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Optical distance measurement systems

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Abstract: The article deals with optical systems suitable for distance measurement. Contactless distance measurement must be implemented, for example, when detecting the presence of persons and objects in the monitored area. In industry, there are increased demands on measurement uncertainty using these systems. In these cases, verification and calibration of these measurement systems are also necessary.

1 Introduction

Optical measurement systems are intended for non-contact measurement of the distance of objects. Light in the visible or invisible light spectrum is used. From a physical point of view, the triangulation principle or the Time of Flight (ToF) principle is used. The modulated light is mostly used to eliminate the influence of daylight, and a day-light filter is used to separate the measurement signal from other light sources. Compared to traditional measuring systems based on other physical principles, these optical systems are advantageous mainly due to their reliability and durability. Their disadvantage is, for example, operation in a polluted environment, which causes the measurement system to malfunction [1-7].

From a price point of view, optical measuring systems are mostly quite expensive, but there are also cheaper solutions that are commonly used in traditional products such as copiers, printers, automatic devices and other applications. This article examines precisely these low-cost optical sensors, which are very popular due to their favourable price and good reliability. These sensors' operation principles are based on the triangulation principle (Figure 1). The range of these sensors is from 4 cm to 1.5 m, depending on the type, and the output signal of these sensors is analogue electrical voltage.

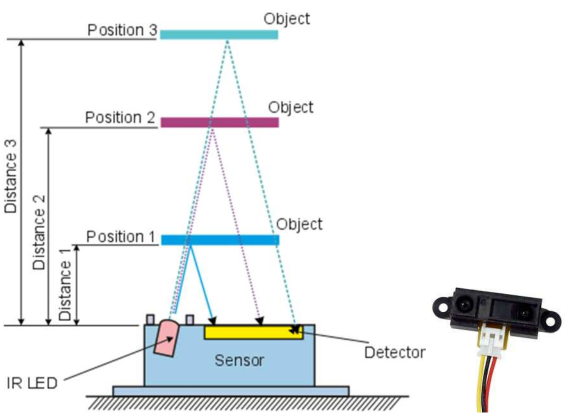

Figure 1 The principle of optical sensor for distance measurement

This tested type of optical sensor [8] is also very popular in mobile robot applications. It is an affordable type of sensor that can be easily applied to mobile robots and other applications (Figure 2, Figure 3) controlled by microcontrollers.

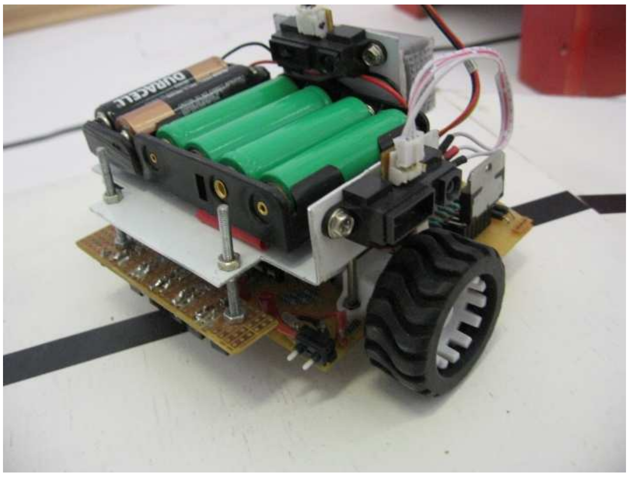

Figure 2 Line follower robot with applied optical distance sensors

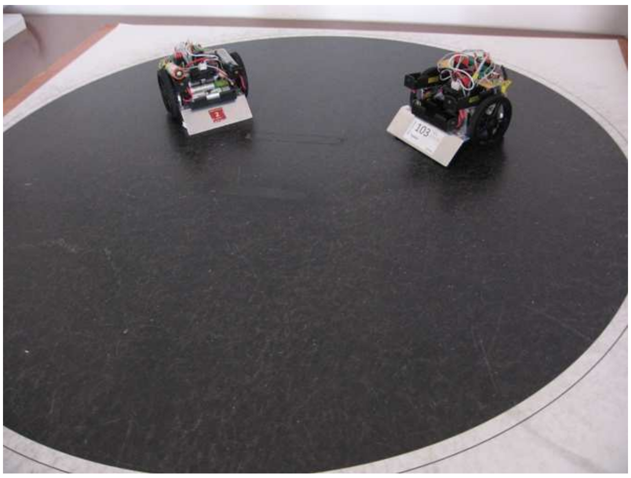

Figure 3 Sumo robots with applied optical distance sensors

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2 Experimental verification of sensor

The manufacturer of the optical sensor provided a graphic form of the static characteristic (Figure 4) in the datasheet for the sensor. It follows from this graphic process that the electric voltage is the carrier of information about the measured distance of the object. The area of the measurement range up to 3 cm distance is unusable for duplicate output values. The sensor can only be used from an object distance of more than 3 cm [8].

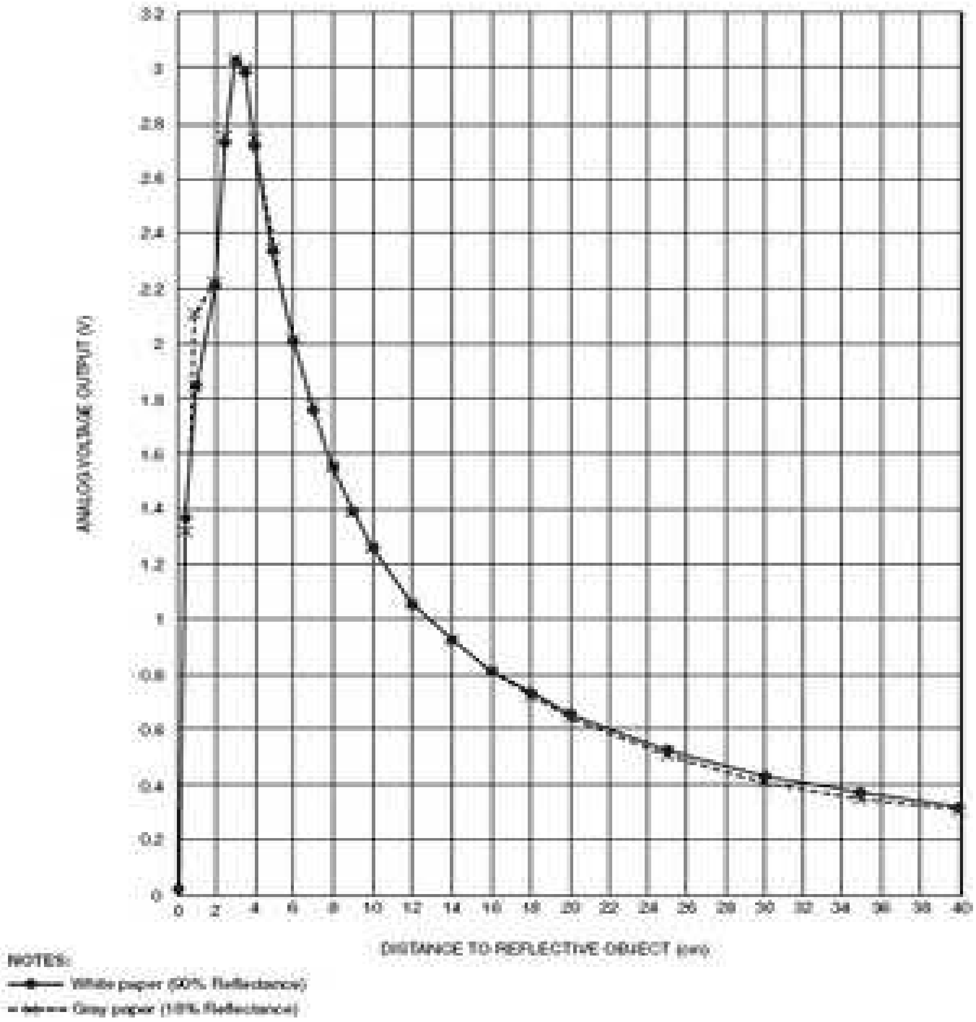

Figure 4 Static characteristics of the sensor [8]

For testing the distance sensors, the apparatus that was used for the investigation of the sensors was already assembled (Figure 5). However, the measuring range of this apparatus is only up to 200 mm and it is not sufficient for testing the optical distance sensor. Length gauge blocks were used as a distance standard and the output voltage values were monitored.

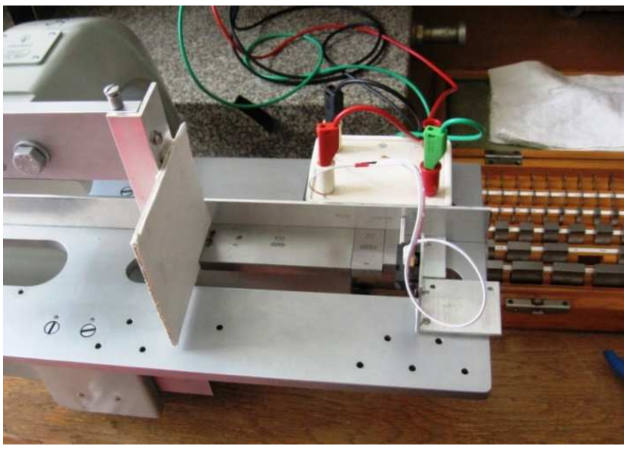
Figure 5 Pipe robot arrangement with adjustable bristles

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Based on experience from experimental testing of optical sensors, another apparatus was designed, which already enabled testing of optical sensors in the range of 1200 mm (Figure 6). The target measured surface was formed by a wooden board with a replaceable surface, on which different types of materials for testing can be placed with the help of clips. The reflecting surface can be moved along a linear guide and at the same time it can be rotated in the range of +-45° so that it is also possible to test the effect of non-perpendicularity of the reflecting surface (Figure 7).

Figure 6 Improved apparatus for testing the optical distance sensor

The sensor is placed on a height-adjustable platform (Figure 8) so that it can be positioned so that it does not interfere with objects other than the reflective surface. Setting the distance of the reflective surface from the tested optical sensor is realized using a set of length gauge blocks.

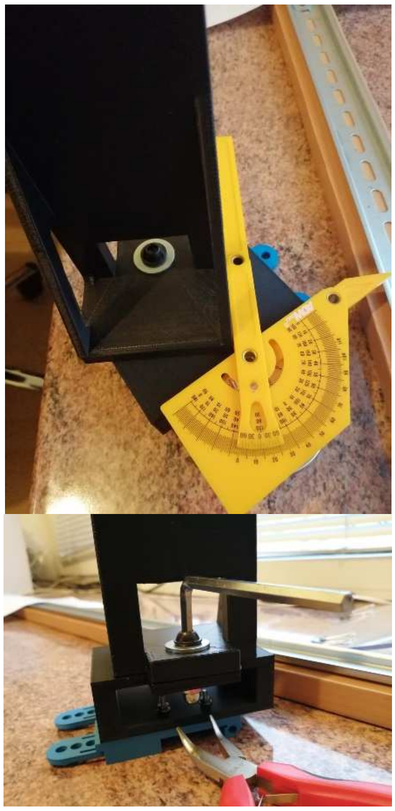

Figure 7 Adjusting the rotation of the reflective surface

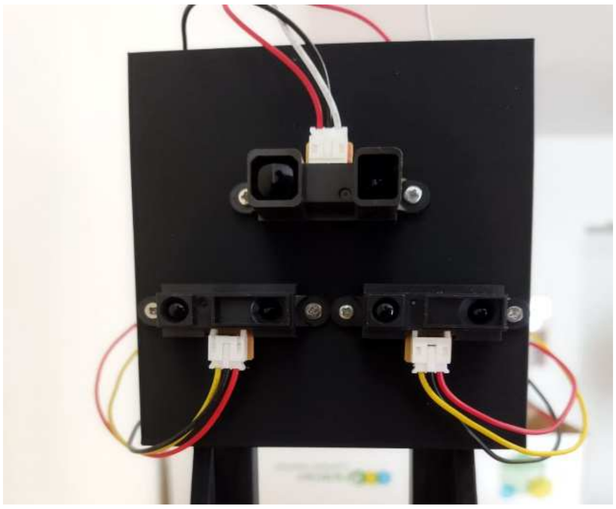

Figure 8 Location of the tested sensor

3 Results of experimental testing of the optical distance sensor

Colored papers with matte colors in shades RAL-3024, RAL-6027, RAL-6018, RAL-1016 were used for the measurement (Figure 9), which were placed on the reflective surface of the apparatus. The distance of the sensor from the reflecting surface was gradually adjusted using length gauge blocks. The response of the sensor was monitored using a multimeter, which was used to measure the output voltage.

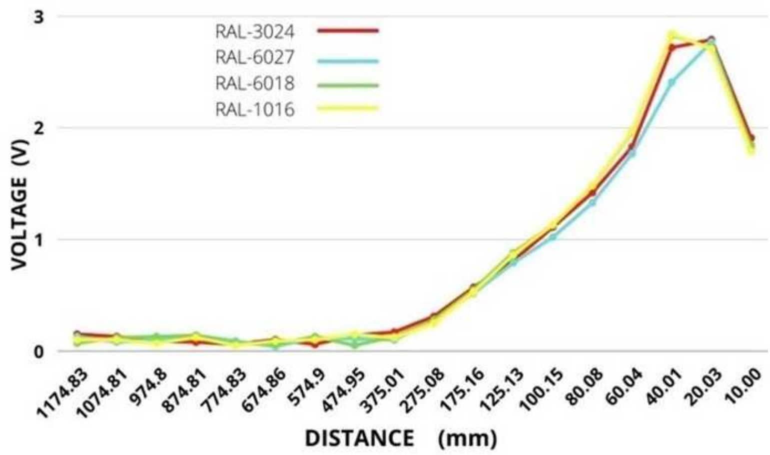

Figure 9 Electric voltage when approaching the optical sensor to a reflective surface with different colored surfaces

The data obtained from the tested sensor were approximated by a mathematical model of static characteristics (Figure 10). For application purposes, it is advisable to use the range of the sensor in the interval from 30 mm to 200 mm. The created calibration characteristic (Figure 11) from this selected working interval is then approximated by a polynomial mathematical model (Figure 11), which is already practically applicable in any controller or microcontroller, which, using this mathematical model, will be able to convert the output voltage of the sensor to the values of the measured distance.

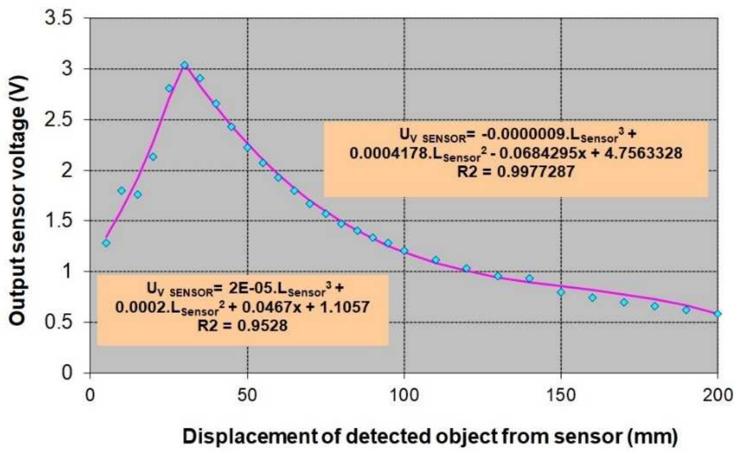

Figure 10 Experimental static characteristics of the tested optical distance sensor

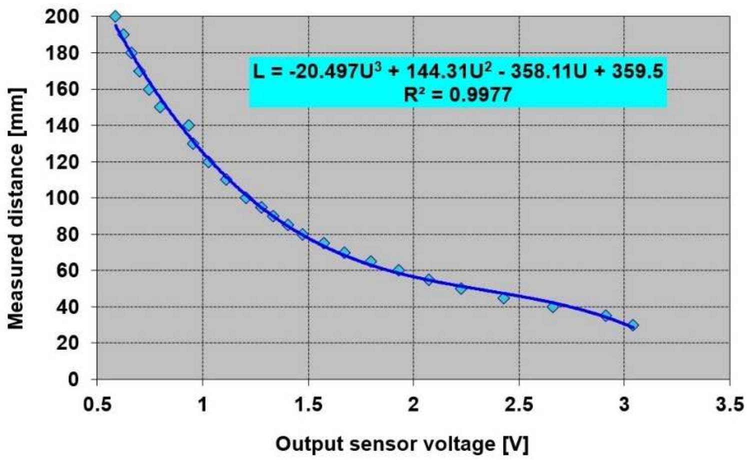

Figure 11 Calibration characteristic of the selected working interval of the tested optical distance sensor

4 Conclusion

The tested optical distance sensor is an affordable sensor for non-contact distance measurement of objects. Although the calibration characteristic is non-linear, it can be described by a mathematical model that was created in this work, and this model can be implemented in a microcontroller to convert the sensor's output voltage to the measured distance. The influence of the color of the reflective surface of the object was also tested, where no significant difference was demonstrated when using different surface colors [22-23].

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