Adaptive Reflector Code on Roadside for Acquiring Information by Infrared Laser Range Scanner

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Abstract:
We have proposed an information acquisition method with detecting the reflector code on roadside by using infrared laser range scanner. The scanner on vehicle scans the reflector code on roadside while traveling. However, we cannot change the code pattern according to the road information, GPS location and so on. Hence, we propose an adaptive reflector code by switching infrared LED to express appropriate information. Through some experiments, we show that the vehicle can obtain different information from roadside according to the use case.

Keywords: reflector code, infrared laser range scanner, infrared LED

Classification: Sensing

References

[1] I. Shim, J. Choi, S. Shin, T.-Hyun Oh, U. Lee, B. Ahn, D.-Geol Choi, D. H. Shim, I.-So Kweon, “An Autonomous Driving System for Unknown Environments Using a Unified Map,” IEEE Transactions on Intelligent Transportation Systems, vol. 16, issue 4, pp. 1999-2013, Aug. 2015.

[2] D. Moser, R. Schmied, H. Waschl, L. del Re, “Flexible Spacing Adaptive Cruise Control Using Stochastic Model Predictive Control,” IEEE Transactions on Control Systems Technology, vol. 26, issue 1, pp. 114-127, Feb. 2017.

[3] R. Thakur, “Scanning LIDAR in Advanced Driver Assistance Systems and Beyond: Building a road map for next-generation LIDAR technology,” IEEE Consumer Electronics Magazine, vol. 5, issue 3, pp. 48-54, Aug. 2016.

[4] S. Velupillai and L. Guvenc, “Laser Scanners for Driver-Assistance Systems in Intelligent Vehicles,” IEEE Control Systems Magazine, vol. 29, issue 2, pp. 17-19, April 2009.

[5] T. Wada, Yusuke Shikiji, Keita Watari, and Hiromi Okada, “Novel Vehicle Information Acquisition Method using 2D Reflector Code for Automotive Infrared Laser Radar,” IEICE Transaction on Fundamentals, vol. E98-A, no. 1, pp. 294-303, Jan. 2015.

[6] T. Wada and Susumu Kawai, “Detection of 3D Reflector Code on Guardrail by
1 Introduction

Intelligent Transport Systems (ITS) have been developing for reducing traffic accidents among vehicles and pedestrians. In addition, people in the world have more attention to autonomous driving cars to improve traffic safety and efficiency. The autonomous driving systems have been improving the performance of recognizing surround environments by many sensors such as cameras, radars, and so on. However, the autonomous driving car cannot recognize several cars and pedestrians behind buildings. In the Non-Line-Of-Sight (NLOS) environment, wireless communications are effective for recognizing other cars and pedestrians. The wireless communications are categorized into three kinds of V2V (Vehicle to Vehicle), V2P (Vehicle to Pedestrian), and V2X (Vehicle to Infrastructure) communications.

Recently, Autonomous Driving Systems [1] are developing by obtaining various technologies such as Adaptive Cruise Control (ACC) [2] and Advanced Driver Assistance Systems (ADAS) [3] which integrate many sensors and communication devices. The ACC is one of radar technology applications. Inter-vehicle distance warning systems for trucks and intelligent cruise control systems for vehicles are spreading for practical use. Since the infrared laser radar on a vehicle can obtain the distance to obstacles accurately, the vehicle can avoid collision with the obstacles. However, it is difficult to obtain information other than the distance and the angle [4]. If the vehicle can obtain the information of the target by only radar, it makes a new application of radar technologies. In addition, to recognize vehicles and pedestrians accurately is also important for improving safety in traffic environments.

Hence, we proposed a new recognition method of the reflector code by using infrared laser radar [5]. This method obtains the vehicle information contained in the reflector code which is composed of reflectors and non-reflectors. It is possible to make an inexpensive system by using only 2D scanning infrared laser radar because the reflector code is easily constructed with low cost by combination of reflectors and non-reflectors.

On the other hand, we have proposed an information acquisition method using infrared laser radar by detecting 3D reflector code on roadside [6]. The infrared laser radar on the vehicle scans the reflector code on roadside while the vehicle is traveling. The reflector code has local information such as the road repairing and its own absolute position. The information amount of the reflector code is increased by using 3D reflector allocation. The vehicle can get the information along the roadside. In [7], we investigated the recognition performance according to the change of the tilted angle of the radar and the distance between the reflector...
code and the radar. In urban canyon with many tall buildings, it is important to obtain the accurate position for correcting the position error from GPS signals. This method can be applied to an autonomous mobile robot for obtaining its accurate positions in an indoor environment.

However, we cannot change the code pattern due to physical construction in [5, 6, 7]. If we change the code pattern, we have to recreate the reflector code physically again. If we can change the code pattern by electronic control, we can embed appropriate information easily. Hence the vehicle can obtain the information according to the use case. For this purpose, we propose an adaptive reflector code which can change the code pattern by switching infrared LED. In order to study the detection performance of the proposed method, we carry out several experiments and discuss experimental results.

2 Proposed method

2.1 Overview

Infrared laser range scanner can recognize the reflector code in the situation of rainfall and night-time. Usability in night-time is an advantage for applying to vehicles. To obtain road information by using infrared laser range scanner, we make a reflector code using some infrared LEDs on the roadside. The LEDs are connected to power line and control signal line. So, the LEDs are ON or OFF by switching the control signal. If the received signal strength indicator (RSSI) in case of ON and OFF of the LED are different, we can distinguish the ON and OFF of the LED. Therefore, we can obtain one bit information on the place of LED. If the places of LEDs are 32, the reflector code has 32 bits information.

2.2 Information amount in reflector code

Fig. 1 shows the infrared laser range scanner on the vehicle scans the 3D reflector code on roadside. The scanner scans the code from bottom to top with θ degrees tilted from the vertical axis repeatedly to increase the number of scanning of each LED. The reflector code has x lines and y rows. The scanner’s scanning line moves from left to right with traveling of the vehicle. This reflector code has x×y bits information because each place of LED has one bit. If we need to increase the information amount, the reflector code can be change to three dimensional (3D) with convex areas. The scanner can detect the convex or not by measuring the distance to the surface of the reflectors. By using 3D reflector code, we can get the twice amount of information comparing with the two dimensional (2D) reflector code.
2.3 Detection process

We explain the detection process of the reflector code on roadside as follows.

Step 1: Detection of the reflector code by the infrared laser range scanner

At first, the infrared laser range scanner detects the reflector code by measuring RSSI of reflectors repeatedly. In detecting area of the reflector code, RSSI of reflectors is higher than other areas. So we can detect the area of the reflector code.

Step 2: Paring RSSI and the distance of each LED

Next, the infrared laser range scanner measures the distance to each LED accurately. Since we relate the distance with the RSSI, we can recognize the reflector code in 3D.

Step 3: Obtaining the code pattern by recognizing ON or OFF of each LED

RSSI of ON of the LED is larger than that of OFF of the LED. Hence, we can obtain the code pattern by recognizing ON or OFF of each LED in the reflector code.

Four LEDs are set on each reflector area which has enough horizontal and vertical length to be detected. The horizontal and vertical intervals between LEDs must be appropriate values to reduce interference from the neighboring LEDs. The depth of the convex area should be larger than the resolution of the infrared laser range scanner to distinguish the area is convex or not. When four LEDs are arranged in a square, each LED is turned ON and OFF independently, and there are 16 ON-OFF patterns. Information is read by associating the information with these 16 displays in advance.

3 Performance evaluation

To compare the detection performance of reflectors and LEDs, we construct the 2D reflector code composed of corner cube mirror reflector, glass beads reflector, white board sheet and LED on black vinyl chloride plate which is non-reflector. To investigate the detection performance of the reflector code, we carry out several
experiments in a sunny day. Since the ambient direct light such as the Sun may cause the effect on the detection performance, we set the infrared laser range scanner without direct light from the Sun. We use the scanner, UTM-30LX produced by HOKUYO AUTOMATIC Co., LTD. Main specification is as follows. The wavelength of the laser is 905 nm, the ranging distance is 0.1 to 30 m, the ranging angle is 270 degrees, the ranging accuracy is 30 mm, the angle resolution is 0.25 degrees, and the scanning time is 25 ms/scan.

![2D reflector code with infrared LED on roadside.](image)

Fig. 2. 2D reflector code with infrared LED on roadside.

Fig. 2 shows the 2D reflector code on roadside in the experiments. Since there are 7 areas in horizontal axis and 3 areas in vertical axis on the reflector code, the reflector code has 21 areas in total. Four infrared LEDs are set on the center area of the reflector code to distinguish LEDs and other reflectors. We switch the LED ON or OFF to investigate RSSI. The vehicle has the infrared laser range scanner on its side to detect the reflector code. When the vehicle travels along the reflector code on roadside, the scanner detects different positions of each reflector in one cycle period repeatedly. In order to increase the scanning number of each reflector, we set the scanner 45 degrees tilted from the vertical axis.

![RSSI vs. distance in infrared LED ON and OFF](image)

Fig. 3. RSSI vs. distance in infrared LED ON and OFF

The distance between the scanner and the reflector code is 1m, 2m and 3 m. Size of each reflector is vertical 4.5 cm and horizontal 6 cm. The vertical and
horizontal reflector intervals are 12 cm and 18 cm, respectively. The height of the radar is 80 cm and the vehicle traveling speed is 5 and 10 km/h. We carry out the experiments three times in each condition of the distance and the vehicle speed. Fig. 3 shows the average RSSI vs. the distance in the case of the infrared LED ON and OFF. From this figure, we find that it is possible to increase RSSI by the LED ON. Moreover, we find that once the speed is determined, the difference between the ON and OFF RSSIs is almost constant without depending on the distance. Therefore, the ON and OFF reading thresholds are set to intermediate values between the RSSIs according to the distance and the speed so that the ON and OFF reading errors are minimized. By combination of the LED ON and OFF, we can obtain the information with ranging according to the use case.

4 Conclusion
We have proposed an adaptive reflector code on roadside by switching the infrared LED on the reflector code. By several experiments, we have found that we can detect the infrared LED ON and OFF to recognize one bit. If the 21 areas have four LEDs each, we can recognize 42 bits by configuring 3D reflector code. For future work, we have to investigate the detection performance of the reflector code and increase the number of LEDs to change the code pattern dynamically in use case.

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