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Obstacle Detecting System for Unmanned Ground Vehicle using Laser Scanner and Vision

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Abstract: This paper describes obstacle detecting system of unmanned ground vehicle. Obstacle detecting system of UGV is important system for driving safety and stability. Our obstacle detecting system is consists of 2 component. One is laser system component and the other is vision system components. These systems are based on JAUS. In This paper we introduce UGV system configuration and explain obstacle detecting system using laser scanner and camera.

Keywords: UGV(Unmanned Ground Vehicle), Obstacle detecting system, Vision, Laser scanner

1. INTRODUCTION

The Defense Advanced Research Projects Agency (DARPA) held first DARPA Grand Challenge on 2004. This challenge aimed at fostering the development of a completely full-scale autonomous vehicle. At the first challenge, no vehicle had completed more than 7 miles of the course. Second challenge held on 2005, 5 vehicles finished the 132 mile race.

Fig. 1 Unmanned Ground Vehicle (Stanford racing team)

At the result of the challenge, the navigation system and obstacle detecting and avoidance system are important to drive at the full-scale autonomous vehicle. For stability driving, vehicle has to detect obstacles and avoid obstacles. Especially 2007 DARPA Grand Challenge's target is a city driving. So, unmanned ground vehicle has to avoid various obstacles better than 2005 DARPA Grand Challenge. For example, kinds of obstacle are driving car, traffic signal, traffic sign and fixed street furniture.

In this paper, we describe obstacle detecting system using Laser scanner and Vision for unmanned ground vehicle.

2. UGV SYSTEMS

Unmanned ground vehicle (called KUL-1) is based on electric vehicle that used at golf club. KUL-1 is composed of four system such as vehicle control system, navigation system, path planning system and obstacle detecting system. Each system connected by UDP network. And KUL-1 is developed by LabVIEW 8.2 of NI Corporation.

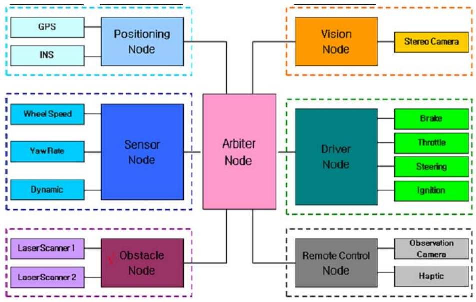

Fig. 2 KUL-1 system configuration

Fig. 3 KUL-1 based on electric vehicle

3. OBSTACLE DETECTING SYSTEM

Obstacle detecting system is consists of two components. Laser system component used two Laser scanners and Vision system component used one camera for detecting obstacles and recognition.

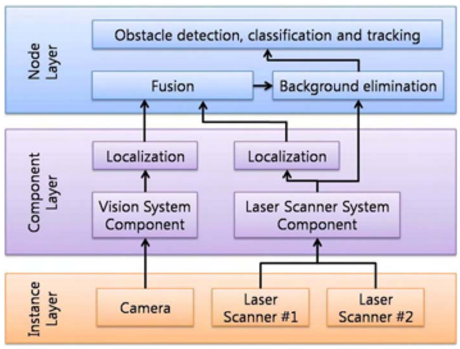

Fig. 4 Obstacle detecting system of UGV

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3.1 Laser Scanner System Component

Laser scanner is one of the obstacle detecting sensors. Most UGV use this, because it is easy to connect PC to have accurate value of distance. Obstacle system uses LMS291 laser scanner from SICK Optic Inc. It has 180 degrees detecting range and maximum detecting distance is 80 meter. Its angular resolution is 0.25°, 0.5° and 1°, and distance resolution is 1cm. This Laser scanner offers two interface methods. One is RS232C and the other is RS422. According to the interface method, data update rate is different. Using RS422 interface method, its maximum update rate is 37Hz. So It can detect obstacles quickly and can find obstacles positions.

Fig. 5 SICK laser scanner (LMS-291 outdoor type)

Its data protocol of Laser scanner shows table 1. Its all data size is 732bytes including STX, data, and checksum. Among them, distance data is 724 bytes.

All transmit is started STX(0x02) and finished CRC for checking error. And the data that consist of 2 bytes more was transmitted by Intel type.

Table 1 Data protocol of laser scanner

Description	STX	Address	Length		Response	Data		Checksum	
						Data	LMS statue		
Byte position	1	2	3	4	5	6 to 729	730	731	732
Hex. Value	02	80	D6	02	B0	724 byte	10	15	D4

Fig. 6 Received Data from LMS291

Fig. 6 shows data structure of scan. The Laser scanner generates 732 bytes data from a scanning. Coordination system of laser scanner is polar coordination system. Generally UGV use rectangular coordination system. So, the Laser scanner component use an equation of coordinate conversion

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} r\cos\theta \\ r\sin\theta \end{bmatrix} \quad (3.1)$$

In this research, Laser scanner parallels the ground on a vehicle. Its level is 0.7m from the ground to the vehicle, as shown Fig.7 (a). The size of region of interest (ROI) is 10-by-20m, as shown Fig.7 (b).

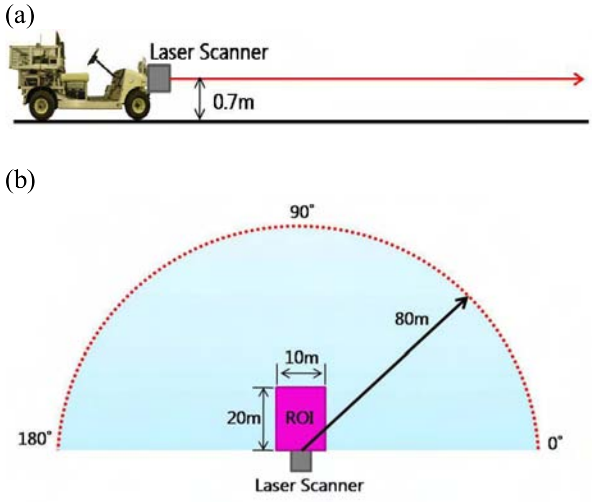


Fig. 7 Scanning area and setting ROI: (a) Side view (b) Top view

3.1.1 Obstacle Detection

The Laser scanner cannot figure out accurate features of obstacle because of the plane scanning. However, it can get an accurate position of obstacle. Therefore, it gets the position of obstacle in compliance with the processing, as shown Fig.8.

In a first step, the detection of obstacles requires a segmentation of the distance measurements. Segmentation means in this context clustering of distance measurements that probably belong to the same object in the real world.

So the distance measurements generated by one scanning are divided into segments, which are assumed to belong to the same obstacle.

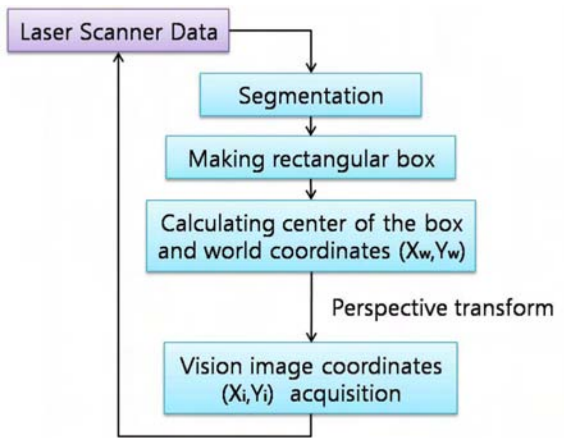


Fig. 8 Overview of the obstacle detection process

Second, these segments are represented by a rectangular box around the measurements, providing length and width of the segment.

Third, Laser scanner system calculated center of the box. And the world coordinates (X_W , Y_W) of the center is calculated.

(a)

(b)

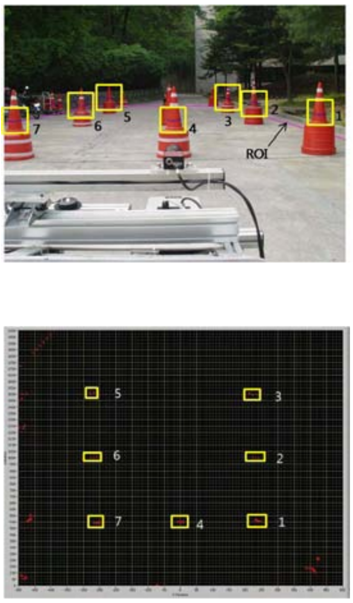
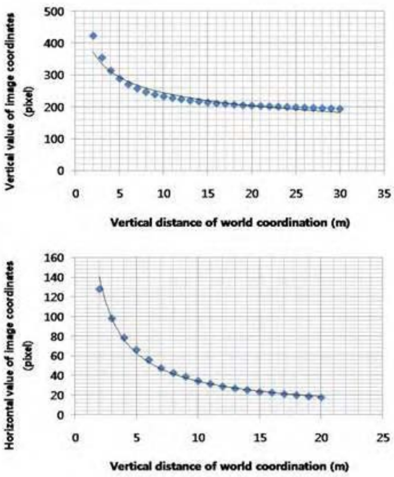


Fig. 9 Make a comparison between a camera image and a scanning graph:
(a) Camera image (b) Scanning graph & segment

(a) (b) (c)

Fig. 10 Vision image coordinates acquisition

Lastly, the calculated coordinates are transformed into the vision image coordinates (X_i , Y_i) by the perspective transform.



$$Y_i = 411.8 \times Y_w^{-0.25} \quad (3.2)$$
$$X_i = (159.7 \times Y_w^{-0.71} \times X_w) + 320 \quad (3.3)$$

Fig. 11 Perspective transform by an experiment

Perspective transform function was obtained by doing measurement test. A camera put on center of vehicle and at altitude of 172cm and degree of ten from vehicle to ground. The experiment divides into 3 branch type and it executed. The first test using vision measured 30m in 1m intervals in the front of vehicle. The second test measured 30m in 1m intervals from the location where is 2m front of vehicle. The third test measured 30m in 1m intervals from the location where is 3.5m front of vehicle. The result showed on fig.11.

But the Laser scanner is difficult to detect a kind of obstacles. Therefore, vision system is required to get precise information of obstacles.

3.2 Vision System Component

Vision system of UGV is a part of obstacle system. KUL-1's vision system is used for detecting obstacles and recognition on a dirt road. KUL-1 used Marlin F-033C CCD camera. It is support IEEE-1394 interface. It cans grab 60 frames per second.

Fig. 12 AVT IEEE-1394 Camera (Marlin F-033C)

3.2.1 Obstacle Detection

Vision system component is got the position data from Laser scanner system component. Then the system set region of interest using obstacles positions. And then the system analyzes the region for classifying the obstacles. Using this system, KUL-1 can know kinds of obstacles on the ground, as shown Fig.13.

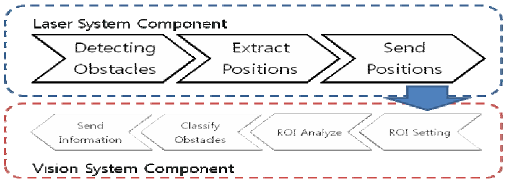


Fig. 13 Obstacle detecting algorithm flow chart

Fig. 15 illustrates a function diagram of the classifying phase. Preprocessing operations prepare images for better feature extraction. Preprocessing includes noise filtering; thresholding; rejecting particles that touch the image border; and removing small, insignificant particles. Feature extraction computes the feature vector in the feature space from an input image.

Fig. 14 Image acquisition and preprocessing steps

Feature extraction reduces the input image data by measuring certain features or properties that distinguish images of different classes. Which features to use depends on the goal of the classification system. The features could be raw pixel values or some abstract representation of the image data. For identification applications, select features that most efficiently preserve class separability - feature values for one class should be significantly different from the values for another class. For inspection applications, select features that distinguish the acceptable from the defective.

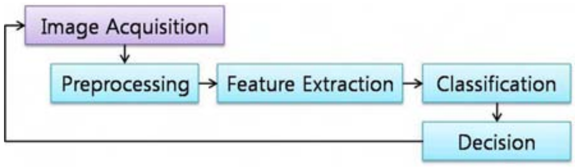


Fig. 15 Step of the classifying phase

Classification algorithm is K-Nearest Neighbor. In K-Nearest Neighbor classification, an input feature vector X is classified into C_j based on a voting mechanism. The classifier finds the K Nearest samples from all of the classes. The input feature vector of the unknown class is assigned to the class with the majority of the votes in the K Nearest samples.

The outlier feature patterns caused by noise in real-world applications can cause erroneous classifications when Nearest Neighbor classification is used. As Fig.16 illustrates, K-Nearest Neighbor classification is more robust to noise compared with Nearest Neighbor classification. With X as an input, K = 1 output Label 1, and K = 3 output Label 2.

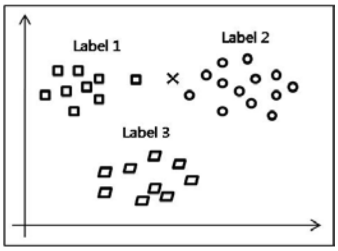
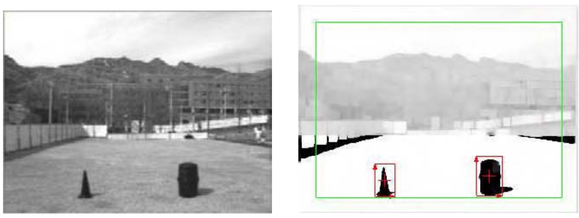


Fig. 16 How K-Nearest Classifier Works

So, Vision system can distinguish a con form a barrel, as shown Fig.17.



(a) Raw image **(b) Classified image**

Fig. 17 Distinguish con from barrel:

4. CONCULTION

In this research, we suggest the method of detecting obstacles by using laser scanner and vision. The Laser scanner cannot figure out accurate features of obstacle. It is difficult to detect a kind of obstacles. However, it can get an accurate position of obstacle. Vision system gets numerous data. So, it is difficult to process data. Therefore, it gets the position of obstacle from the Laser scanner system component. And vision system component can know kinds of obstacles on the ground. And then the component decides the obstacle is moving obstacle or is fixed obstacle. The result of analysis sent the path planning component to perform special processing routine.

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