BlindCrown - Classification and characteristics of proximity sensors

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1 Introduction

Often during the development of environment-interactive systems, we find ourselves in the need to measure the distances between objects. In such scenarioes we connect proximity sensors to our system and measure their output, but there are so many different types of proximity sensors that we cannot help but ask: which should we choose? This document is meant to shed some light onto the question above.

2 Classification based on the technology used

Based on the principles and the type of signal used, there are multiple categories of proximity sensors.

2.1 Inductive proximity sensors

Inductive proximity sensors function using electromagnetic principles. They emit an oscillating electromagnetic field. Upon reaching a metal object, currents that drain energy from this field are generated, decreasing the amplitude of the oscillation. The sensor detects changes in amplitude over and under a certain threshold, determining a switch in the output. We can now conclude that the output of these types of sensors has a binary form: either metal is nearby or it is not. They are not used to measure distances, only to detect changes.

2.2 Capacitative proximity sensors

Capacitative proximity sensors use an electric field instead of an electromagnetic one. This allows them to detect a larger variety of materials. Similarly to the inductive sensor principles, capacitative sensors measure with the environment via the amplitude of the field, which changes depending on the type of material and its proximity. Under a certain threshold a signal is triggered, switching the state of the sensor from on to off, or viceversa. The output is, as described above, also binary.

2.3 Ultrasonic proximity sensors

Ultrasonic sensors follow these simple steps for measuring distances:

1. propagate an ultrasonic beam
2. wait until the beam hits an object and the sensor receives the signal back
3. measure the time it took for the beam to return and calculate the distance off of a known signal velocity and the duration

This principle makes it so that ultrasonic sensors can measure distances continuously. Due to their nature, ultrasonic sensors have a "blind zone", a minimum distance where they cannot be used to measure anymore, the beam returning too quickly for the sensor to account for. If any material is placed in the blind zone of the sensor, the detection will fail.

3 Characteristics of different types of proximity sensors

3.1 Inductive proximity sensors

Usage:

- in security as metal detectors
- in production for determining the presence and/or position of a piece of metal on an assembly line
- in robotics for determining whether the position of a robot's part is correct or not

Advantages:

- high precision and detection speed
- not affected by harsh environmental conditions (wind, rain, dust, etc.)
- durability

Disadvantages:

- can only detect metals
- short range detection

3.2 Capacitative proximity sensors

Usage:

- liquid level detection
- in quality control to detect whether a specific material is present or not

Advantages:

- wider varienty of materials
- adjustable sensing range

Disadvantages:

- can be affected by environmental conditions
- detection sensitivity is dependent on the material (based on its dielectric constant)

3.3 Ultrasonic proximity sensors

Usage:

- RADAR and robotics systems for position detection
- in pipelines for flow monitoring
- in the automotive industry for parking assistance

Advantages:

- high accuracy
- analog output
- wide range of distances based on the amplitude of the beam

Disadvantages:

- sensitive to extreme weather conditions
- affected by sound absorbant materials and the rotation of surfaces relative to the sensor's beam
- slower response time compared other types of sensors

4 Further expansion on ultrasonic proximity sensors

Most ultrasonic sensors are made up of 2 main parts: a transmitter and a receiver. The transmitter's job is to generate the sound waves that are used to measure distance. The receiver captures the sound waves that come back after they collide with something.

On the connection side of things, a typical ultrasonic sensor uses 4 pins:

- VCC - the power pin
- TRIG - the output pin; it transmits the sound wave
- ECHO - the input pin; it gets triggered when the wave returns
- GND - the ground pin

On the physics side, the sensor will be used together with a simple formula: $d = v * t$. By measuring the time between the signal sent and the signal received and knowing the speed of sound through the air ($343m/s$ for the air at $20°C$), the distance can be easily calculated. The only thing we would have to account for is that the timestamps are for a round trip, so we would have to divide the resulting distance value by 2. Since a typical sensor does not come with a processing unit that manages the calculation for us, we will need to do it on our microcontroller.

Specifically on the HC-SR04 sensor, a basic ultrasonic proximity sensor designed for microcontrollers like Arduino boards, this is the process of measuring distance:

1. Connect the VCC pin to power (5V) and the GND pin to the Arduino board's grounding.
2. Send a signal to the output TRIG pin for 10 microseconds to trigger the pulse. After 10 microseconds, the ECHO input pin will be set to HIGH by the sensor until the sound wave returns.
3. Use a function like pulseIn() to measure the time it takes for the ECHO pin to change from HIGH to LOW.
4. Calculate the distance using this delta time and the speed of sound, as explained above.

5 References

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