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An Analysis of Target Materials Influence on Optical Sensors Performance

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***Abstract*—the performances of the optical sensors systems are influenced by the target materials, by the distance from sensor to target and the angle of target according to sensor. The type of target material influences the response of optical sensors systems according to their physical properties. The sensor performance is influenced by the color, by the density, by the shape and the others physical properties. This paper presents the influence analysis of the target materials of the optical sensors performance for autonomous mobile robots. Measurements were made with infrared distance sensors and with the proximity sensor with visible light.**

***Keywords*—optical sensors; optical reflection; infrared sensors; distance measurement; performance analysis**

I. Introduction

This paper presents the behavior analysis of the optical sensors systems for different target materials. Optical sensors are used in a wide range of applications, due the advantages and costs.

Optical sensors are important for autonomous mobile robots and other applications. The behavior of optical sensors is disturbed by the misinterpretation of ray reflected from the surface, or the lack of reflected ray. In applications like autonomous mobile robots, is required that the values returned by sensor, to be accurate as possible. Because of the errors generated by reflected ray, mobile robots are affected when they need to take fast decisions.

II. Theoretical background

The fundamental principle that underlies on behavior analysis of the optical sensors system is based on the reflection law. The direction of incident ray and the direction of reflected ray make the same angle with respect to the surface normal. [1][2]

The equation reflected ray is related by the following relation:

$$\theta_i = \theta_r \tag{1}$$

The aim of this study is to reveal the behavior of the optical sensors systems, at the interaction at different distances with multiple types of materials. To achieve this purpose several measurements were made on different types of optical sensors systems. The first problem to achieve this measurement was the highly rouge surfaces which implies a non-ideal surface.

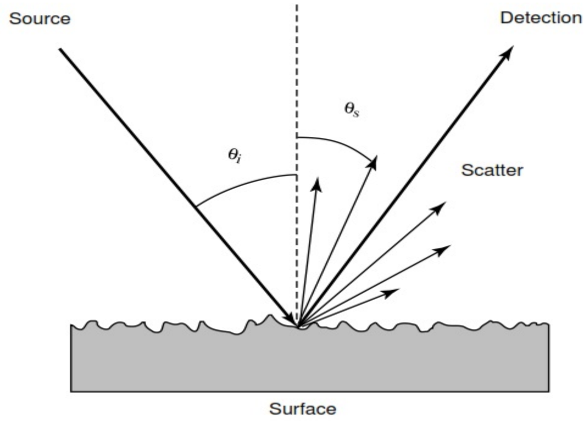

Figure 1. The Bechmann model of the specular reflection [3].

Using the approximation Beckmann arrives at a general result for the angular distribution of the electromagnetic radiation incident to a rough surface. The relation of the mean power for the reflection coefficient on the one dimensionally case of the rough surface is related by the following equation [3]:

$$< |R_1|^2 \geq \frac{A}{4\pi r^2}\frac{\nu^4}{\nu_z{}^4}\frac{T^2}{\sigma^2}\exp\left(\frac{\nu_{xy}{}^2T^2}{4\nu_z{}^2\sigma^2}\right) \tag{2}$$

where A is the illuminated area by the incident light, r is the sensor distance to the detector, v_x , v_y , and v_z are the x,y and z axes components specify for the parameter v the parameter v is determined by the incident (θ_1) and scattered (θ_2 and θ_3) angles and represents the sum of the parameters v_x, v_y and v_z in quadrature. v_{xy} represents the sum of v_x, and v_y in quadrature, the parameter σ is the *rms* roughness and T is the correlation length of the surface [3].

III. Measurement Protocol

A protocol was established to achieve the measurements of the optical sensors system behavior. The measurements were made at the distance of: 0%, 50% and 100% of measuring

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range for each type of sensor. In order to obtain relevant results, target materials with different proprieties placed perpendicular to the sensor were used.

The materials used as target materials are the following types: black rubber, brown felt, gray sponge, brown plywood, artificial black fur, transparent plexiglass, white paper, green matt aluminum, black painted plexiglass with painted side to the sensor or in the back, and ribbed aluminum plate. The black painted plexiglass is a piece of plexiglass, painted on one side and normal on the other side. This material was tested on the both sides. These materials were used to determine the behavior of each sensor at different distances. In the case of Pepperl+Fuchs sensor, the target materials were also placed at the angle with values between 10° and 90° from sensor, at distances of 10cm to 80cm. On the measurements with the target placed in angle from sensor, the measuring range was tested from 5cm to 5 cm, for accurate results.

Two Sharp infrared distance measuring sensors and one Pepperl+Fuchs proximity sensor with visible red light were used for the measurements. For the first sensor: Sharp GP2D120XJ00 analog distance measuring sensor, the target materials were placed perpendicular to sensor at three established distances: 6cm, 15cm and 30cm. These distances represent the bottom, the middle and the top of the measuring range. The second sensor: Sharp GP2D12J0000F analog distance measuring sensor, was tested at the following distances: 10cm, 40cm and 80cm, with target materials perpendicular to sensor. The measuring range of the sensor is: 10-80 cm.

For the third sensor: Pepperl+Fuchs RL31-8-H-800-RT proximity sensor with visible light, the target materials were placed at distance of 10cm to 80cm according to the sensor range.

IV. RESULTS

The results of the measurements, according with the established protocol were used to compare the performance of the sensors

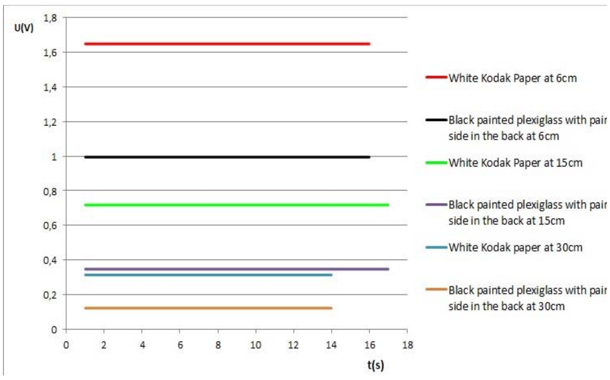

Chart 1. Measurements with Sharp sensor GP2D12J0000F.

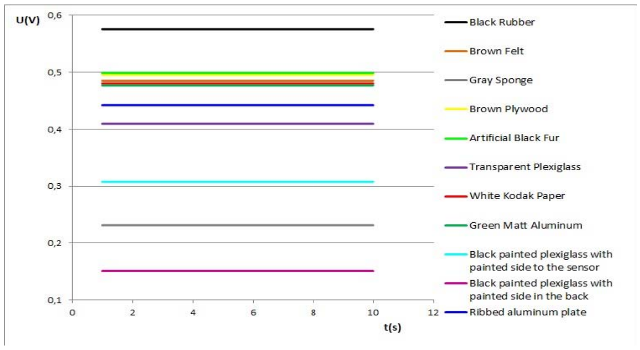

Chart 2. Measurements with Sharp sensor GP2D12J0000F at 80cm.

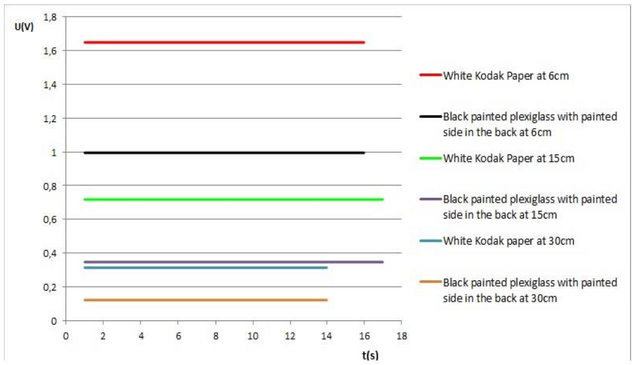

Chart 3. Measurements with Sharp sensor GP2D120XJ00.

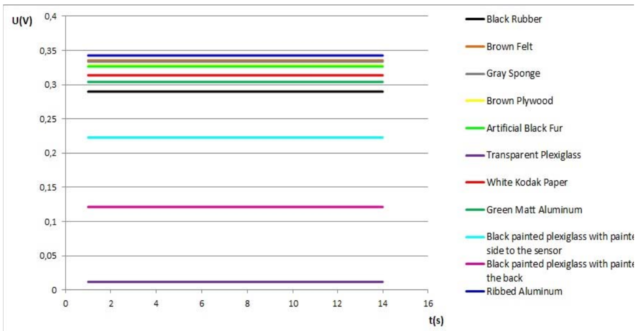

Chart 4. Measurements with Sharp sensor GP2D120XJ00 at 30cm.

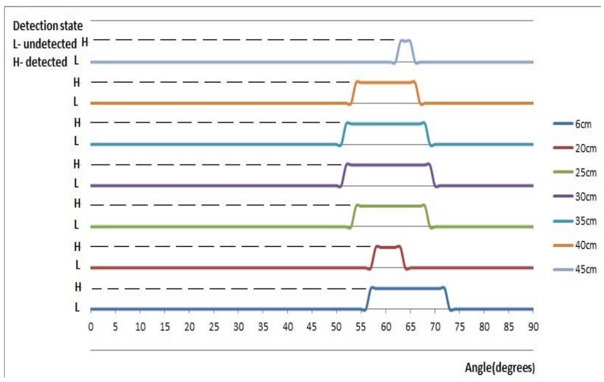

Chart 5. Measurements for black fur with Pepperl+Fuchs RL31-8-H-800-RT sensor.

From these measurements were possible to calculate the level of detection for black painted plexiglass reported to Kodak 100mg/m2 white paper for Sharp sensor GP2D12J0000F, which is the material with best reflection according to sensor datasheet. Using the values for white Kodak paper as reference values, were calculated the percentage share of distances measured for black painted plexiglass .The percentage share calculated for the material at the measuring distances are: 78.87% at 10cm, 76.85% at 40cm, 63.95% at 80cm.

Due to differences between the real distance and the distance measured by the sensor, a correction equation must be used for the most materials in order to obtain an accurate measure. In case of black painted plexiglass, the distances measured by sensor are different to the real distance.

The distances measured by sensor are different by the real distance. The distance read by the sensor at 10 cm was 6.49 cm, implied an error of 35.06%, at the distance of 40cm the detected distance was 13.64cm, and the implied error was 65.88% and for the 80 cm distance, the detected distance was 25.16 cm, implying an error of 68.55%.. For this material and not the only one, the correction equation must be proportional with the measuring error, to compensate the difference between the distance detected by the sensor and the real distance.

According to the measuring protocol, measurements with Sharp sensor GP2D120XJ00 were made. For this sensor were calculated the percentage share of measured distance, reported to the results obtained for the white Kodak paper at the same distances. The results used for the comparison were the ones obtained with black painted plexiglass with the painted side in the back as a target material. The percentage values are: 60,33% at 6cm, 48.8% at 15cm, 38.66%at 30cm.

In order to determine the correction equation, the measurements must be done to at a known distance, using target materials required for the respectively application.

For this study measurements were also made with a Pepperl+Fuchs digital sensor that only detects the presence of objects in its range. During tests, this sensor detected with no problems, all the materials used except one. The material that was not detected or the detection was poor is: artificial black fur. This material is an artificial fur, colored in black, whit a dense structure of fibers. If the fibers of the material are randomly oriented, the material is not detected.

After few measurements, were observed that the material is detected only if all fibers are oriented to the receptor diode. Even if the fibers are right oriented; the material is detected only between certain angles and distances as showed in chart. 5.

The explanation of these anomalies resides in specular reflection, and can be explained by the Beckmann theory. For artificial black fur the Sharp and Pepperl+Fuchs sensors offer different responses due to different wavelength of light used by the sensor. In the case of Sharp sensor the light is in infrared spectrum, and for Pepperl+Fuchs sensor, the light is in visible spectrum with a wavelength of 680nm.

V. CONCLUSIONS

In the future are necessary more experiments to establish the sensors behavior in the case of mobile targets.

Sensors can be used for multiple applications: automated gates for airports or barriers, detection of packages for mail services and packing area of plants, backing tape detection, empty sleeve detection, spin box cover and distance monitoring on the spinning devices, in the unwinding system for coils of sheet metal for the manufacturing of body parts.

Also they are especially used for robotic, but the nature of the application must be analyzed in order to determine a correction factor.

For surfaces other than white paper, a correction factor must be applied to obtain the right results. Otherwise the results will be incorrect and the application where the sensors are used may not function properly.

The two types of sensors behave different on the artificial back fur due to the different wavelength of light, and how this light is reflected from this type of material.

VI. REFERENCE

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