Road Detection Method Corresponded to Multi Road Types with Flood Fill and Vehicle Control

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***Abstract*—This paper proposes the road detection method corresponded to multi road types with Flood Fill. Flood Fill is one of the image processing methods to partition the region of input image based on RGB color model. Road detection is useful for automatic robots because the robots work on various road surface in outdoor environment. The proposed method has two features. Firstly, the method can cancel the influence of shadow on road by using HSV color model. Secondly, the method can recognize multi road types by k-nearest neighbor algorithm. By using the proposed method, the robot can select the suitable controller for road surface or the safety route. We implement the proposed method in vehicle navigation and the availability is verified by the experimental results.**

***Keywords*-Image Processing, Flood Fill, Road Detection**

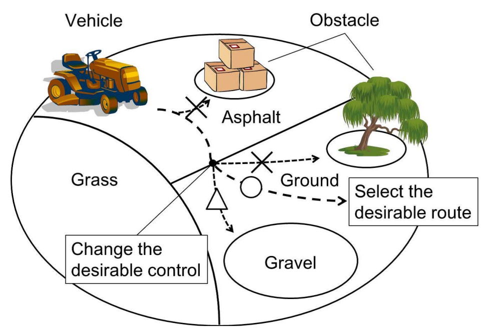

Figure 1. Concept of the road detection corresponded to multi road types with Flood Fill

I. Introduction

Recently, it is expected that autonomous mobile robots work in outdoor environment. In particular, Autonomous agricultural machines are needed because of the reduction and aging of agriculture worker in Japan. The machines are also worthy to manage the broad field in western countries.

One of the main technical issues about the automation of agricultural robots is environmental recognition. Agricultural robots have to plan the action based on environmental recognition observing the position and condition of target crops.

Additionally, agricultural robots have to work on various rough ground like soil, grass, gravel and so on. The condition of road surface also changes by weather. If there are some road detection methods, robots can select the suitable controller for road surface or the safety route automatically. Therefore, this research focuses on the road detection method to determine the road type of the place that the robot works on.

In previous research, road detection for pavement like asphalt is major, but road detection for various road surface is minor. As road detection for pavement, the methods to detect the white line on the road with Snake which extracts the contour of the objects are proposed [1] [2]. The method to utilize the road pattern learned by neural network is also proposed [3]. The method to utilize the vanishing point of road is proposed [4]. This method can detect the rough road region without depending on the color of road. The road detection with Watershed which is region partition method by using gray scale image [5]. It is difficult to applying these research on the field with various road types.

An influence of shade is major problem for road detection to improve robustness with respect to environments. Many solutions to remove shade from input image have been proposed [6]–[8]. In these research, the method to detect the plane of road by stereo camera and the method to utilize three-dimensional information obtained by laser sensor are proposed. But, it is difficult to develop the road detection methods to be able to adapt to various environments with only monocular camera.

This paper proposes road detection method corresponded to multi road type with Flood Fill. Flood Fill is one of the image processing methods to partition the region of input image based on RGB color model. The proposed method has two characteristics as follows.

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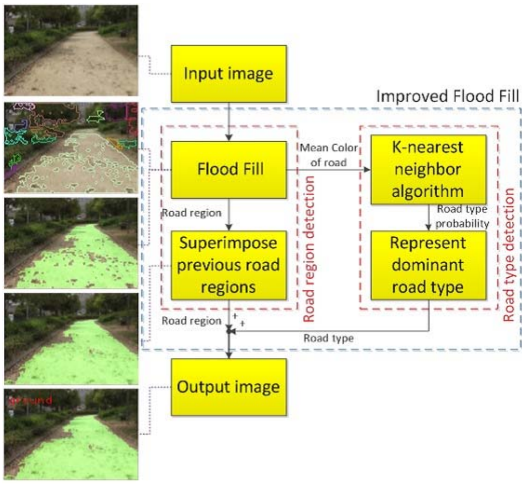

Figure 2. Flowchart of road detection

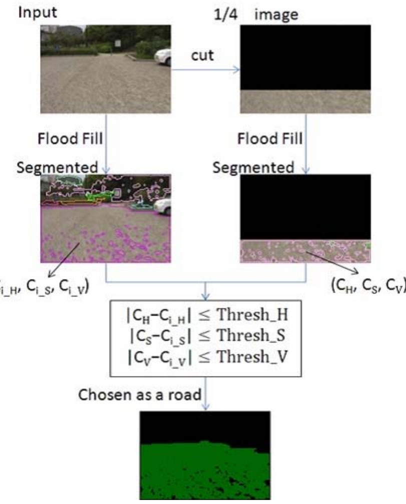

Figure 3. Decision of road region

1) This method can cancel the influence of shade or the change of lighting with only monocular camera by using HSV color model
2) This method can be applicable to autonomous robot control because the method can recognize some road types by using RGB color model.

The concept of the proposed method is shown in Fig.1. The proposed method can realize that the robot select the suitable controller and the safety route automatically.

II. Recognition of road surface

This chapter proposes the algorithm of road detection. The algorithm consists of three main steps as follows. The flowchart of road detection is described in Fig.2.

1) Region partition of input image with Flood Fill
2) Decision of road surface with HSV color model
3) Decision of road type with k-nearest neighbor algorithm

A. Region partition of input image with Flood Fill

Flood Fill is one of the image processing methods to partition the region of input image based on RGB color model. Flood Fill operates that image spatial coordinate (x, y) connects (x', y') which is next to (x, y) as same region when (1), (2) and (3) are satisfied. This operation is conducted to all pixels and input image is partitioned into some regions.

$$R(x', y') - T_R \leq R(x, y) \leq R(x', y') + T_R \tag{1}$$

$$G(x', y') - T_G \leq G(x, y) \leq G(x', y') + T_G \tag{2}$$

$$B(x', y') - T_B \leq B(x, y) \leq B(x', y') + T_B \tag{3}$$

R(x, y), G(x, y), B(x, y) are the values of R, G, B at the coordinate (x, y) respectively. T_R, T_G, T_B are the allowable values to determine if coordinates (x, y) and (x', y') are in same region or not.

Flood Fill utilizes the values of RGB as shown in (1), (2) and (3). Therefore, Flood Fill is suitable for automation of agricultural robot because there are many objects in the field which have color characteristic like crops, plants, tree and so on.

B. Decision of road surface with HSV color model

Road surface is determined with HSV color model from some regions partitioned by Flood Fill (Fig.3).

H(Hue) represents the type of color and the range of value is within 0-360. S(Saturation) represents colorfulness and the range of value is within 0-1. V(Value) represents brightness and the range of value is within 0-1. These definitional equations are shown in the following. max is the maximum value of R, G, B. min is the minimum value of R, G, B. If the value of H is negative, 360 is added to H.

$$H = \begin{cases} 60 \times \frac{B-G}{max-min} & \text{if max = R} \\ 60 \times \frac{R-B}{max-min} + 120 & \text{if max = G} \\ 60 \times \frac{G-R}{max-min} + 240 & \text{if max = B} \end{cases} \tag{4}$$

$$S = \frac{max - min}{max} \tag{5}$$

$$V = \frac{max}{255} \tag{6}$$

In decision of road surface, we assume that the maximum region in the lower forth of input image is the road which robot can travel on. Based on the average HSV values of this region, road surface is determined from upper three fourths of input image.

The conditional equations are shown in (7), (8) and (9). C_H, C_S, C_V are the average HSV values of the lower

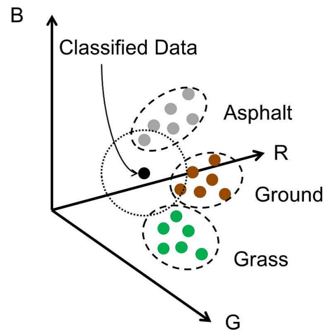

Figure 4. Road type classification by k-nearest neighbor algorithm

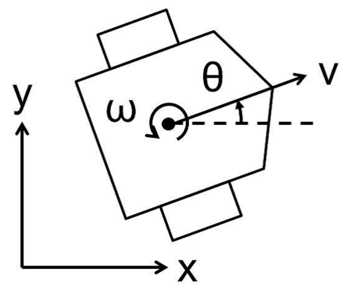

Figure 5. Model of robot

Figure 6. Experimental environment

forth of input image. C_{Hi}, C_{Si}, C_{Vi} are the average HSV values of the ith region partitioned by Flood Fill in upper three fourths of input image. T_H, T_S, T_V are the allowable values to determine if ith region is similar to the road or not. The ith region is regarded as road when (7), (8) and (9) are satisfied.

$$|C_H - C_{Hi}| \leq T_H \tag{7}$$

$$|C_S - C_{Si}| \leq T_S \tag{8}$$

$$|C_V - C_{Vi}| \leq T_V \tag{9}$$

To Adjust the values of T_H, T_S, T_V can cancel the influence of shade or the change of lighting by using HSV color model.

C. Decision of road type with k-nearest neighbor algorithm

Road type is determined by k-nearest neighbor algorithm (4). This algorithm is statistical classification method based on the nearest training data. To recognize road type can realize that the robot select the suitable controller and the safety route automatically.

Data to determine the road type are the values of RGB. In this research, asphalt, ground and grass are defined as road type. The data point to be classified is the coordinate of the average values of RGB in the lower forth of input image. Among the k nearest data points to the standard data point, the place that robot works is determined as the most common road type. The road type is unknown when number of votes is same.

III. Experiment

A. Experimental conditions and content

The allowable values of road detection in (1) - (3) and (7) - (9) are described as follows.

- T_R, T_G, T_B = 5
- T_H = 90, T_S = 0.1, T_V = 0.2

In this research, we implement the road detection method in vehicle navigation. The robot which we used is two-wheel drive robot (Fig.5). The robot is equipped with the monocular camera (Logicool HD Webcam C270, Logitech). The geometric model equation of the vehicle is described in (10). (x, y, θ) is the position and posture of robot. (v, ω) is the input of robot. v is the translational velocity. ω is the angular velocity of rotation.

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix} \tag{10}$$

Experimental environment is the path in university as shown in Fig. 6. The robot travel on only middle road. Therefore, the robot travels along the path based on the proposed road detection method.

The navigation rule is shown in (11) and (12). K_x and K_θ are the gains of control. In this experiment, the parameters of gains are (K_x, K_θ) = (0.125, 1.0). x_e and θ_e are the errors of position and angle. x_e means the distance which the robot can travel. x_e is decided from the result of road detection and the range of value is within 0-4. The robot stops (x_e = 0) when the road is not detected. The robot also stops when the road type is unknown. The maximum speed of robot is 0.5 m/s (x_e = 4) when $x_e \geq 4$. θ_e means the direction which the robot should travel in. θ_e is decided from the gravity point of road region. The value is the angle between the line connecting the center point of input image with the gravity point and the center line of the vertical.

$$v = K_x x_e \tag{11}$$

(a) Input image

(b) Output image of road detection and road type recognition

Figure 7. Result of road detection

$$\omega = K_{\theta} v sin\theta_e \tag{12}$$

B. Experimental results

The result or road detection is described in Fig. 7. Figure 7 (a) is the input image from the camera. Figure 7 (b) is the output image of road detection.

The road region is described in green. The output image shows that the region of asphalt is detected correctly. Although there are some small obstacles like fallen leaves on the road surface, they are excluded because they does not affect robot traveling. If there are a big obstacles like the mass of fallen leaves at the left side of road, the region is not recognized as road.

Regarding robot navigation, the robot was able to travel about 20 meters detecting road surface on the road without shade. But, It is difficult for the robot to travel on the road with shade like Fig.6 because the allowable values need to be adjusted depending on time zone or condition of weather.

Besides, the result of road type recognition by k-nearest neighbor algorithm is described at the upper left of output image. The correct road type is shown as “Asphalt”. As shown in Fig. 8, we verified that the proposed method can recognize some road types correctly in various environments.

IV. Conclusion

This paper proposes the road detection method corresponded to multi road types with Flood Fill. This method can realize recognizing road region and various road types. In this paper, we implemented the proposed method in two-wheel drive robot and verified the dynamic stability by robot navigation.

As future works, we will experiment the automation of robot traveling on the field with some road surface. To realize that, there are some problems about introducing path planning based on road type recognition and optimizing allowable values according to the condition of environment.

Figure 8. Result of road detection in various road type

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