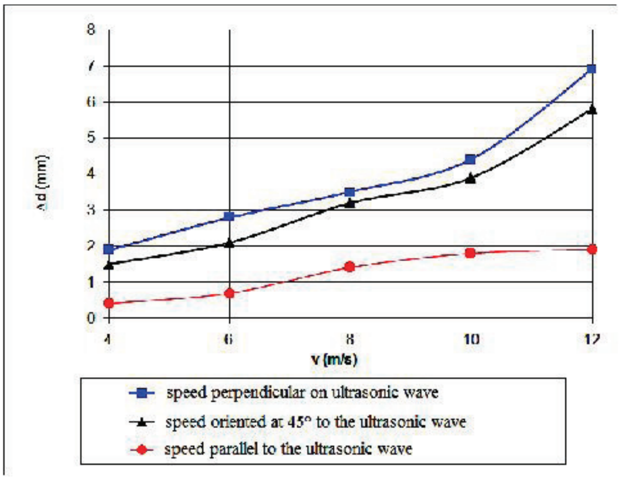


**Fig. 5.** The three speeds in function of absolute error

## 4. CONCLUSION

The object to be detected can be made of a wide range of shapes, colors or texture. Shape, color or material type, has little effect on detection. No major differences had been observed for ultrasonic detection when are applied air speeds from different angles. The ultrasonic sensor Parallax Ping can be successfully used for autonomous vehicle orientation in the working space.

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**

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