Testing method for optical performance of infrared sensor module of autonomous vehicle

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Abstract

This paper presents a justification of performance test in module level and its testing methods for autonomous vehicles (AV). This work has been divided into three parts. In the first part, justification and related international standards. In the second part, the main factors to be measure to define a performance of module. Finally, present about test environment and introduce concept of automated system.

Keywords: infrared sensor, measuring method, LiDAR, optical module, autonomous vehicle

1. Introduction

With Fourth industrial revolution, need for motion sensor in IoT market and autonomous vehicle are dramatically increased. Sensor itself also expand its application from simple human occupation to analyzing the environment.

Table 1: application per type of sensor module

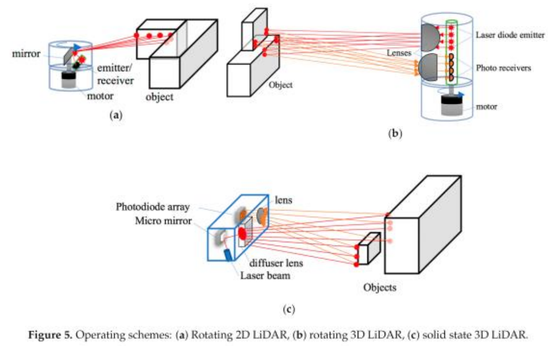
Wavelength	Type of sensor	Application
Far infrared (8~13um)	Pyroelectronics, Thermopile	Presence, temperature
Far infrared (8~13um)	Thermopile array, Microbolometer	Thermal image, temperature
Near infrared (905nm,940nm and 1550nm)	Laser and photodiode	LiDAR, ToF

Definition of optical sensor is "broad class of device for detecting light intensity". Human eye only can detect visible wavelength, but optical sensor can detect infrared and UV also. To use this advantage, various sensors are applied more and more for autonomous vehicle along with higher level of self-driving. *Cameras, radar, ultrasonic and LiDAR are basic sensors to consist autonomous vehicles.* Thermal image is one other necessary sensor to achieve Level 4 and above.

2. Justification of module level test

Sensor itself as components can't provide proper signal or data to AV system. For example, LiDAR sensor consist with emitting LED, photodiode, lens and motor as Figure 1. Especially lens is necessary for detecting light intensity in certain detection area. Most of optical sensors produced MEMS technology contains lenses inside of its package, but still required additional lens for changing optical property and astatic reason. With this reasons, performance measuring of optical sensor is needed to be tested as module.

Figure 2: Operating schemes:
(a) Rotating 2D LiDAR, (b)rotating 3D LiDAR, (c) solid state 3D LiDAR



3. Three test level

There are three different test level for sensor module, which is road test, test facility, and virtual simulation. Road test is the most realistic and good to find unveiled defects of optical module.

However, it takes very long time to cover all the emergency situation and following legal responsibility about accident is also needed to be considered. It is better to mimic the emergency situation from the real world of road test to test facility or virtual simulation.

Using Test facility is the best option for standardization of optical performance test of optical sensor. The method has stable reproducibility, low tolerance, low testing cost, and producibility of various condition.

Virtual test is not commonly use in the field yet. Nevertheless, optical performance test in virtual test has question, since it is a simulation that is computer generated. However, it also has potential in terms of machine learning and test integration between sensor module and overall system that is include not only a vehicle, but also surrounded vehicles and things as V2V and V2X.

Chapter 5 and 6 are about the Testing method for optical performance of infrared sensor module of autonomous vehicle in terms of test facility.

4. Definition of measurable factors

Measurable factors of each module are adjustable depended on table 1. Application per type of sensor module.

A. Resolution

The sensor resolution is the smallest change that can be detected in the quantity that it is being measured. For example, the Field of View resolution is the minimum FoV that can be accurately measured by any FoV measuring devices.

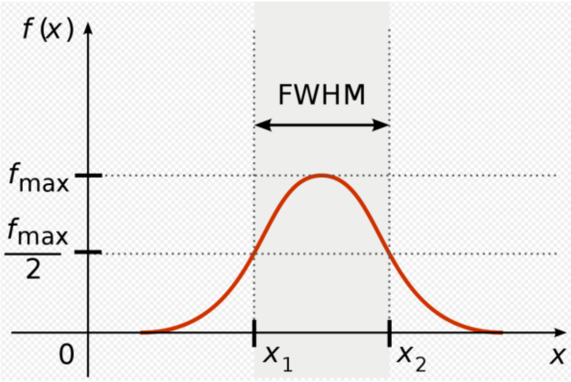
For example, between two thermal image camera using same 32*32 thermopile array, one with 20Hz framerate is higher resolution than the other with 2Hz framerate.

A common problem among non-technicians is the use of the number of pixels on the detector to describe the resolution. If all sensors were the same size, this would be acceptable. Since they are not, the use of the number of pixels can be misleading. For example, a 2-megapixel camera of 20-micrometre-square pixels will have worse resolution than a 1-megapixel camera with 8-micrometre pixels, all else being equal.

B. Field of View

The field of view (FoV) is the extent of the observable world that is seen at any given moment. In the case of optical instruments or sensors it is a solid angle through which a detector is sensitive to electromagnetic radiation. Sometimes FoV of visible CCD camera, thermal CCD imager, and 3D sensors are defined as view angle of captured image. Distortion of image and chromatic aberration are also critical factors of optical module in case of wide FoV. Non-image sensors, such as thermopile, Pyroelectronic and LiDAR, are using Full Width at Half Maximum(FWHM) from detected energy level to define FoV.

Figure 2: graph of calculating FWHM



C. Detection area

Detection area is surface area in which the sensor module is specified to detect the presence or motion of object such as a person, car, animal, and things.

A set of points that sensor module exports its signal to connected system, such as autonomous vehicle. Some of detectable points can be over the FoV of tested module and also there is some blind point even inside of FoV.

D. Response time

Sensors do not change output state immediately when an input parameter change occurs. Rather, it will change to the new state over a period of time, called the response time (Tr in Figure 5). The response time can be defined as the time required for a sensor output to change from its previous state to a final settled value within a tolerance band of the correct new value. For example, Response time is delay between action occurred and export signal or data to autonomous system. Export signal or data is needed notice with this result, since the response time is hugely depended on doing data process in the module or not.

E. Other factors

Factors below are considerable to add.

Frame per Second, Weather resistance, Noise equivalent power, Minimum resolvable temperature difference, Modulation Transfer function

5. Automated scaled Test facility

Current considered scale for automated system is 5:1 scale. Higher scale than 5:1 is not considered at current stage, since there is confliction between scaled dummies and distance, and non-scaled sensor module.

General requirements on tests are sensor module shall be mounted and installed according to the manufacturer's instructions. Test environment shall be separately setup. For example, good weather condition, turbulent snow condition and fog chamber condition. The general ambient conditions, such as temperature, humidity, and luminance, in the test room shall be recorded. The size of the room shall be large enough in order not to influence the test result.

The walls of the test room, if located within the coverage area of the detector, shall not influence the result. The room shall be a closed room and daylight entrance shall be limited. Direct sunlight on the test area is not allowed. The use of artificial light shall not contain an IR component.

Using test dummies is required for automated test systems. A size of human test dummies is as below. The temperature of each zone (head, body and legs) can be controlled separately as follows:

The head is heated to a temperature of 14 K ± 1 K above the ambient temperature of the test room.

The body and legs are heated to a temperature of 7K ± 1K above the ambient temperature of the test room.

All test sides of the dummies shall be heated except the back side and the bottom side, which are not relevant for the test.

The temperature of the surface for each zone of the dummy shall be homogeneous and the spread shall be ≤ 1,5 K.

Specifications for vehicles and small object is to be determined later.

Figure 3: 5:1 scaled human dummy

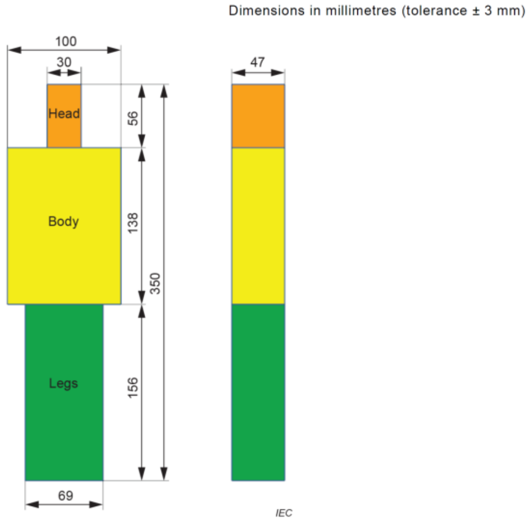


Figure 4: example of dummy movement

The test setup shall be built so that the test dummy can be moved between positions 1 and 2 as tangential and A and B as radial. The span shall be adjustable and centred towards the detector.

The test dummy is positioned on the mounting plate so that the side area is facing the detector.

For tangential movement, the test dummy shall be moved for certain distance from position 1 to position 2 and it shall stay at this

point for approximately 1 s and then return backwards to position 1. If no detection is registered during the above test, the test is repeated once. The result is recorded.

For radial movement within the detection area

The test setup shall be built so that the test dummy can be moved between position A and position B towards the detector.

The test dummy is placed at a starting position outside the expected detection distance.

The test dummy shall be moved between position A and position B until detection occurs. This is repeated once, and the average value is recorded.

Figure 5:
automated Motion detector test facility of Fresnel Factory Inc., built based on IEC63180

6. Conclusion and future work

In general, testing method of optical performance is similar between type of sensors. However, as wavelength and form of data or signal is differently the detailed measuring factors also needed to be modified.

Detailed measurement methodology and factors by type of sensors, and automated test process to consider various test condition, such as good weather condition, turbulent snow condition and fog chamber condition that are mentioned in chapter 6.

References

1. 정용택, 최신온도센서 기술동향, 2015

2. Francisca Rosique, Pedro J. Navarro, Carlos Fernández and Antonio Padilla, A Systematic Review of Perception System and Simulators for Autonomous Vehicles Research, 2019

3. Li Tang, Yunpeng Shi, Qing He, AdelW. Sadek, and Chunming Qiao, Performance Test of Autonomous Vehicle Lidar Sensors Under Different Weather Conditions, Transportation Research Record, 2020

4. Seo Ho Youn, Hui S. Son, Daniel L. Marks, Jeffrey M. Shaw, Paul O. McLaughlin, Steven D. Feller, David J. Brady, and Jungsang Kim, Optical performance test and validation of micro cameras in multiscale, gigapixel Imagers, Duke university, 2014

5. Mark Patrick, Http://www.aitimes.kr/news/articleView.html?idxno=20204

6. Mark Patrick, Creating Safer Roads for Autonomous Vehicles, Mouser, https://www.mouser.com/blog/creating-safer-roads-for-autonomous-vehicles, 2017

7. Danny Jost, What is an IR sensor, https://www.fierceelectronics.com/sensors/what-ir-sensor, 2019

8. 최종찬, 자율주행자동차 V2X 통신 표준화 현황, 한국표준협회, 2019

9. Sensor Terminology, NATIONAL INSTRUMENTS CORP, https://www.ni.com/ko-kr/innovations/white-papers/13/sensor-terminology.html#section--1222941856, 2020

10. IEC 63180, Methods of measurement and declaration of the detection range of detectors – Passive infrared detectors for major and minor motion detection, 2020

11. Maria Jokela, Matti Kutila and Pasi Pyykönen, Testing and Validation of Automotive Point-Cloud Sensors in AdverseWeather Conditions, VTT Technical Research Centre of Finland, 2019

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