Pedestrian Orientation Estimation based on Super Resolution of LiDAR Data

Seokki Lee
College of Information Science and Engineering
Ritsumeikan University
Kusatsu, Japan
is0534hh@ed.ritsumei.ac.jp

Yanlei Gu
College of Information Science and Engineering
Ritsumeikan University
Kusatsu, Japan
guyanlei@fc.ritsumei.ac.jp

Igor Goncharenko
College of Information Science and Engineering
Ritsumeikan University
Shiga, Japan
igor@fc.ritsumei.ac.jp

Shunsuke Kamijo
Institute of Industrial Science
The University of Tokyo
Tokyo, Japan
kamijo@iis.u-tokyo.ac.jp

***Abstract*— Pedestrian detection for autonomous driving has been intensively studied in the past two decades. Especially, with the development of deep neural networks, the performance of pedestrian detection has been significantly improved. However, more details information is needed for autonomous driving in urban environments. Pedestrian body orientation is meaningful information to indicate the pedestrian's walking direction, and pedestrian orientation estimation from the camera sensor has been proposed in previous research. Still, there are few discussions for the pedestrian orientation estimation from LiDAR (Light Detection and Ranging) sensor. This research proposes to estimate pedestrian orientation from LiDAR data using deep neural network-based super-resolution to overcome the low-resolution issue of LiDAR sensors. The experimental results indicate that the proposed method can achieve satisfactory performance. The proposed system can be used as compensation for the camera-based pedestrian orientation estimation.**

Keywords*— Pedestrian orientation, super resolution, LiDAR, deep neural network

I. INTRODUCTION

There are countless factors to account for when developing an autonomous driving system. One aspect that stands out to be a very significant task to be done is detecting pedestrians from a complex background. Pedestrian detection is one of the most important factors to account for to make sure that the autonomous driving system can operate safely on the road. There are already many ways of pedestrian detection fulfilled through, camera, Radar, and LiDAR detection.

However, simply detecting pedestrians is not enough for an autonomous driving system and causes a lack of information about the object. Thus, complementing this could be done through orientation estimation. Orientation estimation is a method to figure out where the body orientation of pedestrians is facing, and to predict their trajectory, walking direction, or behavior. Some other related work has already discussed this problem, the methods they chose mainly used cameras to retrieve the orientations [1]. The method could complete the task, however, the images retrieved from the image sensor have some clear downsides. One of the more serious downsides is suffering very low image quality at night time. That is a problem that needs to be noted since driving at night time is one of the more complex problems of autonomous driving.

One way of overcoming the limit of the image sensor is through the use of LiDAR. LiDAR sensor in general has been used for pedestrian detection [2]. Still, there are few discussions for the pedestrian orientation estimation from the LiDAR sensor. In addition, the higher resolution LiDAR sensor is expected to be used to obtain more information about pedestrians for orientation estimation compared to pedestrian detection. However, the high resolution LiDAR sensor will increase the cost for the whole autonomous driving system.

This research proposes to estimate pedestrian orientation from LiDAR data using deep neural network-based super-resolution to overcome the low-resolution issue of LiDAR sensors. The proposed method employs a Generative Adversarial Network (GAN) to increase the resolution of the LiDAR data, and further classify pedestrian orientation using a deep neural network. A series of experiments are conducted to verify the effectiveness of the proposed method.

II. PEDESTRIAN ORIENTATION ESTIMATION USING LIDAR

Figure 1 demonstrates the flow chart of the proposed pedestrian orientation estimation system. This research works under the assumption that the pedestrian has been detected from the LiDAR sensor data. Therefore, the input of the system is the information in the area of the detected pedestrian. To fully use the information collected from the LiDAR sensor, the reflectivity, distance ranging, and near-infrared spectroscopy information are represented in image format. The three images are imported to a super-resolution GAN. After that, the pedestrian orientation is estimated based in super-resolution images by the deep residual network.

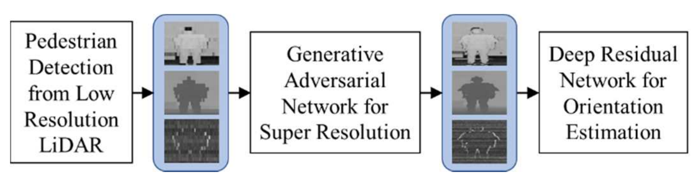

Fig. 1. Flow chart of the proposed pedestrian orientation estimation system

A. LiDAR Data

Generally, a LiDAR sensor can measure the ranging information that indicates the distance from the sensor to each object. Figure 2 (a) shows the ranging information represented as the point cloud data. In addition to the ranging information, many LiDAR sensors also record the reflectivity and near-infrared spectroscopy of the surrounding environment when it works. Figure 2 (b), (c), and (d) show the corresponding reflectivity, ranging information, and near-infrared spectroscopy represented as images. This research mainly uses these three types of images for pedestrian orientation estimation.

This work was supported by JSPS KAKENHI Grant Number JP21K12019.

2023 IEEE International Conference on Consumer Electronics (ICCE) | 978-1-6654-9130-3/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICCE56470.2023.10043577

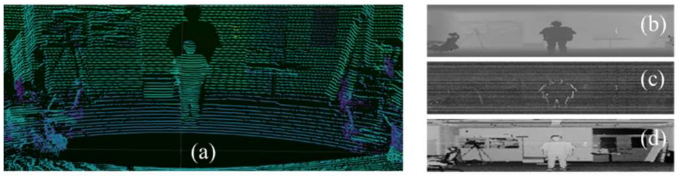

Fig. 2. LiDAR data, (a) ranging information represented as the point cloud data, (b) to (d) reflectivity, ranging information, and near-infrared spectroscopy represented as images.

B. Pedestrian with Different Orientations

In this research, the number of defined pedestrian orientations is eight in total. Starting from the initial orientation the angle of a pedestrian facing toward the center of the Lidar sensor, increases 45 degrees counterclockwise from the object perspective. Thus, on the 5th angle, the person faces backward. Figure 3 shows the pedestrian reflectivity images of all the orientations. The goal of the system is to correctly recognize the orientation of pedestrians.

Fig. 3. Pedestrian reflectivity images of all the orientations.

C. Super Resoltuion and Orientation Classification

Image super-resolution (SR) techniques can reconstruct a higher-resolution image from the observed lower-resolution image, one of the common approaches to solving this task is to use deep convolutional neural networks capable of recovering high-resolution images from low-resolution ones. ESRGAN (Enhanced SRGAN) is one of them [3]. This research adopts a pre-trained ESRGAN model to increase the resolution of the reflectivity, ranging information, and near-infrared spectroscopy images of the low-resolution LiDAR data. Figure 4 (a) to (c) show the example images of low-resolution LiDAR data, after super-resolution and high-resolution LiDAR data, respectively. Then, the system proceeds to the goal of this research after super-resolution, which is to classify body orientation. To accomplish this goal, ResNet model is used as feature extractor and classifier in this research [4].

(a) (b) (c)

Fig. 4. Example reflectivity, ranging information, and near-infrared spectroscopy images from (a) low resolution LiDAR, after (b) super-resolution and from (c) high resolution LiDAR.

III. Experimental Results

To perform experiments on the proposed idea, specific data set is required. The experimental dataset was collected in a laboratory setting. The device that was utilized to record was Ouster OS1-64 with 64 laser beams. The LiDAR sensor was fixed on a platform, and The eight different pedestrian orientations are carefully marked on the floor. The data collection involves a total of 16 people. Participants were instructed to face different directions. We manually cropped the area of pedestrians from LiDAR data. Table I shows the precise number of scans (one scan includes one reflectivity image, one ranging image, and one near-infrared spectroscopy image) for each orientation. The 4-fold cross-validation method was used for the training ResNet model and estimation of the orientation estimation accuracy.

TABLE I. NUMBER OF SCANS FOR EACH BODY ORIENTATION

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2938	2686	2981	2804	3046	2976	3096	2983

In this research, the cropped pedestrian data from Ouster OS1-64 is defined as high-resolution LiDAR data, and low-resolution LiDAR data are generated by down-sampling the high-resolution LiDAR data to simulate the data captured from LiDAR with 16 laser beams. The research compares the results from three different processes: orientation estimation from high-resolution LiDAR data (High-resolution based), orientation estimation from low-resolution LiDAR data (Low-resolution based), and orientation estimation based on the super-resolution of low-resolution LiDAR data (Super-resolution based), as shown in Table II. The experimental results demonstrate the proposed method can improve the pedestrian orientation estimation accuracy by using the super-resolution method.

TABLE II. ORIENTATION ESTIMATION ACCURACY USING DIFFERENT METHODS

Methods	**Correction rate of orientation estimation**
High-resolution based	81.8%
Super- resolution based	80.9%
Low-resolution based	76.8%

IV. Conclusions

This paper proposes to estimate pedestrian orientation from low-resolution LiDAR data. To overcome the low-resolution issue of LiDAR data, the proposed system additionally includes super-resolution before the orientation estimation. The performance of the proposed system has been evaluated in experiments and the experimental result proved the effectiveness of the proposed method.

References

[1] Y. Gu, L. Hsu, L. Xie, S. Kamijo, "Accurate Estimation of Pedestrian Orientation from On-board Camera and Inertial Sensors", IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol.E99-A, No.1, pp.271-281, 2016.

[2] T. Wu, J. Hu, L. Ye, K. Ding, "A Pedestrian Detection Algorithm based on Score Fusion for Multi-LiDAR Systems", Sensors, 21(4), 1159, 2021.

[3] K. He, X. Zhang, S. Ren, J. Sun, "Deep Residual Learning for Image Recognition", Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 770-778, 2016.

[4] X. Wang, K. Yu, S. Wu, J. Gu, Y. Liu, C. Dong, Y. Qiao, C. C. Loy, "ESRGAN: Enhanced Super-resolution Generative Adversarial Networks", Proceedings of the European Conference on Computer Vision (ECCV) Workshops, 2018.