Parking Place Inspection System Utilizing a Mobile Robot with a Laser Range Finder

-Application for occupancy state recognition-

Sanngoen Wanayuth, Akihisa Ohya and Takashi Tsubouchi

Abstract—**The automated inspection is desired to detect the vehicle in large parking space, which is difficult to survey by fixed the vision-sensor. We purposed mobile robot surveillance in parking space for parking lot inspection. To obtain the parking lot information, vision sensor is wide useful for parking lot state checking which measurement is difficult to obtain the positioning of vehicle while achieved by the laser range finder (LRF). In this research aims a laser range finder is acquired the positioning with directly measure the object in range scanner, which is obtains the data in the parking place. This paper purposed on ability of a LRF sensor with including reflection intensity data for data measuring in the parking lot by using a mobile robot which performs patrolling on multiple times in parking place for a parking lot inspection. We present experimental results to evaluate the effectiveness of the occupancy state recognition.**

I. INTRODUCTION

Parking lot inspection play important role in the every parking places. Most of them are manually managed and difficult task to supervise any parking lot in large parking place. The problems that always occur at the parking place are spent duration of time for searching the empty lot, difficult access into the empty lot because the occupant is parked overlap on the parking lot. Moreover, the occupant is used the parking lot for long term parking without movement that risk to use in criminality, or car stolen. These problems usually occurred in many parking place.

In presents, the parking lot inspection task of parking places such as those at shopping malls, airports, stadiums or universities, manual inspection by continuous patrolling is a hard work, some types of automation are necessary. Within the parking place, there are many technologies that have been accomplished for parking lot checking in the parking area. The simple function of the parking place has been required such as checking the parking lot state which is occupancy or empty lot and counting the number of vehicle at the car park entrances those function have been installed in parking place.

The vision sensor technique is useful for monitoring and detecting in the parking lot state, which is can operate whether the indoor parking lot or the outdoor parking lot. Many researches utilized vision surveillance [1-3] in the parking area to retrieve the information regarding to each parking lot whether there is an occupancy state or empty lot state. Nevertheless, the vision system has limitation due to the lighting condition and relatively high cost for survey in the wide parking area.

By patrolling, the mobile robot is favorite use for operate and inspect the vehicle in the parking place that can performs in continue task, repeatedly task and also robustness than the human. Therefore, many functions are developed on mobile robot for automatically vehicle detection in parking lot with the sensor devices which are required to obtain vehicle information such as vision system and laser range finders. The mobile robot can detect and create configuration of the parked vehicle in each parking lot. The LRF sensor widely used for measure the position of the object in range of data scanner, high accuracy and not affect in the lighting condition. The information obtained from the LRF sensor provides the positions and orientations of vehicles in the parking area.

Many researchers proposed various methods for vehicle detection in the parking area by using autonomous vehicle [4],[5] with horizontally installed the scanning laser range sensor for vehicle detection on both the position and orientation of vehicle in the parking area, at the same time, a map of the parking area was generated to obtain the self-localization. Moreover, developed the mobile robot is patrolling in parking area that proposed a method which detected the bumper zone with horizontal installed a 2D laser scanner and locations of vehicles in the parking area (additional camera will take care of the license plate number), all of which were detected by typical autonomous mobile robot [6]. These researchers were purposed the method to detect the vehicle(s) in parking place with horizontal plane scanner of laser sensor. However, the vehicle information such as those of car-size, shape of vehicle comprises the pose of vehicle in parking lot are necessary information of vehicle classification, these kind of information are considering in the parking place inspection system in this research.

Extending our previous work, this research focus is on how to classifying the vehicles in the parking place: 1) the vehicle is parked for long term parking in the parking lot, 2) the vehicle changes state in the parking lot by new occupant or continue occupancy state. For vehicle detection in each parking lot, to detect the parking lot state is changes, long term parking, the required information are obtained from the 2D laser range sensor by using a mobile robot.

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Within a parking place, the information on the ground surface (arrow direction, guideline of each parking lot, etc.) is necessary in the parking place for guiding the driver into collect direction while the pair guideline is assist to get into a parking lot. To obtain the necessary information of the parking place, a mobile robot is patrolling and detecting the vehicle in parking lot with a laser range sensor by set vertical plane scanner is perpendicular on ground surface. The LRF sensor is obtains the vehicle data and the ground data which is included the guideline of a parking lot also. We propose the approach for guideline extraction from the ground data, vehicle classification, occupancy and empty lot checking, state of vehicle based on comparison between pair of data inspection and occupancy state recognition.

The rest of the paper is organized as follows; section II, briefly describes the basic of the parking lot information in the parking area. In section III, we describes the method for guideline extraction by using reflection intensity data of LRF sensor, the vehicle detection in parking lot by using the guideline data, guideline data alignment between data inspection, and vehicle data comparison. In section IV, an overview the hardware of robot platform and laser range sensor. The experimental data are presented in section V. Finally, the conclusion and future work are in section VI.

II. Parking Lot Information

The basically state of parking lot information in the parking area can be classified into two states: the occupancy state and the empty space state. Within the occupancy state in a parking lot, the occupant is parked in a parking lot for long term parking or changing new occupant get into a parking lot, which is occurring in any parking place. In this paper, the parking lot inspection is performs to recognize the vehicle in each parking lot and identify where is the location in the parking place. This kinds of information is assisted the parking manager for parking lot inspection in the parking place. Typical parking lot information is described in Fig. 1.

We designate a circular shape for an occupancy state of the vehicle, a rectangular shape for an empty space state, and the arrow shape for a continue state. For instant, within the parking lot number one, the occupant is a continue state from time t_1 until t_2 and while t_3 the state of parking lot is changing by a new occupant until t_n.

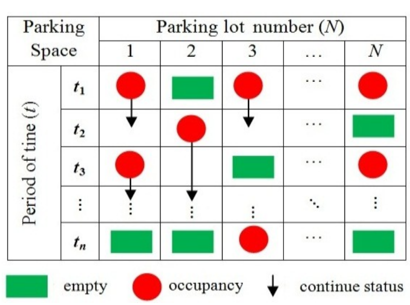


Fig. 1. The demonstrated of parking lot information.

III. System Overview

Our main research aims to inspect the occupancy state within parking lot, recognize the vehicle is parked in long periods and locate the parking lot number in the parking place by using a mobile robot. To detect the parking lot state, the guideline on the ground surface (Fig. 2) mostly used to limit of the width of parking lot size. For considering the parking lot checking, the guideline data is necessary for parking lot inspection. We purposed the mobile robot is performs to patrol (multiple time operate) from starting point area until cover all parking lots and then go back to the initial point. The functional of navigation system is not employed in this paper. To obtain the data in parking lot from LRF sensor, we determined the guideline extraction from ground surface, guideline alignment from data scanner between them, counting the number of vehicle, and detecting the vehicle is parked for long term parking. All of these methods are described in this section.

Fig. 2. Typical guideline (line white color) of parking lot on the ground

A. Data Range Scanner

The 2D plane scan of the LRF provides the upright vertical plane scan that is perpendicular to the ground plane for data scanner in the parking space in Fig. 3. The 2D data range scan (angle and range) and odometery-base of self-positioning of the robot locomotion are combined to the point cloud data in 3D world coordinates. The point cloud data from the LRF, not only the vehicle data is obtained in data range scanner but also included the guideline data. For clustering of these point cloud data, the constant height value of $H_{threshold}$ is applied for divide of all the point cloud data. The two clusters are consisted of both the point cloud of vehicle data $(C_j^{t_i})$ and the point cloud of the ground data $(L_j^{t_i})$. The vertical 2D plane scanner and the $H_{threshold}$ are illustrated in the Fig. 4.

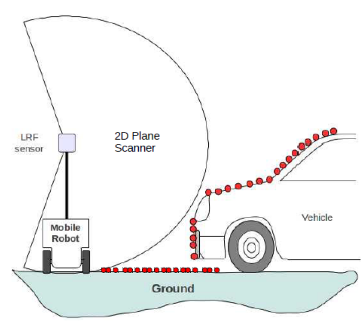


Fig. 3. The 2D plane scanner of LRF sensor.

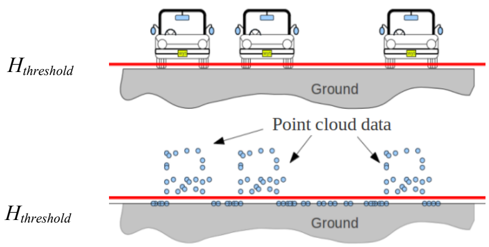


Fig. 4. The point cloud data of parking space is divided by $H_{threshold}$

B. Guideline Data Extraction

The point cloud data is lower than the value of the threshold we provided to determine the guideline data of each parking lot. The LRF sensor also obtained the range data and the intensity data from the data scanner. We considered the reflection intensity data of LRF [7],[8] to determine the guideline(most of the standard color for guideline is white color) having the different laser reflection properties from other ground surface. The intensity data is obtained depends on the range, material, shape with smooth or rough of object detection. In the way, the ground surface and guideline is difference value of intensity data the intensity value of guide line is higher than the ground surface. By guideline extraction, set the two points generate the straight line, the intensity data of each data point over the straight line is the key to determine whether the selected point data is on the straight line, other point data are ignored. The method of detecting the guideline based on the intensity data is illustrated in Fig. 5.

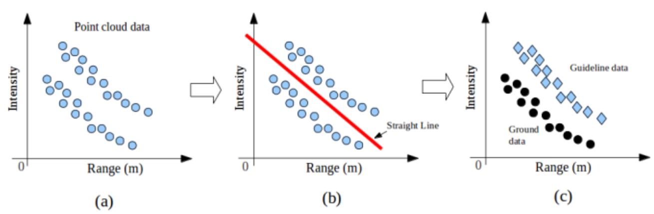


Fig. 5. The data processing of the intensity data: (a) the intensity data of point cloud data, (b) guideline extraction by straight line, (c) intensity data of the guideline selection.

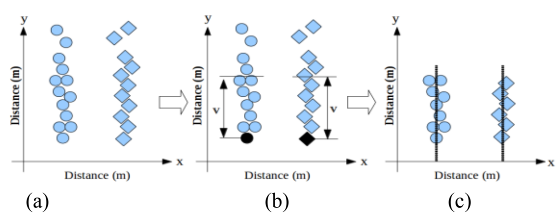


Fig. 6. The data processing of guideline detection: (a) guideline segmentation (b) collected the guideline in range V, (c) pair guideline data of a parking lot.

We extracted the guideline data from all point cloud of ground data based on reflection intensity data of LRF sensor. In this part, the low qualities of guideline data for long range from data scanner have a less fewer point data is removed. In Fig. 6, we determined the guideline positioning of each parking lot as follow: First, the data segmentation is used to determine each guideline of the point cloud data as shown in Fig. 6(a). Second, we collected the guideline data in range with set the constant value V by defined the minimum point of each guideline data (along y-axis) add the set value V as described in Fig. 6(b). Finally, the position of guideline data is used to determine the location of parking lot with pair guideline data by defined the mean value of each guideline (along x-axis) as described in Fig. 6(c). Therefore, two points set from the guideline data is used to define where a parking lot is occupancy state or empty state in next step.

C. Vehicle Detection in Parking Lot

Since, the vehicle point cloud data contains all the vehicle data in the parking lot, this data allow us to find the position of each vehicle in the parking lot. As the result of guideline detection, we determined the each vehicle data from the vehicle point cloud data by using the two points set. In this part, we defined of each parking lot is an occupancy state or empty state, and counting the number of them.

Therefore, we can determine the vehicle in each parking lot by pairing the two points set as follow: First, we used the two points set to determine the vehicle data from the point cloud data of vehicle. Second, shift two points set for parking lot detection and continue counting the number of parking lot also. In case of, having a vehicle in parking lot the vehicle data is recorded, free space is set zero. So that, we can define whether the parking lot is occupied by a vehicle or the parking lot is an empty space. This method is described in Fig. 7.

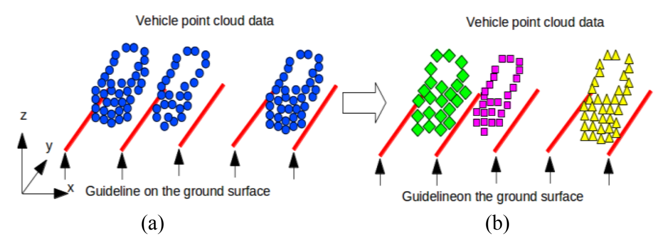


Fig. 7. The vehicle point cloud data (blue point) with the guideline data extraction in (a) and the vehicle data separation in each parking lot (b).

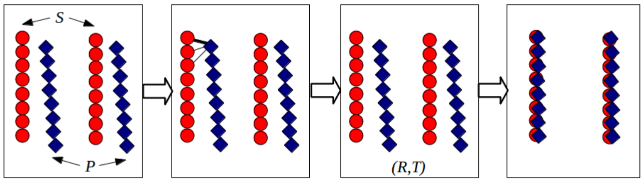
D. Guideline Data Alignment

In this paper, the guideline data from data scanner by using a mobile robot which is difficult to match between pervious scan and current scan (multiple times) because the guideline position is related to the robot position with odometery-based self-position, thus the error can occur while the robot is operational. Therefore, we provided the ICP-Algorithm [9] for guideline alignment and match between base point cloud data and target point cloud data.

With the guideline detection section, we collected the points set from the point cloud data of set L. A pair of guideline is used to compute the data matching between base point cloud $L_i(k)^{t_i}$ and target point cloud $L_j(k)^{t_{i+1}}$, where L is point sets of guideline data, k is the number of the parking lot and t is the multiple of duration time of data range scanner. The method of computing the guideline matching is described as follows:

a) Set base point data $P \leftarrow L_i(k)^{t_i}$, and target point data $S \leftarrow L_j(k)^{t_{i+1}}$
b) Pair each point of $L_i(k)^{t_i}$ to closet point in $L_j(k)^{t_{i+1}}$
c) Compute motion by translation (T) and rotation (R).
d) Apply motion to $L_i(k)^{t_i}$
e) Repeat until convergence of data between $L_i(k)^{t_i}$ and $L_j(k)^{t_{i+1}}$

This solution is illustrated in Fig. 8, for guideline matching. The transformation matrix (R,T) is computing base on the point cloud data of vehicle data simultaneously.



(a) (b) (c) (d)

Fig. 8. The pair guideline matching: (a) the set base point cloud (square shape) and target point cloud (circle shape), (b) pair of each point of base point cloud to closet in target point cloud, (c) compute Rotation (R) and Translation(T) matrix to base point cloud, (d) the guideline matching.

E. Vehicle Data Comparison

In this section, we determined whether vehicle data in the parking lot is the continue occupancy state or change of the new occupant by data comparison between them. In this paper, we mainly interested the state of parking lot is occupant by a vehicle and data comparison of both vehicle in the same parking lot position. We provided the vehicle data of base point cloud $C_j(m)^{t_i}$ (included Transformation matrix) and target point cloud $C_j(m)^{t_{i+1}}$ for data comparison approach, where *m* is the value of vehicle in parking space, *t* is the multiple of duration time of data range scanner. For the data comparison, we described of the data processing as follow: First, set the vehicle data of $\overrightarrow{W_i} \leftarrow C_i(m)^{t_i}$ and $\overrightarrow{E_j} \leftarrow$ Cjmti+1. Second, define the minimum distance of each point pair of $\overrightarrow{W_i}$ to the closet point in $\overrightarrow{E_i}$ by using Euclidean distance $d(\overrightarrow{W_i}, \overrightarrow{E_j})$ in (1) where $\overrightarrow{W_i} = (x_i, y_i, z_i)$ and $\overrightarrow{E_j} = (x_j, y_j, z_j)$.

$$d(\vec{W}, \vec{E}) = \|\overrightarrow{W_i} - \overrightarrow{E_j}\| = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2 + (z_j - z_i)^2} \quad (1)$$

We defined the minimum distance of each point *W* from points of set *E*. Therefore, the minimum distance of the point data between them, we define the average distance of those data. If the value of the average data is very closet to zero that means the same position of vehicle data (continue occupancy state). And if the average distance is very large that means the position of vehicle is changing (new occupant). This is illustrated in Fig. 9.

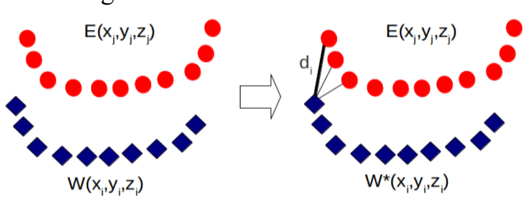


Fig. 9. The base point cloud (square shape) is set W (with computed the transformation matrix), d is distance between of them.

IV. HARDWARE

The robot platform is called "Yamabico" [10] that developed in the intelligent robot laboratory. The laser range sensor is used to obtain the data, has been installed on top of the robot. The position height is 130 cm from the ground plane for the measurement in range of laser range sensor while robot is patrolling in the parking space is demonstrated in Fig. 10. The main processor used is Corei5 2.67GHz, 4GB RAM based notebook computer running Ubantu 11 distribution of Linux (kernel 2.6.38-8-generic-pae) as operating system. The robot controller broad with SH2 processor provides robot locomotion and odometery-based self-position estimation function. The laser range sensor (UTM-30LX) is a compact size (W60xD60xH87 mm), cover detection range about 0.1 to 30 m, distance accuracy is 0.03 m, angular resolution is 0.25 degrees, and angle range is 270 degrees operating at 40 Hz

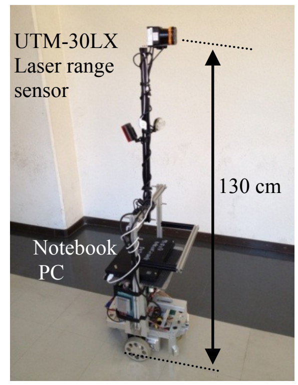


Fig. 10. Yamabico robot platform.

V. EXPERIMENTAL RESULTS

In the experiments, the mobile robot velocity is 0.15 m/sec for patrolling in parking space, and scanning the vehicle parked in each parking lot. We created the parking place information by using mobile robot that patrolling in parking place for multiplies time of data scanner. For the experiment(s) of this research, four times of data scanner $t_1 \rightarrow t_4$ by the mobile robot is operated at the same place of the parking space. The data range scanner from sensor was read every 25*ms* by driver processes and registered in parallel into a shared memory system (SSM) [11] was recorded into Log data file. The data detection tests were performed off-line by playing back this log data file at the same rate of the sensor (40H*z*) using SSM system. The experiment a mobile robot is go straight on a forward (along x-axis) of data range scanner obtained from vehicle data and ground data by using a LRF sensor and including the reflection intensity data in Fig. 11.

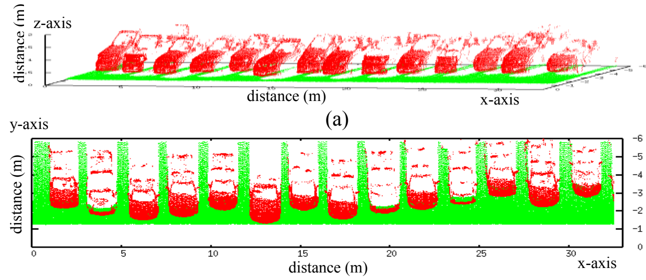


Fig. 11. The experiment result of data range scanner in parking place (a) the vehicle point cloud data (red point) and ground data (green point) in prospective view and top view in (b).

After that, two points were set to define the straight line which is used to separate the intensity data of ground data and guideline data. For defined the guideline data extraction this line is determined experimentally as described in Fig.12.

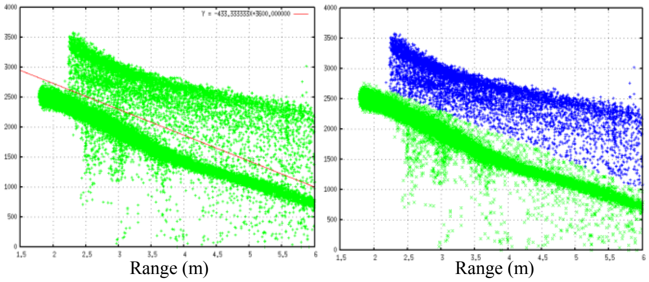


Fig. 12. Two points were set to define the straight line: (a) ground point cloud data (green point) is ignored, (b) intensity data of guideline (blue point) above the straight is collected.

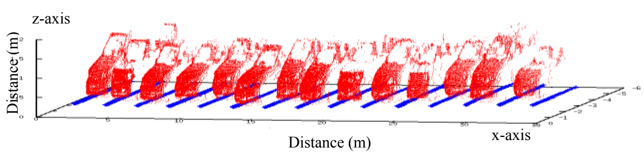


Fig. 13. The guideline data (blue point) is extract from ground point cloud data and positioning of vehicle data (red point) in prospective view.

The experiment result of the guideline extraction by using the intensity data is show in Fig.13. In the experiment for the guideline detection, we collected the guideline data by set the range (V) is 2 meter (m) thus other points is removed. This experiment result is illustrated in Fig. 14.

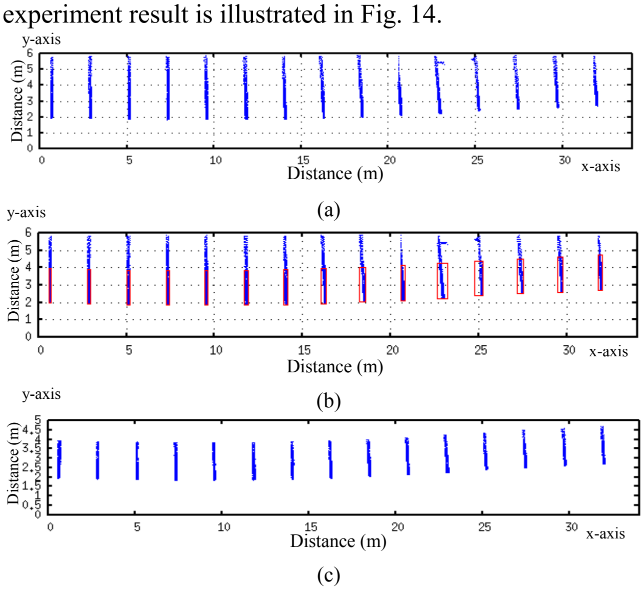


Fig. 14. The data processing of guideline detection: (a) the data of guideline by using intensity data, (b) the guideline data detection by set range V, (c) the guideline detection of each line.

As the result of the guideline detection we used that data to determine the vehicle in pair guideline data. The guideline data used to detect the vehicle data with pair guideline data for parking lot state checking which is occupancy or empty lot by count the vehicle data. For the experimental result of parking lot checking, this experiment is in Table I. In experiment result, we computed the vehicle data in the parking place having 14 number of parking lot on working a day for four time data scanner. Various data were sampled on a timely basis (by mobile robot: 10:51AM, 13:07PM, 15.55PM and 17.58PM) where O is occupancy state and E is an empty state.

TABLE I
The experiment result of parking lot state checking.

Parking space		Parking lot number													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Times	t_1	O	O	O	O	O	O	E	O	O	O	O	O	O	O
	t_2	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	t_3	O	E	O	O	O	O	E	O	O	O	O	O	E	O
	t_4	E	O	O	E	E	E	E	O	O	O	O	O	E	O

The experiment of guideline alignment, we used a pair of guideline data from t_i and t_{i+1} to match the guideline data between them. We applied the translation to both of guideline data and the vehicle of base point cloud data. We computed the vehicle comparison by determining the average minimum distance of point cloud data between them. Next, we defined the average minimum distance by histogram technique which is set the interval range is 0.01 m. Finally, with the result of average minimum distance we set the $M_{threshold}$ value is 0.1 m if the result is more than the $M_{threshold}$ that means vehicle change. The data comparison summaries are in Table II.

For the experiment result, guideline data alignment and computed translation are described in Fig. 15 and the result of average distance of vehicle data comparison is 0.015 m. that means the vehicle data implies the same position between base point cloud data and target point cloud data of the vehicle data. These are illustrated in Fig. 15 and Fig. 16 respectively.

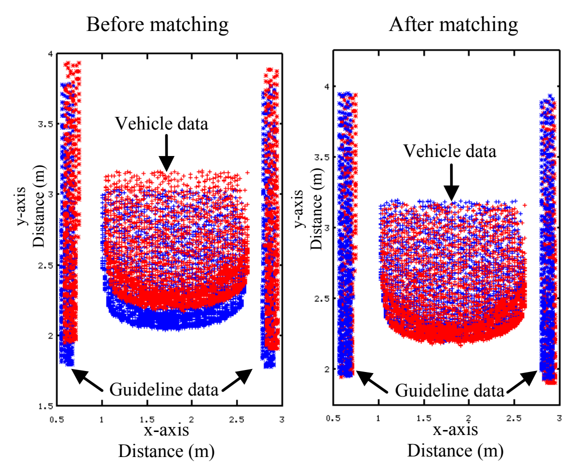


Fig. 15. The guideline data before matching (left) and after matching (right) with base point cloud (blue point) and target point cloud (red point).

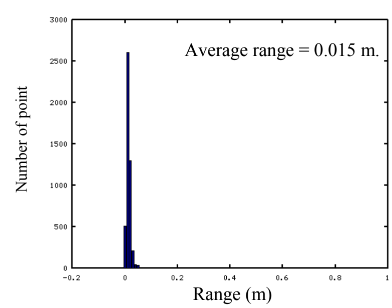


Fig. 16. The result of average minimum distance of data comparison.

TABLE II

Experiments result of average distance of the vehicle data comparison. Unit: meter (m.)

Data Comparison		Parking lot number													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Period of time	t_1 - t_2	0.03	0.01	0.02	0.02	0.01	0.01	-	0.02	0.02	0.02	0.03	0.03	0.02	0.02
	t_2 - t_3	0.03	-	0.03	0.02	0.01	0.02	-	0.02	0.03	0.03	0.03	0.02	-	0.03
	t_3 - t_4	-	-	0.02	-	-	-	-	0.03	0.03	0.02	0.02	0.03	-	0.03

However, in experimental result we can determine where a parking lot is in continue occupancy state or new occupant by a vehicle change. In this experiment, the vehicle data in parking place in case of vehicle change is not appearing so we change the data matching between differences of parking lot number that can be detected the position of vehicle changing as described in Fig. 17.

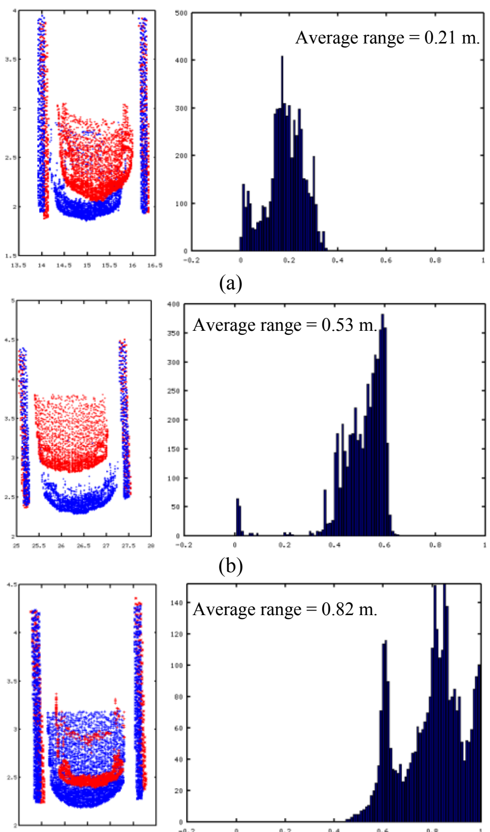


Fig. 17. The results of the guideline alignment and vehicle data comparison by vehicle data comparison of parking lot number 2 and 7 in (a) parking lot number 9 and 12 in (b), and parking lot number 4 and 11 in (c).

VI. Conclusion

Our implementation has demonstrated the feature for parking lot inspection, which achieved the practical use a LRF sensor utilizing a mobile robot in real environment. By multiple time of data scanner of patrol robot was introduced in this work. The laser reflection intensity was introduced to solve the problem of guideline detection by extraction from ground surface. The guideline alignment and vehicle comparison were introduced improving the state of parking lot. By analyzing this method, we accomplished the parking lot checking which are an occupancy status, an empty lot state and the parking lot inspection which is long term parking state in the parking space. This feature is summarized in Table III. Where circle shape is an occupancy state and square shape is an empty state.

TABLE III

Experiment result of the parking lot inspection in the parking lot space.

Parking space		Parking lot number													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Times	t_1	●	●	●	●	●	●	■	●	●	●	●	●	●	●
	t_2	│	↓	│	│	│	│	●	│	│	│	│	│	↓	│
	t_3	↓	■	│	↓	↓	↓	■	│	│	│	│	│	■	│
	t_4	■	●	↓	■	■	■	■	↓	↓	↓	↓	↓	■	↓

As of future works, we plan use these methods to detect in difference of weather such as cloudy, dark, and after rain. The additional features will include data mining techniques, etc., to classify the required vehicle(s) and all related parking space information. Other future steps of this research include robot navigation inside the parking place.

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