Journal of Automation and Control, *2017*, *Vol. 5*, *No. 2*, *37-40*
Available online at http://pubs.sciepub.com/automation/5/2/1

DOI:10.12691/automation-5-2-1

Condition Evaluation of Optical Position Sensor

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Abstract Paper deals with experimental identification of condition of optical position sensor. Optical sensor can be sensitive to reflection surface on measured object. Measurement uncertainty is also evaluated.

Keywords: *sensor, position, uncertainty, condition*

Cite This Article: Tatiana Kelemenová, Miroslav Dovica, Eduard Jakubkovič, and Peter Sedlačko, "Condition Evaluation of Optical Position Sensor." *Journal of Automation and Control*, vol. 5, no. 2 (2017): 37-40. doi: 10.12691/automation-5-2-1.

1. Introduction

Many applications need contact less measurement of distance.

There are several ways of optical distance measurement:

- Time of flight measurement system
- Encoder measurement system
- Triangulation measurement system

The method used to measure distance depends on the accuracy and distance capability required of the device. Measurement principles include triangulation, time-of-flight measurement, pulse-type time-of-flight systems, and modulated beam systems

For distances of a few inches with high accuracy requirements, "triangulation" sensors measure the location of the spot within the field of view of the detecting element.

Time of flight sensors derive range from the time it takes light to travel from the sensor to the target and return. For very long range distance measurements (up to many miles) "time-of-flight" laser rangefinders using pulsed laser beams are used.

Modulated Beam Systems use the time light takes to travel to the target and back, but the time for a single round-trip is not measured directly. Instead, the strength of the laser is rapidly varied to produce a signal that changes over time [1].

Type of used optical range is often as:

- Visible light (red color)
- Infra-Red light

Laser beam source is frequently used for distance measurement. Laser light consists of light waves of the same wave length with a fixed phase ratio (coherence). This results in an important feature of laser systems that is the almost parallel light beam. Long ranges can be achieved thanks to the small angle of divergence. The laser spot which is also clearly visible in daylight simplifies the alignment of the system.

Laser sensors are used where small objects or precise positions are to be detected. They are designed as through-beam sensors, retro-reflective sensors or diffuse reflection sensors [1-24].

2. Time of Flight Measurement System

The distance is measured based on the time in which the emitted laser beam returns to the sensor after hitting the target. The detection is unaffected by the surface condition of the target. The sensor detects the time Δt that is the time until the reflected laser beam is received to calculate the distance L_{VZD}. The calculation formula is:

$$L_{VZD} = c \cdot \frac{\Delta t}{2} \quad (1)$$

Where c is light speed.

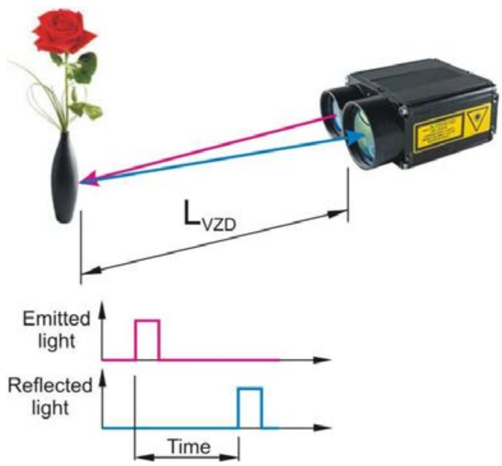


Figure 1. Time of flight position sensor principle

Phase shift between emitted and reflected light is evaluated but other way of measurement is evaluation and comparing of emitted light frequency and returned reflected light frequency.

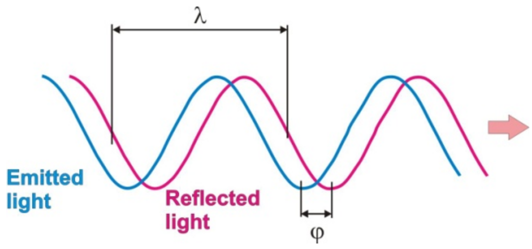


Figure 2. Phase shift between emitted and reflected light

This principle is also used in laser scanner (Figure 3). Pulsed infrared laser beam is emitted from LED diode through the optical systems to rotating mirror. Reflected laser beam is spreads to measured space and it is reflected from object back to the scanner. Beam returned from object spreads to optic system and mirror system and falls to photo sensitive detector. Working area is defined with angle of maximum mirror rotation [1].

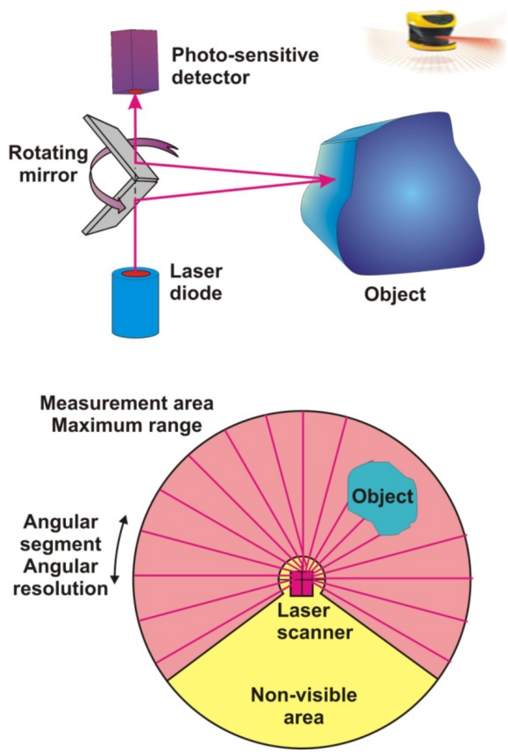


Figure 3. Time of flight laser scanner principle

Main advantage of laser scanner is simple integration into selected application thanks to compact construction and small dimensions. It can be used also in stationary and mobile applications as unmanned ground vehicle (UGV), unmanned aerial vehicle (UAV), Automatic Guided Carts (AGC), Automated guided vehicle (AGV), driverless autonomous car, safety protection of industrial robot working area or working area of automated production lines, navigation of mobile robots, mapping of environment and navigation [1-6].

3. Encoder Measurement System

Incremental position encoder is also called as pulsed encoder or incremental relative encoder IRC.

Principle of incremental encoder lies on fact that movement of the measured object causes the change of reference coded ruler position. Reference coded ruler consist of dark segments alternates transparent segments.

Light from optocoupler is interrupted with dark segments. This arrangement produces square wave. Direction of movement is recognized via using of another optocoupler shifted 90° out of phase from each other with the direction of movement. These two channels of square waves A and B can be completed with channel C called as reference which gives information about reference mark as end point, mid point etc.

Frequently used is also rotation incremental encoder.

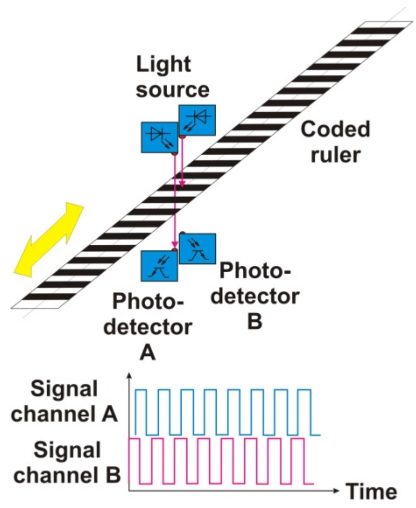


Figure 4. Incremental optical encoder principle

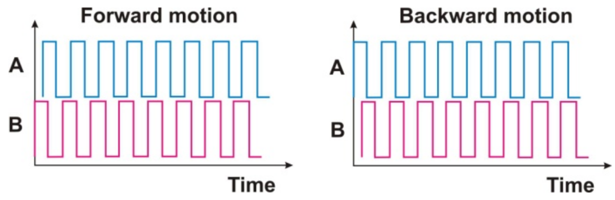


Figure 5. Recognition of motion direction of optical incremental encoder

4. Triangulation Measurement System

Triangulation method is frequently used principle of optical sensors. Laser beam falls to surface of measured object and its reflection returns into photo sensitive detector – PSD sensor. Change of distance causes the change of returned beam intensity and beam returned position on PSD sensor surface – it is called as "Diffuse Laser Triangulation Principle" (Figure 6 left). The reliability of this measuring principle also depends on type and quality of object surface. This principle can be used also for measurement of highly reflective objects or mirror surface objects. The arrangement of sensor for reflective surfaces is changed for this reason (Figure 6 right). It is also called as "Specular Laser Triangulation Principle".

Large measurement range is obtained via using of suitable optics.

Source of light is often semiconductor laser diode with several mW of power. Wavelength of used light is in range of 560 to 670 nm (red light). Nowadays also sensors with blue light are also available. Sensor is position sensitive detector mainly as CCD sensor. Its signal is processed with fast signal processor, which is able quickly to count measured distance from information about position of reflected light spot.

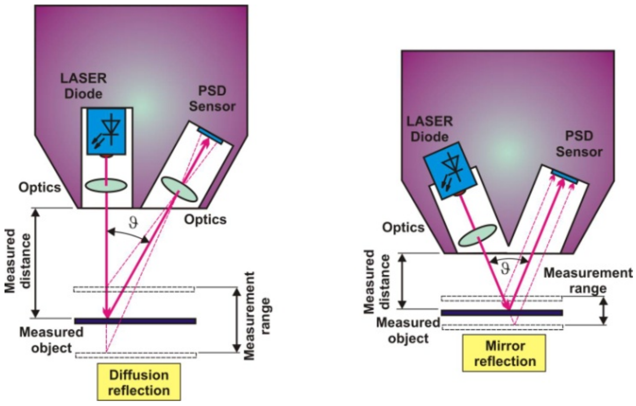


Figure 6. Optical triangulation position sensor principle

5. Experimental Verification of Properties of optical Triangulation Distance Sensor

The optical triangulation distance sensor has been tested for distance measurement against the object with various surfaces (black, white and mirror – reflective surface) (Figure 7).

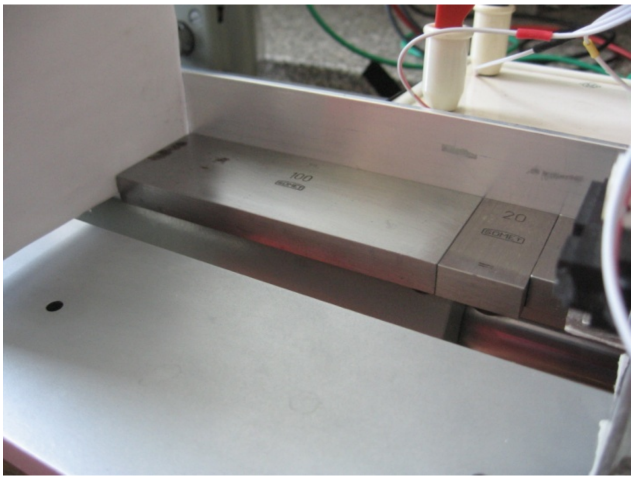


Figure 7. Experimental verification of optical triangulation distance sensor

Set of gauge blocks has been used for calibration of the sensor. Calibration of the sensor has been executed in accordance with standards (EA-4-02rev01) [2]. Temperature if the room has to be regulated via using of air condition at the 20±1°C.

Step of measurement was 10 mm and every tenth millimetre was measured ten times in range of 50 mm to 1000 mm.

Measured data have been stored into the evaluation table. It is possible to evaluate static characteristic shown on Figure 8

Measured data has nonlinear dependence. Color sensitivity occurs only after distance 600 mm. Up to distance 600 mm there is no sensitivity to color of reflection surface of measured object. Measure sensor uses the diffusion reflection principle and for this reason values from measurement on mirror reflection surface differ from standard non-mirroring surface.

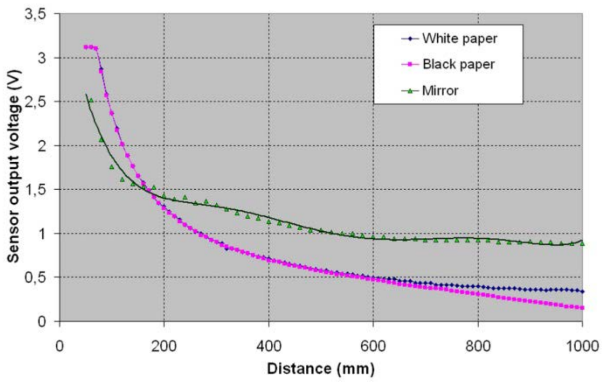


Figure 8. Static characteristic of optical triangulation distance sensor

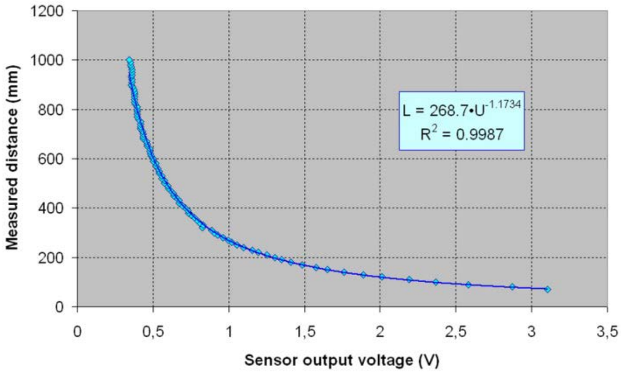


Figure 9. Calibration characteristic of optical triangulation distance sensor measured on white paper reflection surface

Calibration characteristic (Figure 9) is very well fitted with exponential math model. This math model can be used as form for recalculation of measured output sensor voltage to distance of sensor from measured object. If the sensor will be connected to any controller, this math model can be inserted into program code for calculation of distance from measured sensor output voltage.

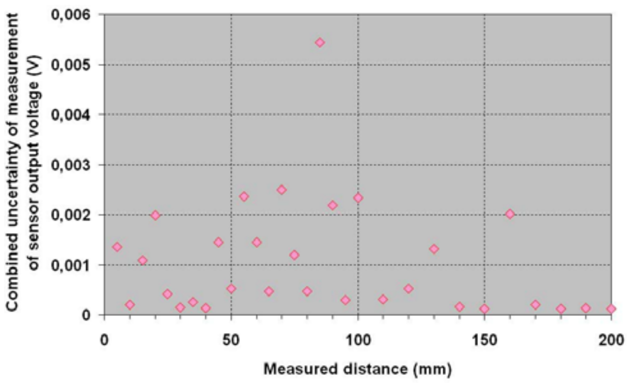
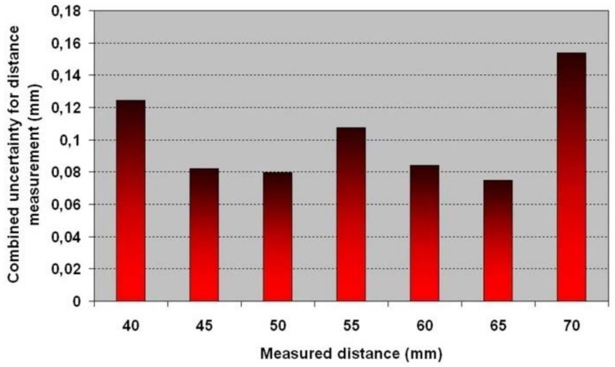


Figure 10. Combined uncertainty of measurement of sensor output voltage for optical triangulation distance sensor measured on white paper reflection surface

Figure 10 shows the combined uncertainty of measurement of sensor output voltage for the tested optical distance sensor. The uncertainty is obtained for measurement on sensor via using of multimeter HP 34401A.



Figuue 11. Combined uncertainty of distance measurement for optical triangulation distance sensor measured on white paper reflection surface

In accordance with standards (EA-4-02rev01) [2] can be evaluated the final combined uncertainty of distance measurement for tested optical distance sensor (Figure 11). It was evaluated on desired range from 40 mm to 70 mm. The evaluation shows that maximum uncertainty (Figure 11) is 0.15 mm. It is evaluated for sensor connected to mentioned multimeter. Real application will differ because of different uncertainty of used equipment for voltage measurement (PLC or microcontroller or other DAQ device).

6. Conclusion

This type of sensor can be used in various application as automotive and supplier industries, mechanical engineering and special machine construction, assembly and handling, the packaging industry, handling and warehousing systems, steel industry, textile and paper industries, wood industry, security system, safety area of machines etc.

The paper shows evaluation results of tested selected sensor. The obtained math model will be used for calculation of distance from obtained sensor output voltage. Every measurement chain should be evaluated form the viewpoint of achievable uncertainty of measurement for identification of condition of tested measurement chain or other tested device [6-26].

Acknowledgements

The work has been accomplished under the research projects No. VEGA 1/0182/15, KEGA 014STU-4/2015 and APVV-15-0149 financed by the Slovak Ministry of Education.

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