A Computer Vision System for Detection and Avoidance for Automotive Vehicles

Altaf Alam
Research Scholar
Dept. of Electrical Engineering
Jamia Millia Islamia, New Delhi
alam.altaf07@gmail.com

Zainul Abdin Jaffery
Professor
Dept. of Electrical Engineering
Jamia Millia Islamia, New Delhi
zjaffery@jmi.ac.in

***Abstract*-This paper presents a vision based algorithm for obstacle detection and avoidance for autonomous land vehicle. For an efficient algorithm it is necessary to know the information about surrounding environment of vehicle. The whole environment is classified in two groups as obstacle and path. This classification helps to find the space for avoiding the obstacle. Data is acquired by a high resolution digital camera. Relative distance of the obstacle, dimension of the obstacle, turning radius of the vehicle and required turning angle of the steering are estimated. The simulation is done using MATLAB 7.1 version.**

Keywords: vision based system, image detection, Autonomous vehicle, image processing.

1. INTRODUCTION

Now a day Accident rate of worldwide is increasing continuously. Automotive industry has been developed its best to secure the human life over the years while driving. Computer vision system has a significant contribution to field of autonomous land vehicle [1]. Major challenge faced by an autonomous vehicle is to detect and avoid obstacle. Many algorithm have been proposed in the literature for obstacle detection [2-7]. University of Maryland developed a visual navigation for robotics and autonomous system [8]. Forsyth et al. [9] proposed the computer vision based linear dynamic model for target tracking. Proposed system consist a calibrated camera, processing unit and a computer system for developing an algorithm of obstacle detection and avoidance. Camera calibration is one of the important aspect to increase the accuracy of system. A high resolution digital camera is used for data acquisition. This data is send to processing unit for further analysis. Processing unit apply some image enhancements technique for improving the quality of image and then extract the shape and boundary of obstacle with the help of edge detection technique. Finally a ROI based technique is used for obstacle detection and recognition. After obstacle detection elative distance, orientation of obstacle from camera and size of obstacle are estimated. The proposed research work may be summarized as follow.

- Mathematical modeling of vehicle.
- Camera calibration.
- Development of algorithm for obstacle detection.
- Estimation of turning angle of steering-to avoids the obstacle.

2. MATHEMATICAL MODELOF VEHICLE

A four wheel vehicle is considered for modelling purpose as shown in fig1(a), and a simplified diagram of fig 1(a) is shown in fig 1(b).

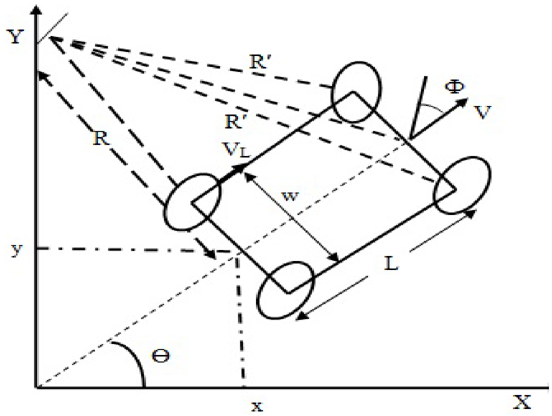

figure 1(a). Vehicle model

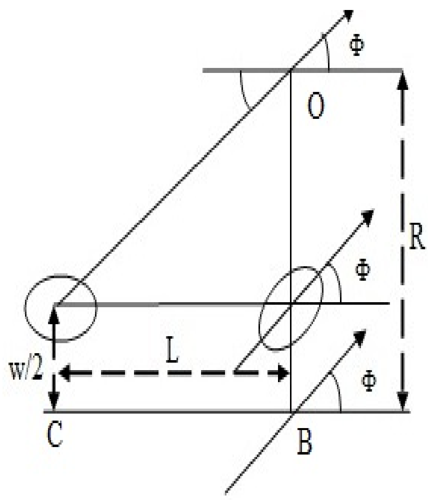

Figure 1(b). Simplified diagram

Where,
(X,Y) show axis coordinate of path
w = width of vehicle
L = length of vehicle
V_L= tangential velocity of left wheel on rear.
Φ = turning angle of vehicle steering
V= speed of vehicle.
Kinematical parameters of vehicle are (x,y,□).

Where, (x,y) = Position vector of vehicle, and

□ = Angular movement of vehicle with respect to its horizontal axis (vehicle heading angle).

From fig1(b), for steady steering or for turning the vehicle with out sliping the turning radius R and angular rotation □ of vehicle about its vertical axis is given as.

$$R = \frac{BC}{OB} = \frac{\mathrm{L}}{\tan\Phi} - - - (1)$$

$$\square' = \Omega = \frac{\mathrm{V_L}}{\mathrm{R'}} - - - - - - (2)$$

$$\mathrm{R'} = \mathrm{R} - \frac{w}{2} \text{if } \Phi > 0 - - - (3)$$

$$\mathrm{R'} = \mathrm{R} + \frac{w}{2} \text{if } \Phi < 0 - - - (4)$$

Speed of the vehicle given by

$$V = \frac{\mathrm{V_L} * \mathrm{L}}{\mathrm{R'} * \tan\Phi} - - - (5)$$

According to the speed of vehicle new position vector of vehicle can be calculated as.

$$\mathrm{X'} = \mathrm{V} * \cos\square = \frac{\mathrm{V_L} * \mathrm{L}}{\mathrm{R'} * \tan\Phi} * \cos\square - -(6)$$

$$\mathrm{Y'} = \mathrm{V} * \sin\square = \frac{\mathrm{V_L} * \mathrm{L}}{\mathrm{R'} * \tan\Phi} * \sin\square - -(7)$$

a. CalculatedVehicle's Parameters

Table 1 shows the calculated parameters of vehicle for three obstacles. Size of the obstacles are different but distance from camera is almost equal. Parameters of vehicle has been calculated by using equation (1) to (7). These parameters are steering angle, turning radius for steady cornering, angular rotation of vehile with out slip, speed of vehicle and position vector of vehicle.

TABLE 1. VEHICLE'S PARAMETERS

Parameters	**Obstacle 1**	**Obstacle 2**	**Obstacle 3**
Steering Angle (Φ) (deg)	6.12	5.91	5.88
Turning Radius (R) (cm)	87.76	95.14	97.09
Angular Rotation (□) (deg)	0.569	0.525	0.49
R′ forΦ<0 (cm)	90.76	98.14	100
R′ forΦ>0(cm)	84.76	92.14	94.09
Speed of vehicle (V)(cm/sec)	48.34	48.47	48.50
X′ (cm)	48.33	48.46	48.49
Y′ (cm)	48.02	44.41	44.41

3. CAMERA CALIBRATION

In autonomous vehicle working of camera is similar to the working of human eye.Camera calibration helps to analyze a three dimensional scenes in to two dimensional image coordinate and determins distance to pixel ratio. Varous steps involve in camera calibration are described below.

a. Camera Arrangement

Figure 2(a) shows the camera arrangement.Camera arrangement is used to set the range (H_{cal}) for different targets to acquire image. Camera arrangement gives important information about path in a particular set of range.

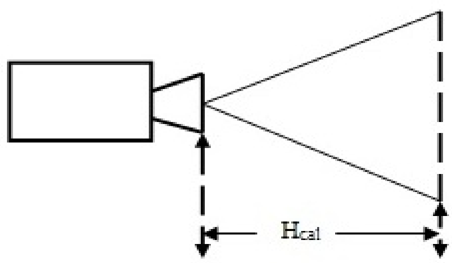

Figure 2(a). Camera arrangement

b. Conversion of pixel coordinate in to image coordinate.

Figure 2(b) shows that how a pixel coordinate is converted in to image coordinate. For coordinate conversion a patternis used to compare distance with the printed paper and number of pixel present in the image.

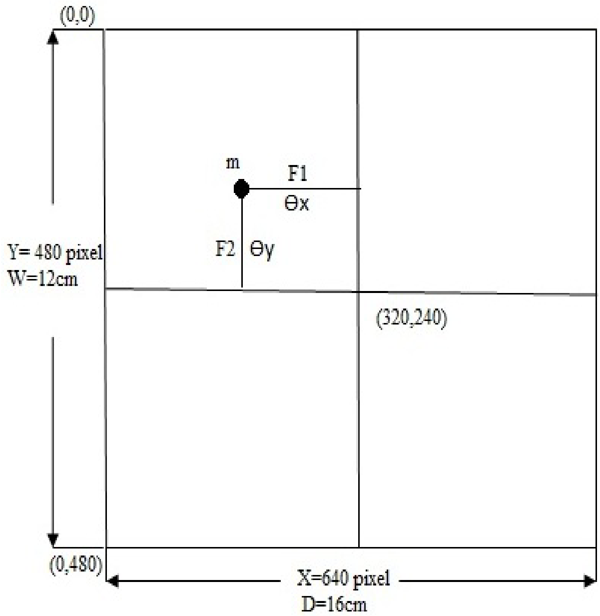

Figure 2(b). Image coordinates conversion

To determine any point (m) in animage,first determine pixel coordinate (X,Y) of that point and then convert it in to image coordinate(F1,F2). Conversion of coordinate is given in table 2 (a).

Length D =16cm = X=640 pixels
Width W= 12cm = Y=480 Pixels

TABLE 2(A). PIXEL TO IMAGE COORDINATE CONVERSION

X(Pixel)	**Horizontal Coordinate (F1) (cm)**	**Y(Pixels)**	**Vertical Coordinate (F2) (cm)**
0	-D/2	0	-W/2
160	-D/4	120	-W/4
320	0	240	0
480	D/4	360	W/4
640	D/2	480	W/2

c. Distance to Pixel Ratio

Table 2(b). gives information about the distance to pixel ratio. Distance to pixel ratio gives relation between distance and pixel in the form of horizontal and vertical coordinate. R_X represent horizontal distance to pixel coordinate ratio and R_Y represent vertical distance to pixel coordinate ratio.

TABLE 2(B). DISTANCE TO PIXEL RATIO

S. no	E(cm)	Pixel X-direction	Pixel Y-direction	E/X R_X	E/Y R_Y
1	2	80	70	.025	.028
2	4	140	125	.028	.032
3	8	200	183	.040	.042
4	11	500	465	.022	.023

d. Calibrated Parameters of Obstacle

Table 2(c) gives information about the calibrated parameters of obstacles. Calibrated parameter has been computed for the three obstacles. These parameters are width (A_{cal}), Hight (B_{cal}), Center (C_{cal}) and orientation angle from horozental and vertical(θ_x, θ_Y) of any point in image.

$$C_{cal} = \frac{-D}{2} + \left({}^{D}/{X_{max}}\right) * X_{center} - - - (8)$$

$$A_{cal} = F_1 * R_X - - - - (9)$$

$$B_{cal} = F_2 * R_Y - - - - (10)$$

$$\theta_x = \tan^{-1}\left(\frac{A_{cal}}{H_{cal}}\right) - - - - - (11)$$

$$\theta_Y = \tan^{-1}\left(\frac{B_{cal}}{H_{cal}}\right) - - - - - - (12)$$

TABLE 2(C). CALIBRATED PARAMETERS

Parameters	**Obstacle 1**	**Obstacle 2**	**Obstacle 3**
Horizontal CoordinateF_1(pixel)	90	108	115
Vertical Coordinate F_2 (pixel)	125	287	226
Obstacle Width (A_{cal}) (cm)	2.52	3.024	3.22
Obstacle Height (B_{cal}) (cm)	2.872	6.601	5.198
Horizontal Angle (θ_x) (deg)	0.721	0.8662	0.922
Vertical Angle (θ_Y) (deg)	0.822	1.890	1.488

4. OBSTACLE DETECTION

Various processes are used during the obstacle detection process. A process flow diagram for obstacle detection is given in fig.3.

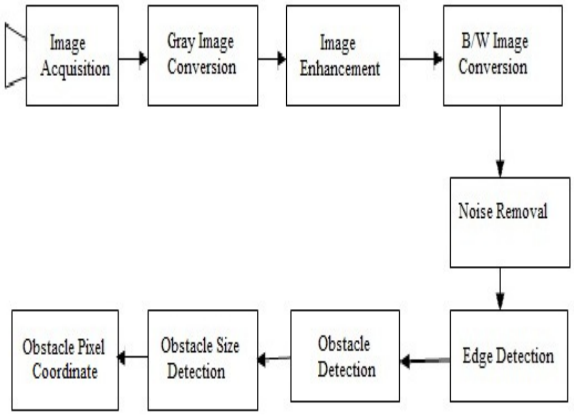

Figure3. Obstacle detection algorithm

Data Acquisition: A digital **c**amera of resolution 640×480 is used for data acquisition in this system. Acquired data is in the form of RGB image.

Gray Image Conversion: Obstacle shape and boundary are identified by detecting its edges. It should be noted that for edge detection, image should be in 2D form. Hence, RGB image is converted to gray scale image [10].

Image Enhancement: Image enhancement improve the quality of edges. During image acquisition periodically noise is caused by the presence of electrical or electrochemical interference, hence, before further processing these noises must be filtered. In this work 2D Median filtering [11] is used for enhancing the image. 2D median filter reduce noise without reducing sharpness of image.

Binary Image Conversion: For better result the gray image is converted to a binary image. Binary image is an array of logical 0s and 1s.

Edges Detection: Edge detection is needed to estimate the shape and boundaries of the obstacle. In this work canny edge detection technique [12] is used. Canny edge detection method uses two thresholds to detect strong and weak edges and includes the weak edges in output only if they are connected to strong edges hence it gives better result.

Segmentation of ROI: Region of interest (ROI) is a process of selecting the area of interest in an image for further processing. ROI removes unwanted background and includes only that portion of the image which characterizes the desired object.

Obstacle Size: After classification of environment as path and obstacle, next step is to extract that obstacle for further processing. This extracted image gives information about obstacle such as Height, Width and relative distance, orientation of obstacle from vehicle.

Obstacle pixel coordinate: Contour tracing technique [13] has been performed on image to extract information about the shape boundary and pixel coordinates of obstacle.

5. SIMULATION AND RESULT

Road cones are used as obstacle for experimental purpose. The proposed algorithm is simulated using MATLAB on a HP-450 computer system with Intel core i3 processor and 2 GB RAM. Figure 4(a) to figure 4 (g) shows the simulation result of various steps which is described in section-4 for one sample image.

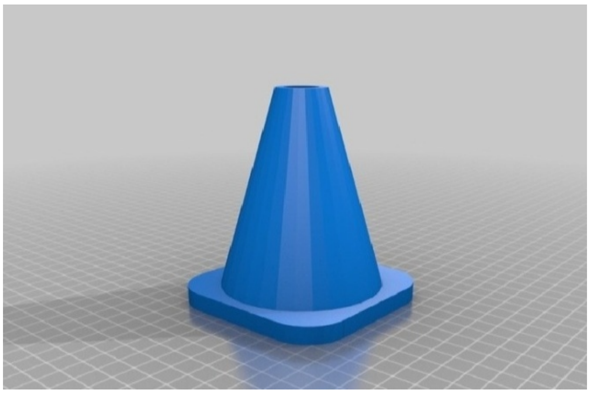

Figure 4(a). Original image

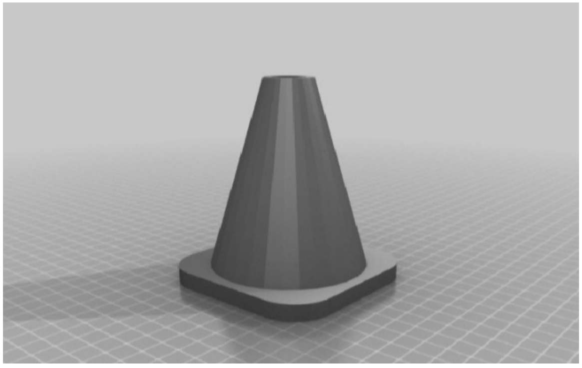

Figure 4(b). Gray image

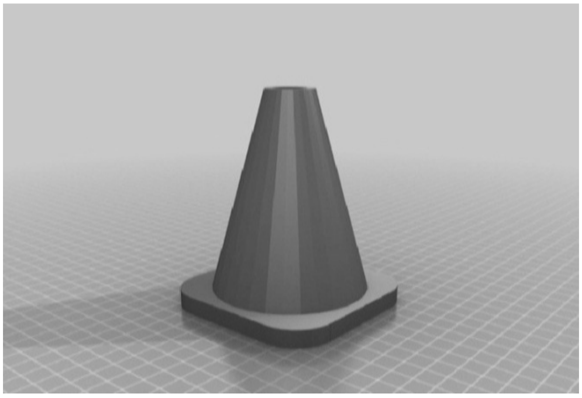

Figure 4(c). Enhanced image

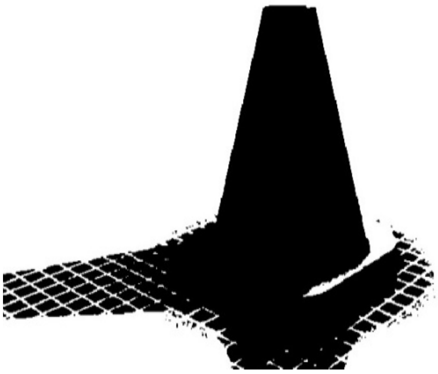

Figure 4(d). Binary image

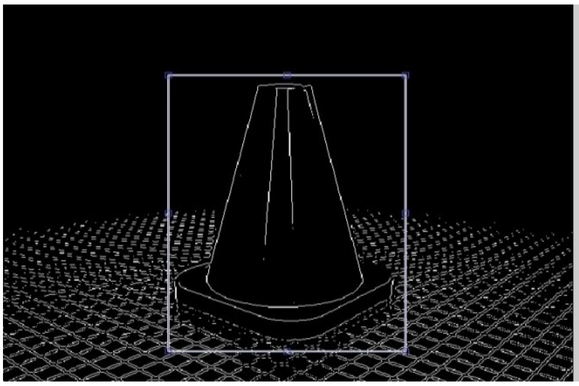

Figure 4(e). Detected Obstacle

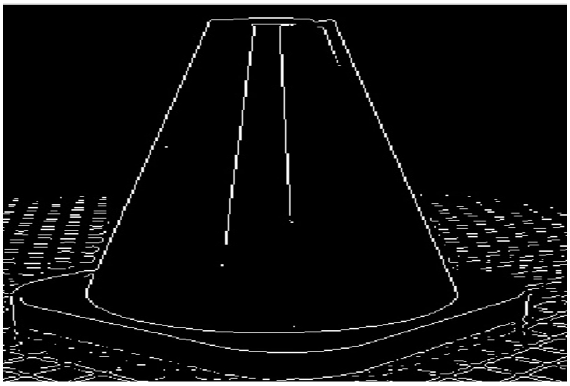

Figure 4(f). Extracted obstacle

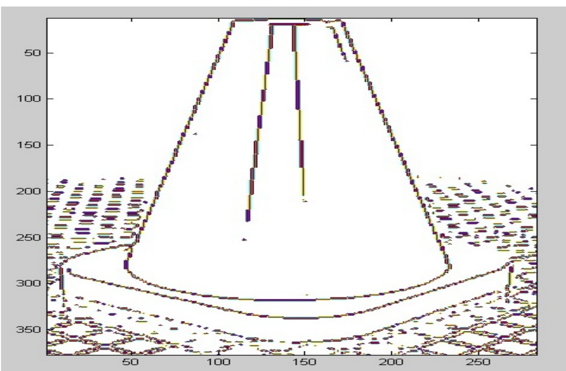

Figure 4(g). Obstacle pixel information

6. OBSTACLE AVOIDANCE

A road cone is considered as an obstacle with fixed height h as shown in fig.5(a). Distance to pixel ratio is used to determine the obstacle's parameters. These parameters are height, width and orientation of the obstacle (r_{ob}, A, θ_{ob}).

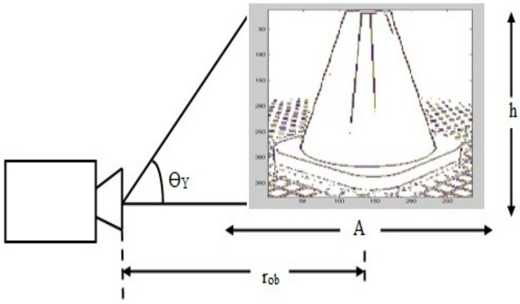

Figure 5(a). Obstacle avoidance analysis

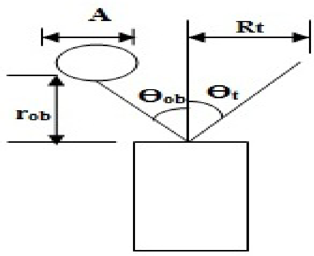

Figure 5(b). Obstacle Avodance Orientation

From fig. 5(b), varrious parameters of the obstacle may be given as;
relative distance from camera to obstacle

$$r_{ob} = \frac{h}{\tan \theta_y} ----(13)$$

Obstacle width

$$A = r_{ob} \times \left(\frac{A_{cal}}{H_{cal)}}\right) ----(14)$$

Obstacle orientation

$$\theta_{ob} = \theta_x ----(15)$$

Using the above obstacle's parameters, thesteering angle for obstacle avoidance is computed as.

$$\Phi = k \times \theta_t = K \times \tan^{-1}\left(\frac{R_t}{r_{ob}}\right) ----(16)$$

$$R_t = 1.5[\sqrt{L^2 + W^2}] + \frac{A}{2} - r_{ob} \times \tan\theta_{ob}] - (17)$$

Where
K= control gain
Rt= turning radius for avopiding obstacle
Φ= steering angle

6a. Calculated Parameters of Obstacle

Three different road cones are used as obstacles for implimentation and analysis using proposed algorithm. Distance from the vehicle and cones is almost equal but their size is different. Equation (13) to (17) is used for calculating the obstacles parameters. These parameters are relative distance, width, turning radius, steering angle for obstacle avoidance and orientation of obstacle from vehicle. Table 3 shows the estimated parameters of the obstacles.

TABLE 3. OBSTACLE PARAMETERS

Parameters	**Obstacle 1**	**Obstacle 2**	**Obstacle 3**
Relative Distance (r_{ob}) (cm)	150	152	151.86
Obstacle Width (A) (cm)	1.9	2.29	2.44
Turning Radius (R_t) (cm)	16.09	15.76	15.64
Steering Angle (Φ) (deg)	6.12	5.91	5.88
Orientation ($\square_{ob}$) (deg)	0.721	0.866	0.922

7. CONCLUSION

A vision based system for autonomous land vehicle is proposed for the detection of an obstacle in the path. Simple image processing techniques are used for the estimation of various parameter of the obstacle. Using these parameters turning angle for steering is estimated to avoid the obstacle in the path. The simulation results show that proposed algorithm is working effectively.

REFERENCES

[1] G.N. De Souza, A.C. Kak, "Vision for mobile robot navigation: A survey," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, pp. 237–267, 2002.

[2] M.A. Turk, D.G. Morgenthaler, K.D.Germban, M. Marra, "a vision system for autonomous land vehicle navigation," *IEEE Trans.on Pattern Analysis and Machine Intelligence*, pp.342–361, 1988.

[3] M. Schwarzinger, T. Zielke, D. Noll, M. Brauchmann, W.V. Seelen, "Vision-Based Car-Following: Detection, Tracking, and Identification," *Proceeding of the Intelligent Vehicles '92 Symposium, Detroit, USA,* pp. 24–29, 1992.

[4] M. Cappello, M. Campani, A. Succi, "Detection of Lane Boundaries, Intersections and Obstacles," *Proceeding of the IntelligentVehicles,*pp.284–289, 1994.

[5] U. Regensburger, V. Graefe, "Visual Recognition of Obstacles on Roads," *International Conference on Intelligent Robots and Systems,* pp. 980–98,1994.

[6] B. Ulmer, "An Autonomous Road Vehicle for Collision Avoidance in Traffic," *Proceeding of the Intelligent Vehicles,* pp. 36–41, 1992.

[7] T.S. Abd Al- Zaher, M.M Bayoumy, A.M. sharaf, Y.H. Hossan El-din "Lane Tracking and Obstacle Avoidance for Autonomous Ground Vehicle," *13th International work shop on research and education in mechatronics,* pp.264-272, 2012.

[8]L.S. Davis, "Visual navigation at the University of Maryland, Robotics and Autonomous Systems," pp.99–111. 1991.

[9] D.A. Forsyth, J. Ponce, "Computer Vision: A Modern Approach," Prentice Hall, USA, 2002.

[10] Rafel C. Gonzalez, Richards E Woods, Steven L Eddins, Digital Image Processing using MATLAB, New Delhi, India: Pearson Edition, 2006.

[11] Akarun, Haddad, "Adaptive Decimated Median Filter for Image Processing," *International Congress on Acoustic, Speech and Signal Processing*, pp.69-72, 1993.

[12] Huili Zhao, Guofeng Qin, Xingian Wang, "Improvement of Canny Algorithm Based on Pavement Edge Detection," *International Congress on Image and Signal Processing*, pp.964-967, 2010.

[13] Catanzaro, Brayan, Bor-ying Su, "Efficient High Quality Image Contour Detection," International Conference on Computer Vision, pp.2381-2388, 2009.