Vehicle speed detection based on gaussian mixture model using sequential of images

Vehicle speed detection based on gaussian mixture model using sequential of images

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Abstract. Intelligent Transportation System is one of the important components in the development of smart cities. Detection of vehicle speed on the highway is supporting the management of traffic engineering. The purpose of this study is to detect the speed of the moving vehicles using digital image processing.Our approach is as follows : The inputs are a sequence of frames, frame rate (fps) and ROI. The steps are following : First we separate foreground and background using Gaussian Mixture Model (GMM) in each frames. Then in each frame, we calculate the location of object and its centroid. Next we determine the speed by computing the movement of centroid in sequence of frames. In the calculation of speed, we only consider frames when the centroid is inside the predefined region of interest (ROI). Finally we transform the pixel displacement into a time unit of km/hour. Validation of the system is done by comparing the speed calculated manually and obtained by the system. The results of software testing can detect the speed of vehicles with the highest accuracy is 97.52% and the lowest accuracy is 77.41%. And the detection results of testing by using real video footage on the road is included with real speed of the vehicle.

1. Introduction

Along with the ease of having vehicles and increased population growth, the amount of vehicle is now increasing rapidly. But, the road facilities are not good enough to handle this increased vehicle amount, so that there are many traffic problems, such as traffic jam and traffic violation for exceeding the speed limit which can be very dangerous. So that, the regulations must be implemented to rule this speed violation. Speed limitation is an effective way to rule the speed violation and prevent traffic accidents caused by speed violation. To implement this rule, a surveillance system is needed and be the most important thing to monitor the traffic condition and detect the vehicle speed.

For detecting the vehicle speed, the methods which most used are Laser Infrared Detection and Ranging (LIDAR) or Radio Detection and Ranging (RADAR), but these methods need high cost and specialized skill for the operation. The alternative way to monitor traffic condition, which is now performed, is to utilize CCTV cameras named Road Traffic Monitoring Service (RMTC). CCTV cameras installation is now widely performed and be used only to monitor traffic condition, whereas the video recorded from CCTV cameras can be used to detect the vehicles speed based on digital image processing.

2. Related Work

There are many researches related to this topic. Huei-Yung Lin with the research "Vehicle Speed Detection from a Single Motion Blurred Image" [1], Chomtip Pornpanomchai with the research "Vehicle Speed Detection System" [2], and Arash Gholami with the research "Vehicle Speed Detection in Video Image Sequence using CVS Method" [3] which the result of speed detection is depend on the light intensity in video data so that can cause inconsistency speed detection result. This research use Gaussian Mixture Model which can adapt the changes of light intensity in video data [4].

3. System Architecture

The system architecture for detecting vehicle speed from video data consists of 5 processes that are discussed further later in this paper. Each process will do particular work which the result will be used by next process until vehicle speed is detected. Block diagram for this system is given by Figure 1.

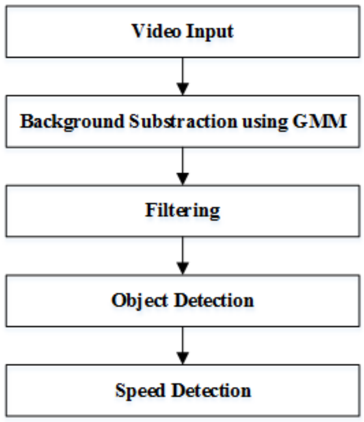

Figure 1. Block diagram for system architecture.

3.1. Video Input

Video data is captured from a static camera at top position of highway. Parameters that are needed for calculation are angle of the camera (θ_3), angle of blind spot area (θ_2), height of the camera from road surface (H), and horizontal distance from the camera to the starting point of area covered by the camera (D). Video capturing layout is given by Figure 2. Then video data is extracted into frames for the next process, given by Figure 3.

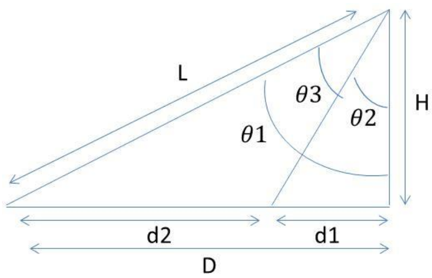

Figure 2. Video capturing layout.

3.2. Background Subtraction using GMM

Background subtraction is used to extract foreground image based on background model for each frame. There are many background subtraction methods which have their own advantages and disadvantages. This paper uses Gaussian Mixture Model known as GMM method to do background subtraction process because it is a good algorithm to use for the classification of static postures and non-temporal pattern recognition, more robust than other models, and it can handle multi-modal situations [5]. Then, apply filtering to the foreground image for removing noise. Noise can be occurred because of light illumination, wind blowing, object shadow, etc. Noise removal is done for improving object detection result. Background subtraction using GMM is given by Figure 4 and Figure 5.

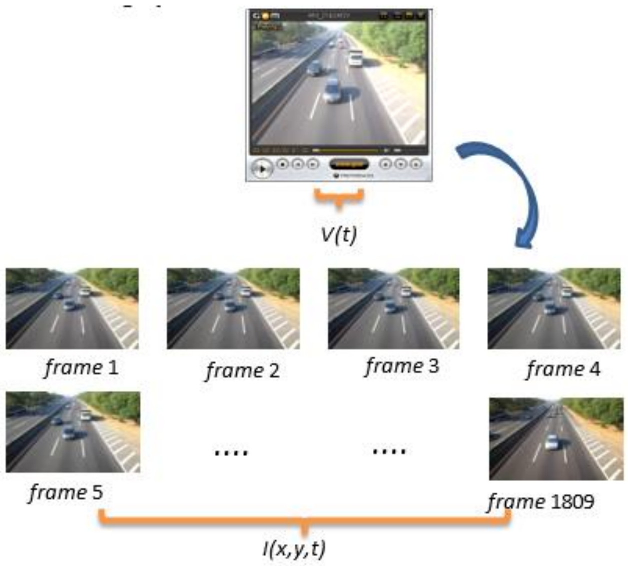

Figure 3. Video extraction.

Figure 4. Image input at frame t.

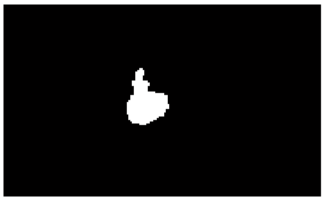

Figure 5. Foreground image extracted using GMM.

3.3. Object Detection

Object detection is done by applying blob analysis to filtered image and give label to each object detected. Connected component is used to blob analysis which each group of pixels with pixel value 1 will be described as one object. From this blob analysis, there will be information about centroid, area, height and width of the object, represented by a rectangle. Object detection is given by Figure 6 and Figure 7.

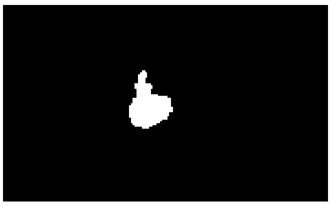

Figure 6. Filtered foreground image.

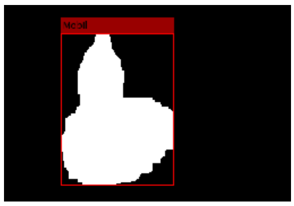

Figure 7. Detected object using blob analysis.

3.4. Object Tracking

Detected object will be tracked using blob tracking. Blob tracking is used to determine the object in frame t and frame $t-1$ is the same object or not. This can be done by calculating the distance of object centroid for every detected object. If the centroid distance less than a given threshold value, the object in those frames is the same.

3.5. Speed Detection

3.5.1. Distance Calculation

Object centroid is determined from bounding box. Let $B(i, j)$ is a bounding box which starts at coordinate (i, j), then centroid point $C(i, j)$ which has coordinate (C_i, C_j) can be determined by equation (1).

$$C_i = B_i + \frac{B_{width}}{2}, C_j = B_j + \frac{B_{height}}{2} \tag{1}$$

where C_i is centroid coordinate at row i, C_j is centroid coordinate at column j, B_i is bounding box coordinate at row i, B_j is centroid coordinate at column j, B_{width} is the width of bounding box, and B_{height} is the height of bounding box.

To calculate distance between object centroids, let $C_t(a,b)$ and $C_{t-1}(c,d)$ are centroid point of the object in frame t and $t-1$ respectively. The distance d calculated by equation (2).

$$d = \sqrt{(a-c)^2 + (b-d)^2} \tag{2}$$

Then, the distance d in equation (2) is still in unit pixel, so that conversion is needed to convert unit pixel to unit distance (cm) by using equation (3).

$$z = \frac{1}{x/y} \tag{3}$$

where x is real distance in cm, y is image height, and z is ratio between real distance and image size.

3.5.2. Time Calculation

Time travelled by the object is calculated from the start point (getting in the ROI) to the end point (getting out the ROI). FPS (frame per second) is the amount of frame captured in one second. Time t calculation is given by equation (4).

$$t = f \times w \tag{4}$$

where t is time travelled by the object in seconds, f is frames total, and w is the time needed for one frame.

3.5.3. Speed Calculation

Speed calculation is the last step in the processes. Speed v is calculated from distance between object centroids and time travelled by the object, in unit cm/s, given by equation (5).

$$v = \frac{d}{t} \tag{5}$$

4. Result and Discussion

4.1.1. System Interface

To do experiment with ease, we create GUI interface using MATLAB R2015a to put all processes into one system. GUI interface for the system is given by Figure 8.

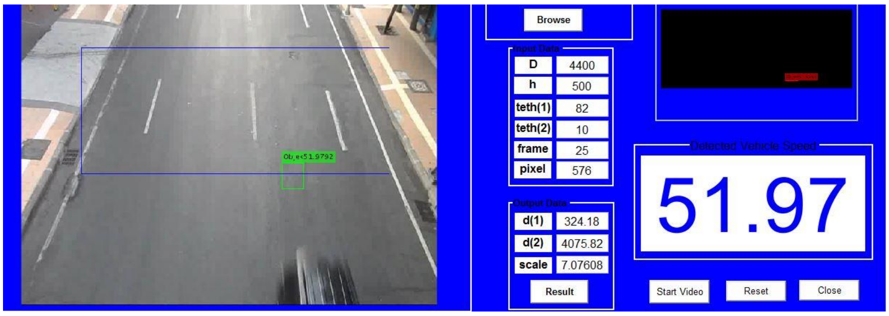

Figure 8. GUI interface.

4.1.2. Data Tables

For testing purpose, video data have various frame rate and known speed to do validation with detected speed from the system. The detail about video data which is used in the experiment and the result is given by Table 1. Graphic chart for result accuracy is given by Figure 9.

Table 1. Video data for experiment.

File name	Frame rate	Size (width x height)	Real Speed (km/h)	Detected Speed (km/h)	Accuracy (%)
Movie1.avi	25	1280x720	18	19.52	91.56
Movie2.avi	25	1280x720	20	21.49	86.89
Movie3.avi	25	1280x720	24	24.70	97.08
Movie4.avi	25	1280x720	7	7.80	88.6
Movie5.avi	25	1280x720	10	9.63	96.3
Movie6.avi	25	1280x720	11	10.29	93.54
Movie1.avi	30	1280x720	18	19.18	93.44
Movie2.avi	30	1280x720	20	21.17	94.15
Movie3.avi	30	1280x720	24	25.23	94.87
Movie4.avi	30	1280x720	7	8.58	77.41
Movie5.avi	30	1280x720	10	10.38	96.20
Movie6.avi	30	1280x720	11	10.53	95.72
Movie0.avi	25	640x480	30	35.94	97.52
Movie01.avi	25	640x480	30	36.40	78.67
Movie12.avi	25	640x480	35	36.36	95.34
Movie0.avi	30	640x480	30	28.10	93.67
Movie01.avi	30	640x480	30	33.63	87.90
Movie12.avi	30	640x480	35	38.67	89.51

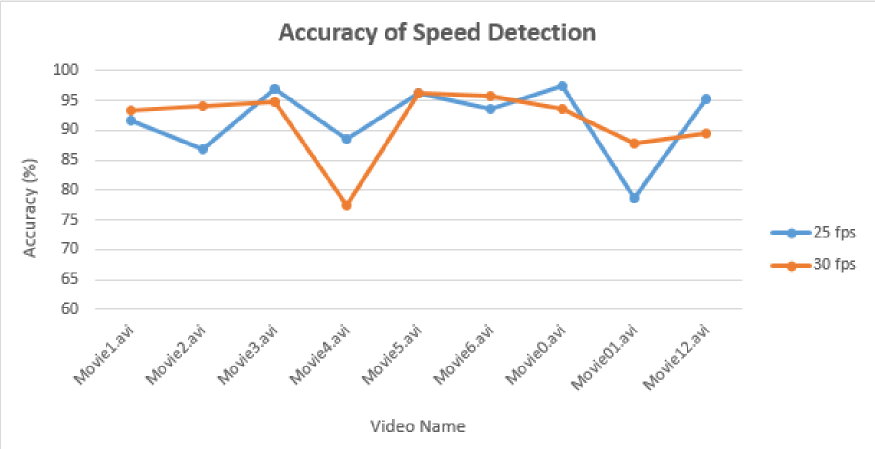

Figure 9. Accuracy of speed detection.

4.1.3. Conclusions

According to our experiment results, we can obtain the following conclusions:

- The accuracy result for speed detection is obtained with the lowest 77.41% and the highest 97.52%, thus the average accuracy from 18 experiment results is 91.58%.
- Video with high resolution give better result for speed detection.
- Video with frame rate 30 give better overall result.

5. Acknowledgments

The research received was supported by Penelitian Unggulan Perguruan Tinggi contract number 661/PKS/ITS/2017 with the title of Sistem Deteksi Kecepatan Kendaraan Berbasis Pengolahan Citra Sebagai Pendukung Manajemen Transportasi from the Ministry of Research, Technology and Higher Education of the Republic of Indonesia.

6. References

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