Road Detection for Supporting Autonomous Guided Electric Vehicle Robot

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ABSTRACT
Road detection is a vital part in autonomous guided vehicle or robot. In this paper, we describe a road detection method for urban area. The challenge of road detection in urban area is some part of the roads are covered by vehicles. To solve that problem, we propose a method that consists of 3 main steps. First is an image capturing to takes digital image. Second is pre-processing that consists of prediction and cutting road area in an image, and the last is line detection and road labeling. The method has good performance and its has evaluated by using precision, recall and accuracy. That result have been presented in this paper.

CCS Concepts
Computer systems organization~Robotic autonomy

Keywords
color-space , road detection, line detection

1. INTRODUCTION
Recently, the control technology has been growing rapidly, especially in the fields of science, such as automotive, robotics and industrial. The research of Autonomous Guided Vehicles (AGV) is a hybrid technology that combines several fields such as mechanical system, electronic system and vision system. One part in vision system is a road detection. The road can be found by analyzing an image which is captured from the camera. Various problems can be found in road detection using a camera such as different light intensity, contrast, shadow, etc.

ICRCA 2019, July 26–28, 2019, Guangzhou, China

ACM ISBN 978-1-4503-7183-4/19/07…$15.00
https://doi.org/10.1145/3351180.3351205

Detecting roads in real time using a camera placed in front of the vehicle have many challenges such as an ever-changing environment, different types and conditions of roads, different objects etc. Many researchers develop their method to improve the performance of road detection [1]. The most basic method for detecting roads is used the texture [2],[3] and color of the road [4]. After that is continuing to classify the input image into roads and non-roads. While color will provide strong information about the color of the road. In here, a user must provide true or good sample color of road during road detection process. However road detection using color-space has a problem against changes of light intensity and shadow during imaging process.

Generally, road detection, which is based on line mark is commonly used in AVG [4]. Roads with line marks are found in urban areas [5], however, most of the roads in urban areas are covered by vehicles, making it very difficult for road detection in the front of the vehicle. Therefore, several approaches have been taken to solve the problem, such as a obstacle detection in the front of vehicle by line laser [6] and a road estimation uses multilayer laser scanner [7]. Line laser or multi-line laser can be used to detect the surface of the road. Line laser on the surface will be captured by camera to obtain a digital image, and then a line laser is detected by line detection method. After the line is detected, its continuing to analyze for knowing the surface condition. If the line laser is not straight then, that indicates the surface of the road is not flat. Yet, road detection uses laser can interfere other user, which is due the light of laser appears on the road surface. The Line Laser array was implemented for improving the performance of that method.

The properties of the road such as color, line marking and texture of the road area have been widely used for detecting surface of the road and segmenting the road in urban area [8], [9], [10]. The methods of Hough transforms, steerable filters and Spline model usually used for detecting a road markings [11], [12], [13] like zebra cross and any kind of line marking. However, they only detect a mark line of structured roads which have road markings or borders.

In this paper, we propose a method for detecting a road in urban area, which have road marking or borders. So that, our method combines between line detection and color-space for detecting the road. To increase the performance, the proposed method only worked in road area which is predicted by road-prediction which is based on correlation.

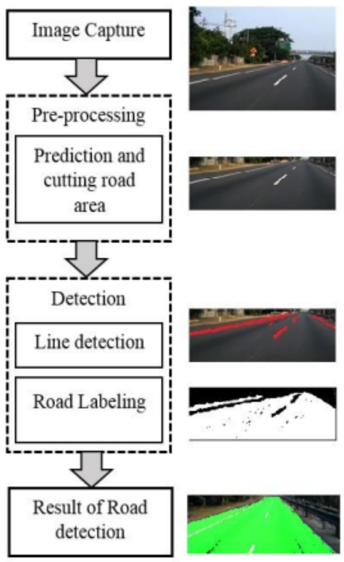


Figure 1. Steps of Proposed Image

2. PROPOSED METHOD

Figure 1 shows the step of the proposed method that consist of three parts, there are image captured, preprocessing, and detection. Image capturing is taking a real-image to become digital image. Pre-processing is to predict and cutting road area in an image. Processing consists of line detection and road labeling which is based on the color-space. The output is road detection result.

2.1 Pre-processing

Reducing the size of image can be significant increase the faster computation-time and also accuracy. This is good for real-time road detection. So, the input image is resized and the non-road area must be cut. To do it, here give a sample road image as $\hat{\mathbf{F}}$ with the size of sample image $\hat{\mathbf{F}}$ is 10×15 pixel. A sample image $\hat{\mathbf{F}}$ is selected from capturing image $\mathbf{F}$ which is confident road-image sample. The size of image $\mathbf{F}$ is resized into 400×600 pixels. We used AMIK [14] method for image resizing. AMIK method is based on filling pixel to the target image size. In this paper, the target image size is 400×600 pixels. A pixel that will be filled in each coordinate of the target image is calculated using AMIK. AMIK method uses sample 3×3 pixels which are corresponding between coordinate of target and source image.

To predict the confident road, We calculate the correlation $\mathbf{r}_j$ between sample image $\hat{\mathbf{F}}$ and $\boldsymbol{W_T}$ by using Equation (1). $\boldsymbol{W_T}$ is a part of image $\mathbf{F}$ which is the same size with $\hat{\mathbf{F}}$. $\mathbf{R}(\boldsymbol{i})$ on Eq.(4) is the average of correlation value for each row. If the value of r_j is close to one, then $\hat{\mathbf{F}}$ and $\boldsymbol{W_T}$ correlate. Equation (5) states if the average value is less than 0.25 then the row "i" will be deleted.

$$r_j = \frac{\sum_{y=1}^{M}\sum_{x=1}^{N}(\hat{F}(x,y)-\bar{f})(W_T(x,y)-\overline{W_T})}{\sqrt{AB}} \quad (1)$$

$$A = \sum_{y=1}^{M}\sum_{x=1}^{N}(\hat{F}(x,y)-\bar{f}) \quad (2)$$

$$B = \sum_{y=1}^{M}\sum_{x=1}^{N}(f_T(x,y)-\bar{f_T}) \quad (3)$$

$$R(i) = \frac{1}{N}\sum_{j=1}^{N} r_j \quad (4)$$

$$R_{cut} = R(i) \leq 0.25 \quad (5)$$

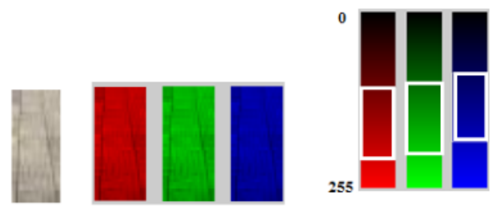
2.2 Processing

The famous method for line detection is Hough Transform for line detection. Basically, line detection using Hough Transform is used Eq. (6). Equation (6) represents straight lines in an image for all various of slope angle values. A line in (x,y) space at least must lie on the intersection of two lines in the (m,c) space (by Eq. (7)). Which means that all pixels in the same line on (x,y) space will be expressed by all lines which through a single point in the (m,c) space. However (m,c) space has a disadvantage when it detects parallel or vertical lines in the space (x,y), which is detected lines infinite lines. To solve that problem, we use Eq.(8), which is expressing a point in (x,y) space to the (r,θ_i) space.

$$y_i = mx_i + C \quad (6)$$

$$c = y_i - mx_i \quad (7)$$

$$x\cos\theta + y\sin\theta = r \quad (8)$$



(a) (b) (c)

Figure 2. Color space illustration. (a) RGB Image, (b) independent R, G and B of image (a), (c) Range of color-space in 24 bit color.

In this paper, we use color-space which refers to data set for pre-road detection. The data set is symbolized by $\mathbf{D}$. The color space of data set $\mathbf{D}$ is expressed by Eq. (9).

$$C_{RGB} = \min(D_{RGB}) : \max(D_{RGB}) \quad (9)$$

Equation (9) expressed the range of color-space that start from the minimum pixel value ($\min(D_{RGB})$) up to the maximum pixel value ($\max(D_{RGB})$). White box in Figure 2 (c) shows the range area of data set D in 24 bit RGB.

The pixel that represents a road, if the pixel locates in the range of color space. Equation (10) is used for mapping road and non-road pixel. The pixel road will be labeled by "1" and "0" for non-road.

$$\mathbf{L} = \begin{cases} 1 & if\ F_R \in C_R\ or\ F_G \in C_G\ or\ F_B \in C_B \\ 0 & others \end{cases} \quad (10)$$

Equation (10) will mapping the road area in an image and to reduce the false detection, it's combined with line-detection. If the road mapping connects with a line, then the map area will be maintained and vice versa, if the map doesn't connect with a line then will be reduced.

3. EXPERIMENTAL RESULT AND ANALYSIS

The performance of proposed method is analyzed by qualitative and quantitative analysis.

3.1 Qualitative Analysis

The qualitative evaluation is evaluated by observing the result of the proposed method. Figure 3 shows, how to predict road area in an image. Figure 3(a) up to 3(d) are capturing images as an input image that has been resizing in to 400×600 pixels. Figure 3(e) up to 3 (h) are the plotting result of average correlation value for each row. The "x" axis is the number of rows (400) and the "y" axis is the average value of the correlation. If each row of $\boldsymbol{W_T}$ are correlated with $\hat{\mathbf{F}}$, then they will have the correlation value close to one, and vice versa. Figure 3(i) up to 3(l) are red line position that indicates the road boundary area. The position of red line depends on average of correlation value in each row. In our experiment, we have threshold value for correlation is 0.25. By select all rows that have a correlation value greater than 0.25, then we can predict the road area. As an example in Fig. 3(e), the threshold value of correlation is 0.25, then we obtain a cross line in 225 of row. To find out the truth, we show the red line on row number 225 as shown in Fig. 3(i). So, we can predict the road area start from 226 up to 400 of rows, that caused it has an average of correlation value greater than 0.25. The selected road image is shown in Fig. 3(m) up to 3(p).

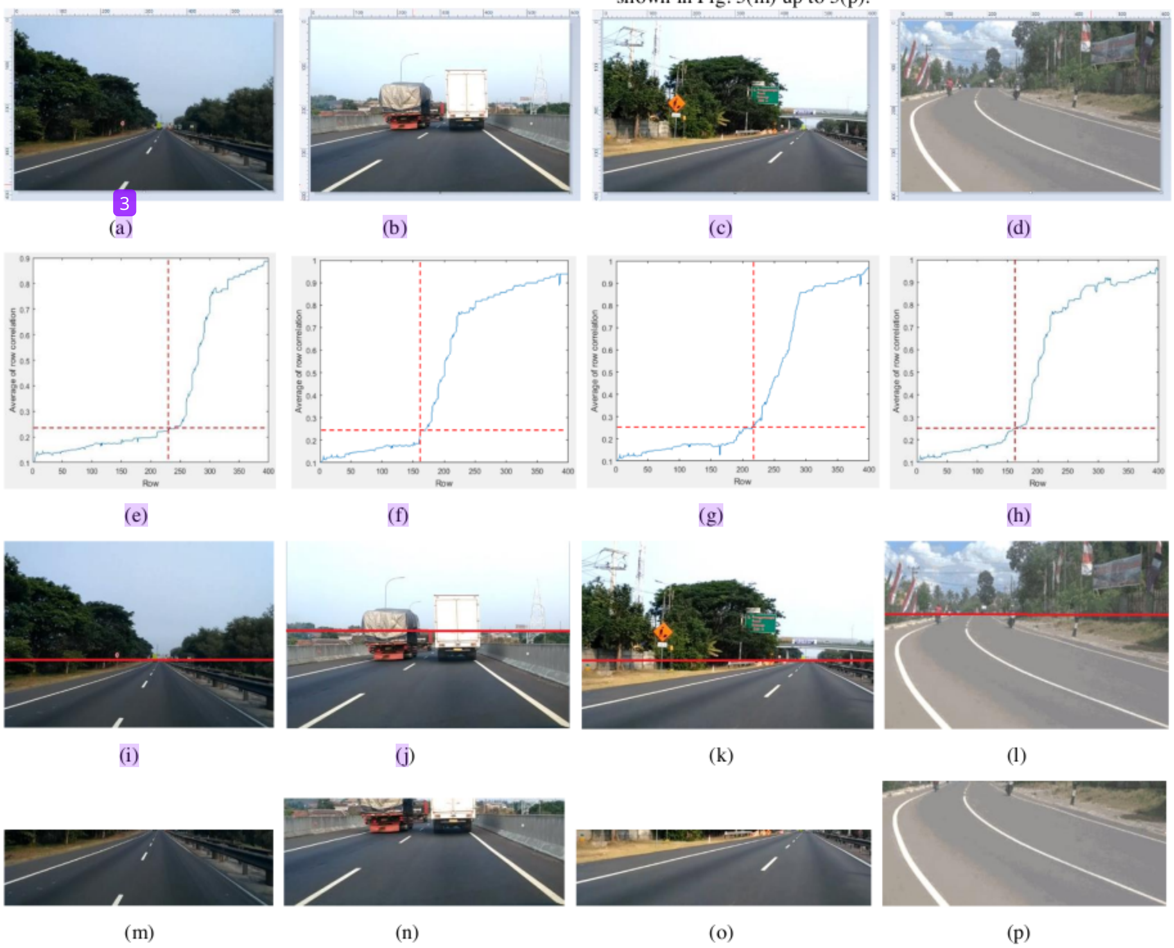


Figure 3. Pre-processing Result. (a) up to (d) are capturing image, (e) up to (h) are plotting of the row-correlation average, (i) up to (l) are the red line position, and (m) up to (p) are the result of road cutting.

Figure 4 shows the comparison result for road detection. Figure 4(a) up to 4(d) are capturing image that will be process. Road detection using template matching (TM) has false detecting when a template of road similar with non-road in an image as shown in Fig. 4(e) up to 4(h). Figure 4(i) up to 4(l) shows the road detection using color-space which is combined with cluster connecting method. This method capable to reduce false detection as happened in road detection using a color space method only. However, several false detection still found in scattered around the road. Figure 4(m) up to 4(p) show the road detection of proposed method. The false detection which is scattered in around the road can be reduced as shown in Fig. 4(m) up to 4 (p). In here, our method will eliminate the pixel that is not interconnected with line and other pixels.

3.2 Quantitative Analysis

The evaluation method by Qualitative is dependent by human visual and more subjective compare with the quantitative evaluation. In this paper we use four evaluation methods such as Precision, Recall, F-measure and accuracy as shown in Eq.(11) up to (14). These methods are generally used for image analysis [4].

$$\text{Precision} = \frac{TP}{TP + FP} \quad (11)$$

$$\text{Recall} = \frac{TP}{TP + FN} \quad (12)$$

$$F_{\text{measure}} = (1 + \beta^2)\frac{Precision\ Recall}{\beta^2 Precision + Recall} \quad (13)$$

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN} \quad (14)$$

Where is: TP is true positives, in this case, if we detect a road and that true of the road. TN is true negatives, if we predict non-road and that true non-road. FP is false positives, if we detect a road and that is actually non-road. FN is false negatives, if we predict non-road, but in image actually do have a road.

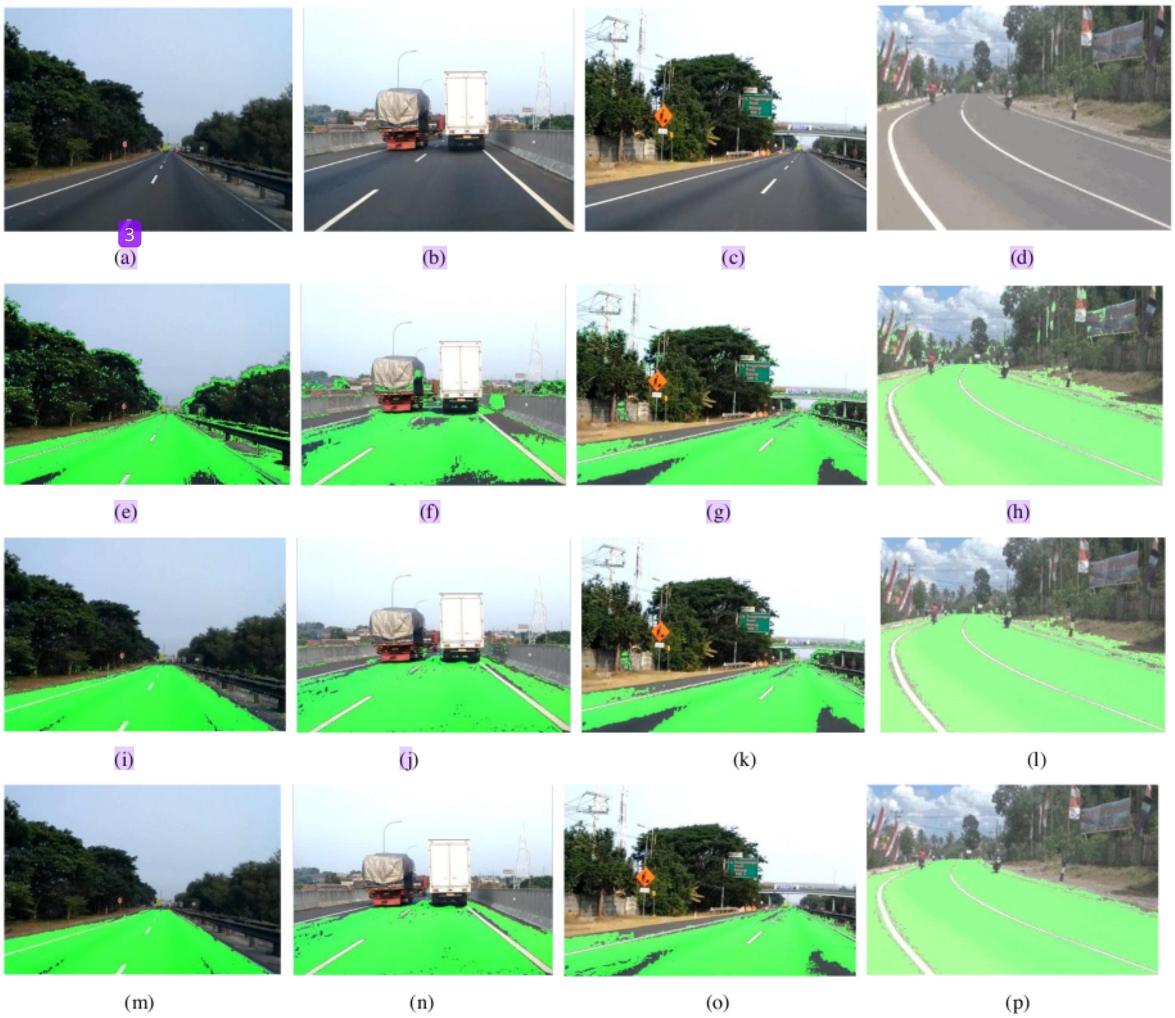


Figure 4. Comparison Result. (a) up to (d) are capturing image, (e) up to (h) road detection using template matching. (i) up to (l) are detection using color-space. (m) and (p) are combination between line and color-space detection.

Table 1. The comparison of evaluation result

	Precision	Recall	F-measure	Accuracy
TM	89,5	85,3	88,1	90,4
Color-space	93.2	85.5	89.4	91.9
Proposed	94,1	85,8	89,7	92,2

The evaluation result using Eq. (11) up to Eq. (14) is shown in Table 1. Template matching (TM) has a lower value, compare with the proposed method that caused the method of TM has false detection, TM detect non-road as a road. The proposed method has good results that stated by slightly higher value for precision, recall, F_measure and accuracy compared with the comparison methods.

4. CONCLUSION

We propose a method of road detection, which combine between line detection and color-space for road detection. Line and color-space for road detection is worked in an image that contain road area. Image road area is predicted by correlation. The experiment shows the proposed method can predict the road area in an image. Line and color-space for road detection is worked in an image that contain road area. Image road area is predicted by correlation. The experiment shows the proposed method can predict the road area in an image and also has good result for road detection. The proposed method can reduce the false road detection that is caused the proposed method only maintain the connected between line detection result and color-space road detection result. As well as for evaluation by using precision, recall, F_measure and accuracy, the proposed method has slightly higher value compare with the comparison method.

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