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ULTRAHANGOS SZENZOR MODELLEZÉSE ÉS ALKALMAZÁSA MOBILROBOTOKNÁL

ULTRASONIC SENSOR MODELLING AND APPLICATION IN MOBILE ROBOT PLATFORM

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Abstract

This paper presents an introductory content about ultrasonic sensors, its modelling and a specific application using this kind of sensors. The application of ultrasonic waves in sensors is very common nowadays, covering a big amount in the field of sensor used to detect objects. The ultrasonic band goes from 20 KHz until 1 GHz and because of two main characteristics, the capability of penetrate opaque materials and the slower speed if compared if the electromagnetic waves, the ultrasonic waves are greatly used in sensors.

In mobile robot one of the main points is the capability to sense the surrounding area, making possible for the robot to detect objects and calculate paths to avoid them. It was elaborated an layout, according to the geometric form of the given robot and the beam pattern of the sensor, displacing those sensors around the robot in order to detect any object with efficiency.

Keywords: ultrasonic sensor, sensor modelling, mobile robot.

Összefoglaló

Ez a cikk bemutatja az ultrahangos érzékelők alapvető működését, matematikai modelljének felállítását, és az ultrahangos érzékelők alkalmazását mobilrobotos környezetben. A cikkben leírom a projektmunkámmal kapcsolatos elsődleges feladatokat, ami ultrahangos érzékelők elhelyezése a mobilrobot kerületén úgy, hogy a mobilrobot minél nagyobb mértékben érzékelje a környezetét, és ne legyenek „vak foltok” az érzékelésben. Ezzel kapcsolatban számításokat végeztem, ami az optimális szenzorhelyezést eredményezte. A projektmunkám második része a szenzorok és a vezérlő processzor (ami egy PIC mikro vezérlő) összekapcsolása, és a szenzorokat lekérdező program megvalósítása lesz.

Kulcsszavak: ultrahangos érzékelő, szenzormodellezés, mobil robot.

1. Introduction to ultrasonic

There are two main characteristics that make the ultrasonic sensing very useful in many applications. First one is that the ultrasonic waves can easily penetrate opaque materials, it's a very important feature making possible the visualization of images inside opaque materials like the ultrasound image of a fetus in the womb. The second one is the fact that the ultrasonic waves travel in a very slow speed if compared if the electromagnetic waves, this allows the possibility to display the information in time. There are plenty of applications of the ultrasonic like radars, industrial measurement systems and medical purposes.

2. Task

In the first part of the project there was an existing mobile robot for what an optimal displacement of the ultrasonic sensors around the body should be developed in such a way, that the sensory-field around the mobile robot has to be unbroken.

In the second part is about the development of an algorithm to do a sequential scanning of the sensors and evaluate the sensory data. So the microcontroller should be able to sense if there is any object in the surroundings and, if there is any, find the distance of the object. The sequential scanning of the sensors will be realized by the PIC microprocessor.

3. Model of an ultrasonic sensor

Velocity of wave propagation is expressed by multiplication of frequency and wavelength, the temperature has an effect over the velocity of sound wave propagation according to the expression (1), where 'c' is the sound velocity and 't' is the temperature (°C).

$$c = 331.500 + 0.607 * t \quad (1)$$

Using the reflection principle, the sensor measures the time between the transmitting pulse and echo pulse of the ultrasonic wave. The relation between velocity, distance and time:

$$V = \frac{D}{T} \rightarrow D = V * T \quad (2)$$

Considering the distance is traveled to times and using the sound velocity:

$$d = c * T / 2 \quad (3)$$

Using the equation (1) and (3) considering the temperature of the ambient 20°C:

$$d(\text{cm}) = \frac{0.0343(\text{cm}/\mu\text{s}) * t(\mu\text{s})}{2} = \frac{t}{58} (\text{cm}) \quad (4)$$

4. The devices

4.1. Ultrasonic sensor SRF05

This is the model of the Ultrasonic sensor used, it has been developed to increase flexibility, increase range and reduce costs and it can operate in two modes.

Fig.1. SRF05 modes, pin assignment and timing diagram

The first mode uses separate trigger and echo pins, and is the simplest mode. To use this mode is just necessary to leave the mode pin unconnected. A pulse, with the minimum of 10

μs , is applied at the trigger input pin of the sensor and as consequence an ultrasonic burst of eight cycles is emitted. Then the sensor waits until an echo to be detected, right after detecting it the sensor lowers the echo line generating a pulse. In the case when no echo is detected by the sensor it will lower the echo line anyway after the timeout of 30 ms.

The second mode uses a single pin for both Trigger and Echo signals, and is designed to save valuable pins on embedded controllers. To use this mode the mode pin must be connected to the ground pin.

With this configuration the echo signal will appear at the same pin as the trigger signal, the same pulse, with the minimum of 10 μs , is applied at the trigger input port of the sensor and as consequence an ultrasonic burst is emitted. Then the SFR05 will not raise the echo line until 700 μs after the end of the trigger signal. This time is used to turn the trigger pin making it an input and activating the pulse measure code. Now that the pin became an input it's possible to measure the echo pulse and calculate the distance as in the first mode, there is also a time out of 30 ms in case no objects are detected. After this timeout or detection of an object happen the pin must be turned again making it an output and then it can send another trigger signal.

Although the first mode is easier to implement it spends twice as much controllers pin than the second mode. Then, besides the higher complex treatment level of the data using the second mode, this is the one chosen to be used in the project.

4.2. Mobile Robot

This component is the physical structure where the sensors and the microprocessor will be coupled. It's made in a steel carcass with the dimensions displayed in Figure 2.

Fig.2. Mobile robot structure and dimensions

4.3. PIC Microcontroller

This component is responsible for all the calculations of the data extracted from the sensors and to elaborate a response. It must have an algorithm to sequentially scan the sensors and determine the position of the obstacles around the Mobile Robot and generate a response for the motors in order to avoid these obstacles.

5. Sensor displacement

Each ultrasonic pulse generated by the transducer has the dispersion pattern shown in Figure 5.

Considering the geometric form of the sensor's beam pattern on Figure 3 and of the robot's frame there was made a study to find the best displacement of the sensors. The most important factor was the blind area, the spots where no sensor could detect an object. The red area is the robot, the yellow one is the area covered by one sensor, the orange the area covered by more than one sensor and the purple area is the blind area.

Fig.3. SRF05 beam pattern and modeling simplification

The first displacement was made using four sensors, it was a basic layout used to give a comparison point with more elaborate ones. This layout and is shown in Figure 4.a.

Fig.4. a - 4 sensors displacement, b - 10 sensors displacement

The blind area is 40% of the total area which is a considerable amount, so there were made several others layouts and the best one using the maximum of disposable sensors is show in Figure 4.b. This last one has almost no blind area, 0.64% of the total area, and also a superposition area of 47.45%.

6. Conclusion/Summary

The main goal of this paper was to find the best displacement of the ultrasonic sensor around the robot in order to detect any object that approaches the surroundings this robot. Observing the results and the figures it's possible to see that the displacement using ten sensors is the best option covering almost all the area around the robot. It is very important, because this mobile robot in future will be autonomously operating in *iSpace* laboratory of the faculty, [6].

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