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# Obstacle Avoidance Sensors: A Brief Overview

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**Abstract:**

The mobile robots development, which is extremely relevant at the moment, is not limited to the creation of the robot design itself. In order for the robot to perform tasks and achieve its goals, it is necessary to develop a control system for it. When it comes to mobile robots, and even more so about autonomous robots, the tasks of planning the path of movement of the robot and its parts, including actuators, come to the fore. To perform such tasks, a variety of sensor-based sensing systems are widely used. There are a huge variety of different types of sensors that are used to control a robot. However, there are no ideal summer cottages for all conditions. they all have their advantages and disadvantages. That is, to select certain sensors, it is necessary to take into account various parameters of the robot itself and its environment. This article provides an analysis of ultrasonic, laser and infrared sensors. their advantages and disadvantages are described, and recommendations are given in which cases and what type of sensors is best to use.

**Key words:** Mobile robot, Autonomous robot, Sensor, Ultrasonic sensor, Laser sensor, Infrared sensor

## Introduction

In the modern world, the use of mobile robots, that is, robots that can move in space, is becoming more and more common [1]-[8]. They are used in completely different spheres of human life, ranging from various types of production to social support for people in various life situations.

At the same time, the key characteristic of a mobile robot is its movement in space. And very rarely such spaces do not contain some kind of obstacles. Consequently, there is a need to bypass these obstacles or avoid them. In general, we talk about the need to avoid collisions with obstacles.

To solve this problem, various approaches are used [9]-[16]. If the environment in which the mobile robot is located is deterministic, that is, its parameters such as the location of obstacles, including walls, as well as passages between them constantly, then it is possible to write a strict program for movement along a given trajectory. Otherwise, that is, in a changing environment, and also unknown in advance, writing such a program cannot certainly solve the problem.

For such cases, all kinds of sensors are used to identify an obstacle and, accordingly, adjust the robot's path of movement. Many works address this problem [17]-[21]. However, each type of sensors has its own advantages and disadvantages especially in changing conditions [22], [23]. That is, for each specific task it is necessary to analyze the operating conditions of the robot and select the most suitable type of sensors or their combination.

Thus, the task of determining the necessary sensors is extremely relevant.

## Related works

Many works consider the problem of choosing sensors for mobile, including autonomous robots, taking into account the assigned tasks and environmental conditions. Let's look at just a small part of them.

Alatise, M. B., & Hancke, G. P. in [24] consider autonomous mobile robots. In [24] they unravel the current literatures, the challenges mobile robot is being faced with. A comprehensive

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study on devices/sensors and prevalent sensor fusion techniques developed for tackling issues like localization, estimation and navigation in mobile robot are presented as well in which they are organised according to relevance, strengths and weaknesses.

Paper [25] proposes an autonomous mobile robot that has been developed with Light Detection and Ranging (LiDAR) sensor to avoid obstacle. Braitenberg vehicle strategy is used to navigate the movements of the robot.

In [26] authors use ultrasonic sensors HC-SR04. They used the step optimal method based on fuzzy control. And the results showed that using this method the spherical mobile robot completed the path planning.

Researchers also use 2D LiDAR in a nodding configuration in [27]. Using the proposed nodding LiDAR configuration, a strategy for navigation through occluded crop rows is presented.

Lee, J. and co-author in [28] suggest a method to classify human actions in real-time using a single RGB camera, which can be applied to the mobile robot platform as well.

Article [29] aims to design and implement the multiple adaptive neuro-fuzzy inference system architecture-based sensor-actuator (motor) control technique for mobile robot navigation in different two-dimensional environments with the presence of static and moving obstacles. In order to achieve this goal authors used three infrared range sensors that have been mounted on the front, left and right side of the robot, which reads the forward, left forward and right forward static and dynamic obstacles in the environment.

Scientists in [30] use 2D laser to avoid obstacles. And they note, that multi-sensor fusion plays a key role in 2D laser-based robot location and navigation. Here [30] they present a deep learning-based approach to localizing a mobile robot using a 2D laser and an inertial measurement unit.

Work [31] presents 2D laser scanner and a RGB-D camera using in order to navigate an autonomous self-learning robot in an unknown environment without a map or planner.

Thus, we see that scientists around the world are working on the problem of robot navigation using various sensors, as well as their various combinations. Later in this work we will look at several main types of such sensors, and also analyze their advantages and disadvantages.

## Analysis of some types of sensors for avoiding obstacles

Mobile robots have become an integral part of modern robotics and are widely used to perform various tasks in the external environment. These tasks can include navigating through mazes, performing reconnaissance missions, and gathering information about the environment. To collect this information, mobile robots use different types of sensors, which allow them to receive different types of data about the environment. In addition to video cameras and laser sensors, infrared sensors and ultrasonic sensors are also used to collect information about the environment. Each type of sensor has its advantages and disadvantages, and the choice of a certain type of sensor depends on the specific task of the mobile robot and the characteristics of the external environment.

The main sensors for measuring distance include ultrasonic sensors, laser sensors, and infrared sensors.

An ultrasonic sensor consists of an ultrasound generator, a receiver, and an electronic circuit.

The ultrasound generator is responsible for creating high-frequency sound with a wavelength from 20 kHz to 200 kHz. These are sound waves that do not cause a harmful effect on people, but can be perceived by technical means.

The ultrasound receiver receives the ultrasound signal reflected from the object and converts it into an electrical signal. It can operate in high sensitivity mode to detect even weak echoes from objects at a considerable distance.

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The electronic circuit is responsible for processing the signal generated by the ultrasound receiver. It can include noise filtering, amplification, and various signal processing operations such as noise reduction and signal amplification (Figure 1).

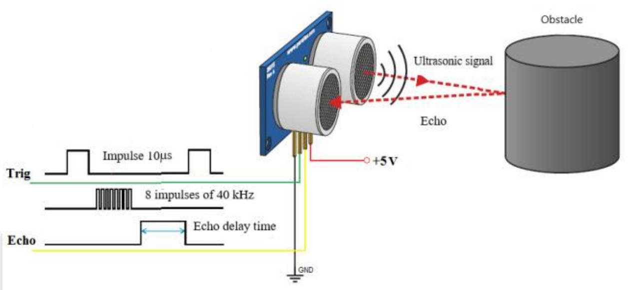


**Figure 1:** Ultrasonic Sensor Operation

The laser sensor consists of a light source - a laser emitter, a receiver and electronics for signal processing. A laser emitter emits a laser beam with a specific wavelength. This beam is directed to the object, and then reflected from it.

The receiver of the laser sensor consists of a special photodiode, which is able to receive the laser beam returning from the object. When a laser beam falls on a photodiode, it generates an electric current. This current is then amplified in an operational amplifier to obtain a sufficient signal level for further processing (Figure 2).

An infrared sensor consists of an emitting LED, a receiving photodiode, and optical components such as lenses and filters. An LED-emitter generates infrared light with a certain wavelength. This light is directed to the object, and then reflected from it.

The photodiode-receiver is used to register the infrared light that is returned from the object. The photodiode is sensitive to infrared light and generates an electric current that depends on the intensity of the light (Figure 3). The main element of such motion sensors is a sensitive pyroelement, which reacts to an increase in temperature in the control zone. Such sensors usually have a capture zone of 120° and react to an object moving at a distance of 12-15 meters horizontally. Infrared devices are equipped with a cellular Fresnel lens that forms several capture zones.

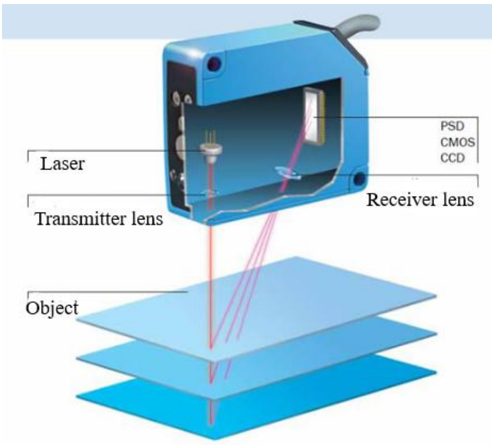


**Figure 2:** Laser Sensor Operation

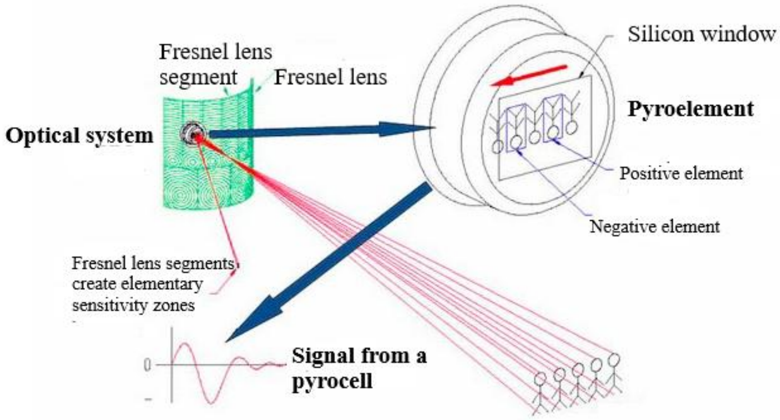


**Figure 3:** Infrared Sensor Operation

To compare the performance of the three distance sensors, we evaluated the accuracy, range, response time, and environmental sensitivity of each sensor.

To assess the accuracy of each sensor, we measured the distance to the object and compared it with the sensor's measurements. To do this, we used objects with known lengths, such as metal rulers and technical drawings. We compared the measurement results with the real length of the object, which allowed us to assess the accuracy of each sensor.

To estimate the range, we used objects at different distances from the sensor and measured the distance to them. For this, we used the distance to walls and other objects indoors and outdoors. The results of measuring the sensors at different distances allowed us to compare their range and accuracy at different distances.

The reaction time of each sensor was measured from the moment when the object appeared in the sensor's range to the moment when the distance to the object was displayed. Reaction time was measured under various conditions, including changes in lighting and speed of movement of objects.

To evaluate the sensitivity to environmental factors, we conducted tests in different conditions, including different levels of light and reflectivity of materials. For example, we tested the sensors on materials with different reflectivity, such as wood, metal, and glass. We also tested the sensors in conditions with dust, moisture and other factors that can affect their performance.

The results of our research showed that each of the three sensors has its own advantages and disadvantages.

The ultrasonic sensor was the most accurate of the three sensors, with a distance measurement accuracy of up to 1 mm. It also had the highest sensitivity to surface reflectivity, allowing it to detect objects up to 4 meters away. It also had a very high adaptability to pollination. However, its disadvantage was that it was less far-sighted than a laser sensor, that is, it could not detect objects at a distance of more than 4 meters. Also, its accuracy was dependent on temperature and air humidity, which reduced its reliability in some conditions.

The laser sensor was the most far-sighted of the three sensors, allowing it to detect objects up to 30 meters away. It also had high measurement accuracy and was less sensitive to environmental factors than an ultrasonic sensor. However, its drawback was that it was less sensitive to surface reflectivity, allowing it to detect objects up to 30 meters away on only some materials. Also, its sensitivity to temperature and humidity was slightly higher than that of an ultrasonic sensor. This is due to the fact that the laser sensor works on the principle of measuring the distance to the object using a laser beam that does not depend on weather conditions.

The advantages of infrared sensors include high accuracy. Infrared sensors typically have high measurement accuracy over small distance ranges, which is important for many

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applications. It also has a wide temperature range, including high temperatures, making them ideal for use in high temperature areas such as metallurgy and glass manufacturing.

But they perform poorly at long distances: infrared sensors are not the best choice for measuring long distances due to their limited operating range. Infrared sensors can give an inaccurate result if they encounter obstacles in the environment, such as dust, smoke or fog. An infrared sensor needs visibility because it depends on the reflection of infrared radiation from the object it is measuring. If the object is too dark or does not reflect infrared radiation, the sensor will not work properly.

Thus, we can draw the following conclusions from the test results:

- the ultrasonic sensor has a fairly high distance measurement accuracy, but is very sensitive to various environmental factors such as wind, humidity and temperature. The range of the sensor reaches 4 meters, which ensures its effectiveness in large industrial premises with a significant number of obstacles.

- the laser sensor has a very high accuracy of distance measurement and a range of up to 40 meters, which ensures its effectiveness in most industrial conditions. However, it is very sensitive to surface reflectivity and lighting levels, so it requires a more careful approach to setup.

- the infrared sensor has a low accuracy of distance measurement and a range of up to 1 meter. It is less sensitive to environmental factors and surface reflectivity, but may be limited in industrial use due to limited range.

## Conclusion

This article discusses three types of sensors that are used to navigate mobile robots to avoid obstacles. Ultrasonic, laser and infrared sensors are considered. Their advantages and disadvantages are given. Recommendations are also given on the use of certain sensors depending on the parameters of the mobile, or autonomous, robot itself, as well as on the properties of its environment.

It should be noted that we looked at these classes, each of which contains a huge variety of sensors. Moreover, they differ in size, weight, sensitivity, operating time, response distance, sensitivity angle, cost, and so on.

When choosing sensors, you need to not just choose the most sensitive one, you need to calculate the necessary and sufficient sensitivity, including taking into account the cost of the sensor itself.

Also, when using a combination of several sensors of one or more types, it is necessary to take into account the possible mutual influence of the sensors on each other.

So, depending on specific requirements and application conditions, each sensor can be effective in its field of application. For example, an ultrasonic sensor can be advantageous in rooms with many obstacles, where the required accuracy of the measurement is not critical. A laser sensor may be a better choice for open spaces with a higher level of measurement accuracy. Infrared sensors can work more effectively than laser and ultrasonic sensors in high temperature situations.

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