Road Detection System based on RGB Histogram Filterization and Boundary Classifier

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Abstract— **The purpose of this paper is to describe a new approach in road detection. This research uses two detection processes approaches: RGB histogram Filterization and Boundary Classifer, which is different from previous works on road detection. RGB Histogram Filterization processes the reading from the camera in greyscale form and afterward processes them by color segmentation. The last step for this process is determining area between the slopes, which is considered to be the road area. Boundary classification process then employs the RGB indexing on slope ranges, and mapping them into real pictures of roads and its environments. The next process is specifically looking for line boundaries by using Hough-Transform and Canny Edge Detection, and transforms them into binary numbers of '0' and '1'. '1' represents road boundaries while '0' represents surrounding area. The coordinate of '1, then mapped by cubic spline to produce connecting line between point '1' coordinates, which in the end produce sharp images on boundaries between road and non-road. This model has proven to be able to detect road conditions and distinguish roads from non-road in a precise way. A test is already conducted for the system by using real-time roads in Bandung, Indonesia. The results are really promising for the road condition on both straight and curved road area.**

Keywords—road detection; RGB filterization; boundary classifier

I. INTRODUCTION

Traffic management constant need of analysis related to road conditions, such as the level of road congestion, is not as simple as it seems. Congestion levels conditions, naturally, require related data on road capacity and the number of vehicles that travelling on the road. This process is quite complicated and requires a focus and determination on each field involved. The system developed will always have three (3) stages of main parameters, as follows (1) vehicles detection, (2) vehicles tracking, (3) classification and trajectory pattern of vehicles (see Fig.1). However, before going through the first stage, the system must be able to recognize the road conditions in advance. The process of recognizing the road or road/path detection, which are quite complex and complicated, is not the one that being discussed in this research. [3].

In road research area, the biggest problem is the surrounding environment such as, road curvature, road heights, roadblocks, lighting (weather), shadows and the unclear or even non-existence physical lane lines. There are two major trends on road detection through image processing, i.e.: single camera-based detection (monocular) and detection using two or more cameras (stereovision). Monocular approach uses techniques of matching an object to the model, shape or color segmentation, the use of the axis coordinates and so forth. On the other hand, stereovision approach has benefited from measuring instantly the forms in 3D coordinates of the image located in a complex environment, but the difficult calibration and quite expensive camera price are still considered to be major constraints.

Existing research tends to utilize the functionality of Grey-Level RGB to determine path detection through the Hough-Transform and canny detection. The threshold value (threshold) is still determined manually. Some studies are still really engaged in mapping the shape by using Inverse Perspective Mapping (IPM) to help estimate the shape of the path without using Kalman Filter, a favorite among researchers in this study. Another studies utilizing virtual positions of certain points to determine the position of road and road markings. Virtual dots used for calculation of Kalman Filter will result in the form of probability, not an actual condition. This is caused by point mapped are only sample points taken in mapping the future shape. The research above shows they still use the sizes/ equations manually to determine the actual shape, whereas the Kalman Filter is a form of statistical equations that still have to be tested for its accuracy.

Based on above description, we developed a method that would be able to detect precisely parts of the road, road markings and surrounding environment by using automatic monocular. Therefore, this research proposes a new intelligent method to detect road markers, separating them from the surrounding environment, based on two approaches of RGB histogram filtering and boundary classifier. This method does not require a huge cost, but really effective in accurately separating the condition of roads, markers and the surrounding environment in a fast and real-time condition.

II. RELATED WORKS

Many researchers are focusing on the road detection research. Liu *et al.* [3] exhibit the measurement model of road shape approximation based on particle-filter. The basic idea of [3] method is by using the concept of Inverse Perspective Mapping (IPM) and then process them in the form of Hough-transform (HT), whereas for the linear shape it seems that [3] still utilizing the Kalman Filter equations so that the curvature of the path can be predicted. Sivaraman *et al.* [5], did the same thing as [3] where they try to introduce a synergetic approach to the detection of lanes and vehicles. There is nothing new in

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the study of [5], which are similar to the study conducted by [3], but [5] is more focused on the straight road.

Another related work case is the one made by Yoo *et al.* [6], which tries to show the method of gradient values conversion for lane detection with strong lighting. The concept uses changes in the level of grey value images obtained by Red Green Blue (RGB) analysis, in order to acquire the RGB of road boundary. Then, by using Hough-transform equation with its Canny detection, it produces easily detected lines. Adjacent pixel detection is used to detect the straight or curved lines, so the differentiation between road lines or non-road lines will be clearly seen. In curved lines detection, [6] using the Linear Discriminant Analysis (LDA) equation so similar adjacent pixels will be seen as road markings and boundaries. However, the RBG histogram values are only used for the conversion of Hough-transform and thus obtained the desired Canny edge detection. A correct threshold value in the Hough-transform and Canny processed manually, which will be very different with the real road conditions with variation such as weather and lighting existed. As a result, a system built by [6] ought to constantly determine the correct threshold value limitation for the conversion process to Hough-transform.

Eum *et al.* [1] research proposed a new method of light detection on the road by means of the intensified Light Blobs (LBS) detection which will be used as a foundation for Highlight Intelligent Control (IHC) analysis. IHC concept uses a single camera image (monocular), which is not easy, as lighting conditions varies (low-exposure/LE and auto-exposure/AE). They are able to analyze the light by LE and AE; the image obtained then mapped, based on the light captured in the process of determining its road boundary conditions. Eum *et al.* [1] do not specifically explain IHC and edge detection method used, although implicitly seem to use a common method such as Canny edge detection.

Fritsch *et al.* [2] suggest two hierarchical stages to study the road condition. The first stage is the basic classification process by analyzing the visual nature of images taken from the monocular camera. They used a classifier to analyze the road, the road boundaries, and the road markers. The principle of the proposed approach by [2] is the calculation of spatial-RAY (SPRAY). Novelty proposed by [2] is as follows:

- SPRAY feature is used to analyze the spatial conditions in metrics space at a particular distance.
- Modeling of visual and spatial characteristics, allows the separation of weather effects/ lighting on particular type of roads (highway and urban).

Basically, research conducted by [2] have the same pattern with [3], [5] and [6]. Which utilize the IPM features for edge detection and then using Base Points (BPs) to determine the shape of the road. The works method is much like a particle filter [3]. If the color being carried through by BPs is similar, then it is certain that a road is detected, while other non-road is not. However, this method has not been able to clearly determine the boundary conditions and road markings, sidewalks are often detected as the streets because it has a similar color gradients and non-specific road markings.

Research conducted by [4] has numerous publications in the field of road detection (lane) and vehicles. Out of the total publications he has, about four of them related to detection path. The process has similarities with others, changing the image into the form of greyscale image. Before the image is processed, [4] use the process of calibration of the cameras by using particular points as the basic coordinates, and then develop methods for projecting the coordinates dots of the pixel against the position of the side road. They [4] tried to map the road inclination based on previous pixel projections process, so the value of the road inclination is found by the system. The results is still not too clear visibly in eliminating non-road factor (sidewalk). There are some points that should be eliminated with a lane function. [4] seems just trying to show the real condition of the road based on pixel template prepared while trying to calculate the road inclination.

In addition to existing methods, there is a general method to separate the foreground and background are well-known, namely Otsu method [7]. This method used as a standard to separate the foreground and background. Otsu method performed digital image segmentation used threshold process. In the process of acquire appropriate threshold value, Otsu calculate the variance histogram on a digital image. The variance value then used as the basis for the separation of background and foreground on the image. image with a variety of colors and shapes are simple, Otsu method can easily separate the foreground and background. However, images with high color variation and complex shapes will be difficult to distinguish between background and foreground. This is due to the fact that the threshold value is too generalize the RGB color changes. In fact, a slight variations in RGB, will have a different histogram, which will affect the results detail. Our approach do described in section IV, address this problem.

III. PROPOSED APPROACH OF ROAD DETECTION

Based on the previous research mentioned above, this research made more details in road detection and road markings. Proposed stages of this research can be seen in Fig.1. It can be seen that this research has more detail in development of methods in road detection. There are two subsystems here, which are (1) RGB Histogram Filterization and (2) Boundary Classifier Process. Each of these subsystems has specific activities that ultimately would be able to tell which parts is the road or non-road. It begins with recording the road on a particular height to get the best picture available. The camera used is Canon 600D. The camera records road movement, for approximately 1 to 5 minutes. Sample of successful frame recorded is as shown in Fig.2.

The Recording image is used as the background to determine the color of road and non-road. Generally, the system used to analyze this picture can be explained as in Fig.1. The captured image will go through two process of analysis, namely (1) Red Green Blue (RGB) Histogram Filterization and (2) Boundary Classification Process (road / non-road).

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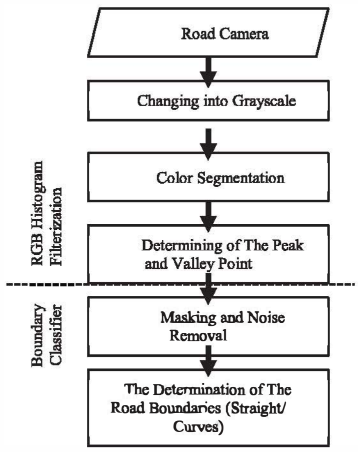

Fig.1. Road Detection System

Fig. 2. Local Toll Road

A. *Red Green Blue (RGB) Histogram Filterization*

As explained, the framework of this system (Fig.1), has the first step of recording the road and sorting the road frame without a vehicle as background material identification process (Fig.2). The cleanest frame then analyzed by the grey levels of Red, Green and Blue. The results are as shown in Fig.3. Differences in the filtering process for red, green and blue will have different color compositions. Fig.3 as shown, is a composition of the red color filter. The green and blue color will have different looks and compositions. Then, based on the results of image filtering, and the composition of its histogram, it will determine which is road or non-road, based on grey level of each histogram. The extracted histogram of each color can be seen in Fig.4.

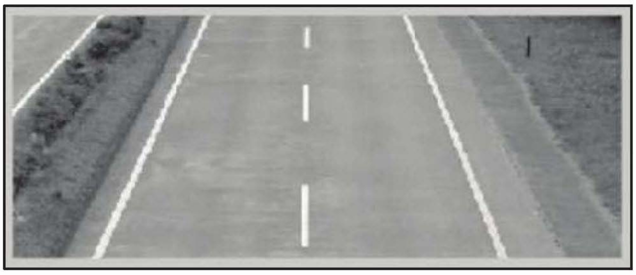

Fig. 3. RGB image for the Red Color.

Fig.4 shows several peaks on the graph. By revisiting Fig.2, it is certain that the road area has bigger area than the non-road, so it can be easily determined that a graph with the area around the highest peaks on each color (Fig.4) is a road. Testing them to some samples road already proves this. The problem is how to determine the limits of the smallest and the largest value among peaks based on grey levels data on each RGB. This can be determined by testing some sample images. As Shown in Fig.5, that each color index has a range between the highest peaks. Based on this, we can easily determine that the highest peak is an area of the road. To determine the maximum value of grey level for each color are determined by the algorithm in (1). Based on Fig.4, a range determined by the peak based on (1) ranging between 153-185. Fig.5 demonstrates that the 162 index is still in the road range.

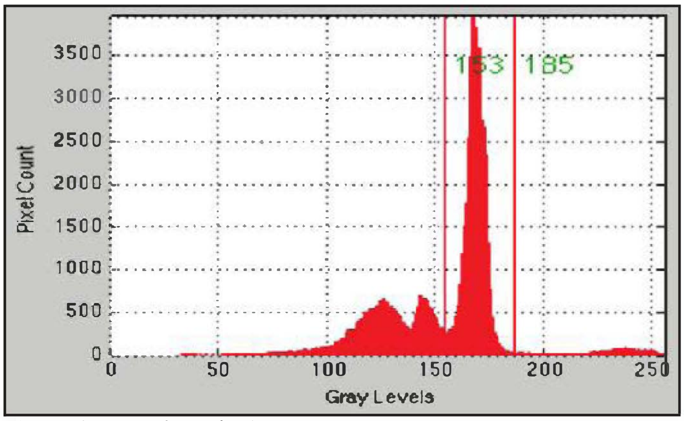

Fig. 4. Histogram for Red color.

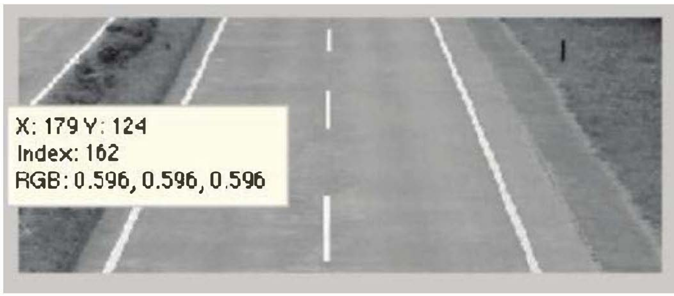

Fig. 5. Example of RGB index to Index Red

Equation (1) used to determine the maximum peak:

$$f(x)_{\max} = max_{1 \le x \le n} f(x) \quad (1)$$

By using (1), the peak value (X, Y) for each RGB composition can be obtained in the position (165, 3964) for Red level (Fig.6). Furthermore, after the highest peak value is obtained, the next step is to determine the boundary between the peaks. The boundary between the actual peaks for Red level is at minimum position (153, 250) and maximum position (185.15). This point is obtained by the (4) and (5) by using (2) and (3). To determine the lowest point as shown in Fig.6, the information on before and after maximum peak are needed. To determine these points, we use (2) to filter some of wave's peaks:

$$f(x)_{top} = max_{1 \le x \le 10} f(x), max_{11 \le x \le 20} f(x), \dots, max_{251 \le x \le 255} f(x) \quad (2)$$

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The equations to determine the maximum point of each wave by (2) are as follows:

$$f(x)_{toppeak} = \max_{1<x<n} f(x) \quad (3)$$

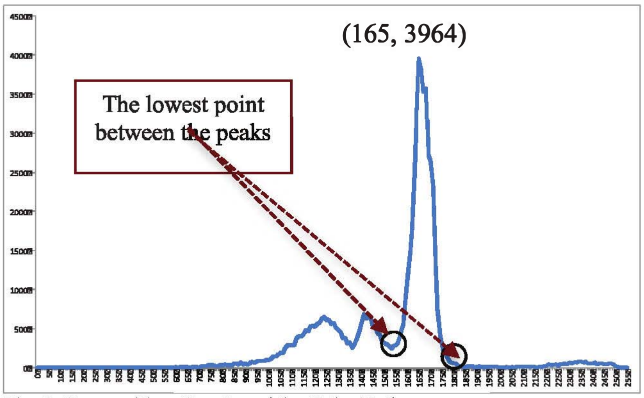


Fig. 6. Composition Grey Level for Color Red

By using the algorithm shown in (2), some peak areas on the wave can be obtained. The algorithm in (2) filters the peak area only, where the algorithm is always filter by multiplier of 10 on each level and then the largest number for each level along to the last level of 255. The result of screening using (2) produces about 15 peaks of grey levels as shown in Fig.6. We can be sure that the highest peak is on the 9th index (165.3964), then the earlier peaks exist in the 8th index (141.689) and the peak after maximum is on the 10th index (188.23). Equation (3) is used to find the maximum peak of peaks, similar to (1), but (3) is simpler because the peak value of the result of (2) has been obtained. Based on (2) result obtained approximately has about 15 maximum point. By using (3) 1 maximum point will be obtained at 165.3946.

Minimum point before peak:

$$f(x)_{before} = \text{minvalue}_{x(peak-1)<x<x(peak)} f(x) \quad (4)$$

Minimum point after peak:

$$f(x)_{after} = \text{minvalue}_{x(peak)<x<x(peak+1)} f(x) \quad (5)$$

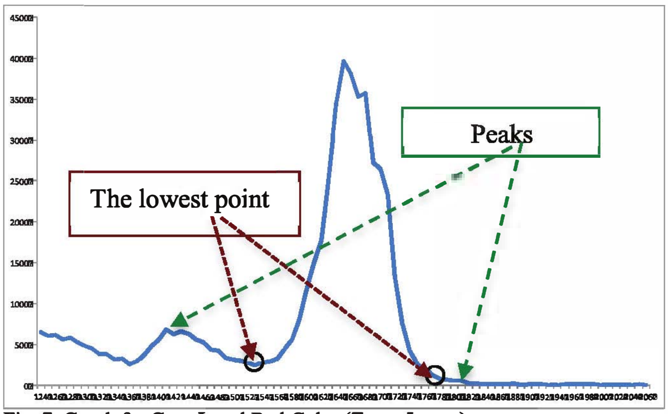
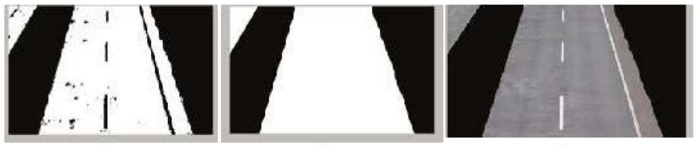


Fig. 7. Graph for Grey Level Red Color (Zoom Image)

By using the algorithm (4) and (5), we can easily define the lowest limit between the peaks before and after. Masking process for the color Red, Green and Blue are able to specifically show the differences in color of road and non-road. RGB masking information is then combined to form a more precise boundary. The combined results of masking it still leaves a small black blobs (Fig.8 (a)). It can be removed with a small pixel elimination process, so that maximum results as shown in Fig.8 (b) can be obtained. Results of Fig.8 (b) then tested in real conditions of the road by each RGB color masking. Result of the separation is better when the three masking of RGB are merged, as shown in Fig.8 (c). Better results are obtained, and the boundary between the road and the surrounding environment becomes more apparent.



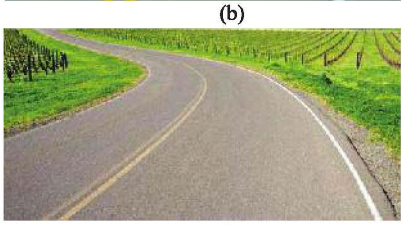
(a) (b) (c)

Fig. 8. The Process : (a) and (b) Noise Removal; (c) Masking Process

In this discussion, we compare the Otsu method [7] with the proposed method using various local road (fig.9). Otsu generates variance as a basic value thresholding. However, the variance values obtained is too general to be applied to the image. So the separation of foreground and background noise are still grainy and many detailed is missing (Fig.10 (a), 10 (c), 10 (e)). This is because the method of Otsu, is too generalize the RGB colors into a single spectrum of colors and applying into thresholding. This process resulted in a loss of detail in each color of RGB. This is indicated resources based on shapes a line that does not smooth and too many points are supposed to be improved.

(a)

(b)



(c)

Fig. 9. The Various Local Road (a, b, c)

In contrast to the Otsu method [7], the proposed method dividing the original image into 3 forms Grayscale RGB. The method then able to obtain detailed information about each level of RGB histogram. Based on the information, the systems detect the position of the background and foreground of each color of RGB by using the equation of peak and valley ((1) - (6)).

The results of the equation are used to determine the position of the background and foreground. The combined information produced by the system produces images that more accurate and detailed (Fig.10 (b), 10(d), 10(f)) and much easier for the next process. In general, the developed methods are able to capture a more detail of colors spectrum.

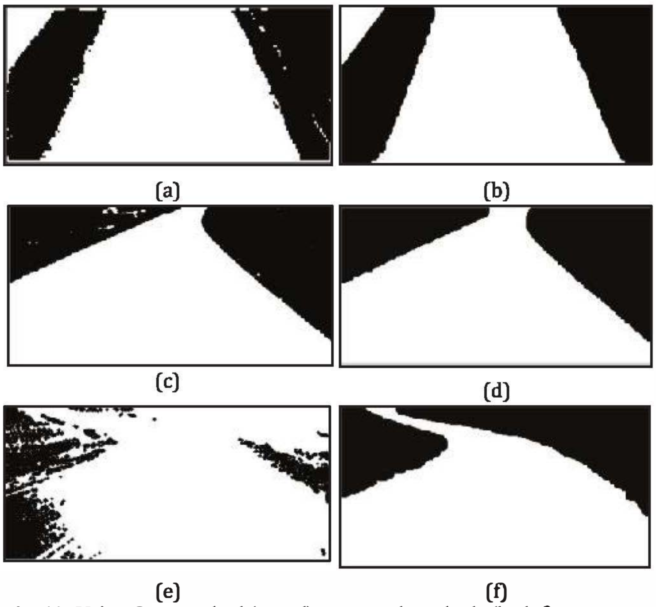


Fig. 10. Using Otsu Method (a, c, d); Proposed Methods (b, d, f);

B. Boundary Classifier

Once we are able to process the boundaries of road and non-road, the next step is to reinforce restrictions of road and non-road path in the form of an elongated line. This process utilizes the classification of pixel values around it. The line obtained from the merger is the best material to determine the identification of road and non-road. As shown in Fig.11, the edge detection process producing the best separation between road and non-road, then with the Hough-Transform (HT) combined with Canny Edge Detection algorithm a simpler image will be obtained. The results of edge detection are mapped in the black '0' and white '1' parts. These results only get the numbers 0 and 1 and value '1' in the form of (x,y) coordinates. The results will be as shown in Fig.11. Now, the identification process becomes a lot easier in determining the boundary path. Small parts of the road are removed in order to get just two sides of major roads only.

The result of the process needs a real line that connects the actual road boundary. Here, we connect the coordinates of points by using (6). Equation (6) is an equation of cubic spline interpolation. By using this equation, the lines will be established based on adjacent points. Fig.11 shows that some known boundary points of a and b are represented by a function $f(x)$ and has a number of data points $a = x_0 < x_1 < \cdots < x_n = b$. Equation process of the line that connects the point 'a' to 'b' is calculated by using an cubic spline interpolation equation. Where the cubic spline interpolation $S(x)$ is a polynomial function of three degree pieces (cubic) connecting adjacent two points, with the provision, for $i = 0,1,2,\dots,n-1$

- (S0) part of the function of the subintervals $[x_i, x_{i+1}]$, $i = 0,1,2,\dots,n-1$.

$$S_i(x) = a_i(x - x_i)^3 + b_i(x - x_i)^2 + c_i(x - x_i) + d_i \qquad (6)$$


Fig. 11. Determination Process Limits road / Non-Road

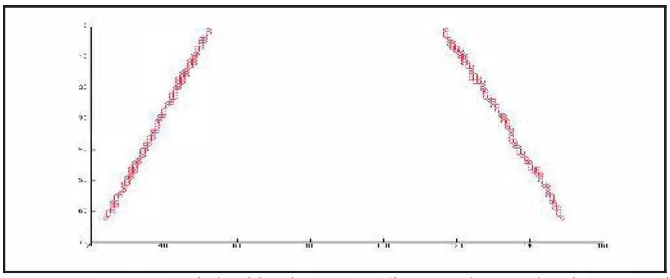


Fig. 12. The process of identification of coordinates Point Road and Non-Road

So, those dots will be connected with some similarities to one another and will be connected resulted in a solid line both linear and curved (Fig.12). The imaginary boundary between road and non-road become more precise. This process is recognized as the boundary classifier process, confirming the limits of road and non-road, and making it more informative.

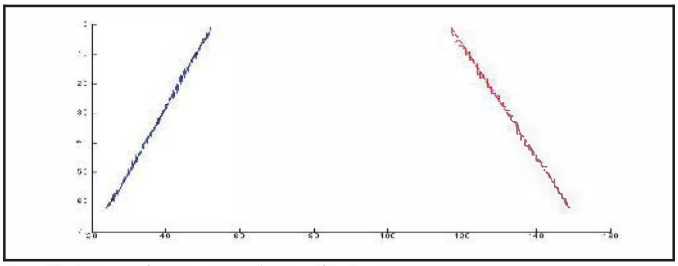


Fig. 13. Connecting Lines each Coordinates

IV. Discussion and Evaluation

In the next stage, we conduct trials for straight (Fig.14) and the curved road conditions (Fig.15). The result shows that the system has worked quite well and able to distinguish road and non-road. Longitudinal stripes seen on the outside of the left and right side of the road which differentiate between the road and non-road, able to be separated well by the use of color way. Fig.14 and Fig.15 show a line extending on the left and right hand side of the road separates by colors. Samples taken tend to focus on the camera position on the roadside. The results will look different when camera is positioned not focusing on the road. In other words, the surrounding environment of the road has taken a quite large portion. So that the highest color in histogram graph does not necessarily indicates the condition of the road. To anticipate this problem, the sample introduction process is required with the initial coordinates becomes the sections where the road usually at. The coordinates position then used as the establishment of grey level histogram for road, so that any camera position will not be able to affect the reading of the system, and in the end are able to distinguish the color of the road/ non-road.

Fig. 14. Test System on the Straight Road

Fig. 15. Test System on the Curved Road

In addition, it should be understood that the developed system runs well on good and adequate lighting conditions, but in the poor lighting condition, like at night, system has to change its parameters in the process of color segmentation. This is caused by the lack of adequate light on the road significantly changes the environment. An additional method is needed to have a good detection process of the road at night, given the limited amount of light compared with the separation process of road and non-road.

V. CONCLUSION

The proposed method is promising in recognizing and distinguishing the condition of the road and non-road with good lighting conditions. However, the developed system has not been tested for varying lighting conditions. The different lighting levels will greatly affect the readings road and non-road. In addition to, the environmental conditions are too many obstacles would affect the final process. The important thing to be considered is the position and location of the cameras should be appropriate and focused on the road. It is necessary to anticipate the variations in the density of gray level for each RGB color. The future work is how to develop the system for low lighting conditions

REFERENCES

[1] Eum, Sungmin., Jung, Ho Gi., (2013), Enhancing Light Blob Detection for Intelligent Headlight Control Using Lane Detection, *IEEE Transactions on Intelligent Transportation Systems, Vol. 14, No. 2, June 2013*

[2] Fritsch, Jannik., Kühnl, Tobias., Kummert, Franz., (2014), Monocular Road Terrain Detection by Combining Visual and Spatial Information, *Transactions on Intelligent Transportation Systems, Vol. 15, No. 4, August 2014*

[3] Liu, Guoliang., Wörgötter, Florentin., Markelic´, Irene., (2013), Stochastic Lane Shape EstimationUsing Local Image Descriptors, *IEEE Transactions on Intelligent Transportation Systems, Vol. 14, No. 1, March 2013*

[4] Nedevschi, Sergiu., Oniga, Florin., Danescu, Radu., Graf, Thorsten., Schmidt, Rolf., (2006), Increased Accuracy Stereo Approach for 3D Lane Detection, *Intelligent Vehicles Symposium 2006, June 13-15, 2006, Tokyo, Japan*

[5] Sivaraman, Sayanan., Trivedi, Mohan Manubhai., (2013), Integrated Lane and Vehicle Detection, Localization, and Tracking: A Synergistic Approach, *IEEE Transactions on Intelligent Transportation Systems, Vol. 14, No. 2, June 2013*

[6] Yoo, Hunjae., Yang, Ukil., Sohn, Kwanghoon.,(2013), Gradient-Enhancing Conversion for Illumination-Robust Lane Detection , *IEEE Transactions on Intelligent Transportation Systems, Vol. 14, No. 3, September 2013*

[7] Otsu, Nobuyuki., (1979), A Threshold Selection Method from Gray-Level Histograms, *IEEE Transactions on System, Man and Cybernetics, Vol. SMC-9, No. 1, January 1979.*

