Vehicle Speed Detection System

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Abstract

This research intends to develop the vehicle speed detection system using image processing technique. Overall works are the software development of a system that requires a video scene, which consists of the following components: moving vehicle, starting reference point and ending reference point. The system is designed to detect the position of the moving vehicle in the scene and the position of the reference points and calculate the speed of each static image frame from the detected positions. The vehicle speed detection from a video frame system consists of six major components: 1) Image Acquisition, for collecting a series of single images from the video scene and storing them in the temporary storage. 2) Image Enhancement, to improve some characteristics of the single image in order to provide more accuracy and better future performance. 3) Image Segmentation, to perform the vehicle position detection using image differentiation. 4) Image Analysis, to analyze the position of the reference starting point and the reference ending point, using a threshold technique. 5) Speed Detection, to calculate the speed of each vehicle in the single image frame using the detection vehicle position and the reference point positions, and 6) Report, to convey the information to the end user as readable information.

The experimentation has been made in order to assess three qualities: 1) Usability, to prove that the system can determine vehicle speed under the specific conditions laid out. 2) Performance, and 3) Effectiveness. The results show that the system works with highest performance at resolution 320x240. It takes around 70 seconds to detect a moving vehicle in a video scene.

Keywords- Vehicle Speed Detection, Video Frame Differentiation

I. INTRODUCTION

The idea of using the video camera to measure the vehicle speed has been proposed to improve the current speed detection approach, which is based too much on the radar equipment. The use of radar equipment to detect the speed has been widely spread into the different kinds of industries. But somehow the equipment itself has some disadvantages, which cannot be fixed no matter how the technology has been improved so far, as long as the equipment is still based on the radar approach.

The way the radar operates is known as Doppler shift phenomenon. We probably experience it daily. Doppler shift occurs when sound is generated by, or reflected off of, a moving vehicle. Doppler shift in the extreme creates sonic booms and when those sound waves bounce back to the wave generator, the frequency of the sound will be changed, and scientists use that variation to calculate the speed of a moving vehicle. However, this technique still has some disadvantages such as the cost of equipment, which is the most important reason to find other compensating equipment that can reduce the cost of investment. Image processing technology can serve this requirement.

Image processing is the technology, which is based on the software component that does not require the special hardware. With a typical video recording device and a normal computer, we can create a speed detection device. By using the basic scientific velocity theory, we can calculate the speed of a moving vehicle in the video scene from the known distance and time, which the vehicle has moved beyond.

Few image processing key methodologies have been applied to this project. The image differentiation is used in the vehicle detection process, image thresholding for the segmentation process and region filling to find the vehicle boundaries. However, the project is still in the prototype mode, which requires more and more research and development in order to overcome the system limitation and enhance the performance of software to be able to perform to real-world application.

II. LITERATURE REVIEWS

Many researchers try to apply so many techniques to detecting and measuring vehicles speed. All techniques are based on the hardware equipment and computer software as follows:

2.1 Electronic Hardware & Computer Software

Yong-Kul Ki et al.[1] used double-loop detectors hardware and Visual C++ software to measure vehicles speed in Korea. Joel L. et al.[2], J. Pelegri, et al.[3] and Ryusuke Koide et al.[4] proposed magnetic sensors combined with computer software to detecting vehicles speed. Harry H. Cheng et al.[5] used Laser-based non-intrusive detection system to measure vehicles speed in a real-time. Z. Osman, et al.[6] applied microwave signal to detect vehicles speed. Jianxin Fang et al. [7] used

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continuous-wave radar to detect, classify and measure speed of the vehicles.

2.2 Image Processing & Computer Software

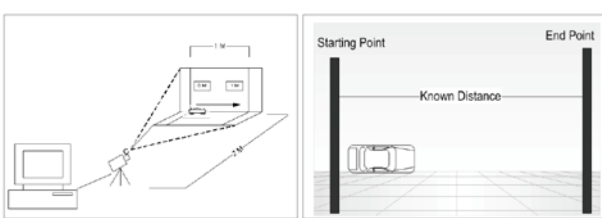
Huei-Yung Lin and Kun-Jhih li [8] used blur images to measure the vehicles speed. Shisong Zhu et al. [9] proposed car speed measurement from the traffic video signal. Bram Alefs and David Schreiber [10] applied the AdaBoost detection and Lucas Kanade template matching techniques to measuring vehicles speed. S. Pumrin and D.J. Dailey [11] presented a methodology for automated speed measurement.
Our system will use a video recorder to record traffic in a video scene. After that we will use a distance measurement to calculate a vehicle speed.

III. METHODOLOGY

This part will introduce our approach to create vehicle speed detection from a video scene system. We will start with the overall framework of the system and the description of each component in the framework and the basic understanding of the technique we are using in each component.

3.1 Overview of Vehicle Speed Detection Framework

The hardware requirement for the vehicle speed detection system is shown in Figure 1(a). The system consists of the normal IBM/PC connected to the un-calibrated camera. Our input of the system must be the scene of a moving vehicle. The scenes have to be known of distance frame, which consists of the starting point and end point and the moving vehicle as displayed in Figure 1(b). Basic idea of the system is to calculate the vehicle speed from known distance and time when the vehicle first passes starting point and the time the vehicle finally reaches end point.



(a) (b)

Figure 1. (a) Diagram showing the required system hardware to gather the input (b) The video scene structure

3.2 Vehicle Speed Detection System Structure Chart

To provide a deeper understanding of the details in each operation of the vehicle speed detection system, we firstly introduce the structure of the system as shown in Figure 2. And we will then elaborate on how each working module is constructed.

Based on the structure chart in Figure 2, our system consists of 6 major components, which are 1) Image Acquisition, 2) Image Enhancement, 3) Image Segmentation, 4) Image Analysis, 5) Speed Calculation, and 6) Report. Each component has the following details.

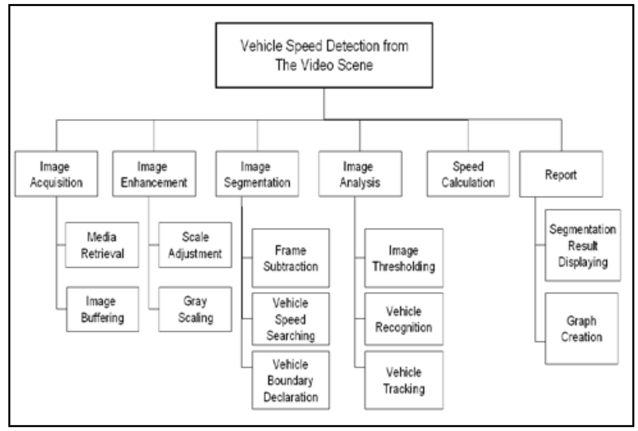


Figure 2. Structure chart of vehicle speed detection system

3.2.1 Image Acquisition

We have decided to use Microsoft Direct Show library as our tool to receive the input to the system. Microsoft Direct Show provides a technology called Filter Graph Manager, which performs as an unformatted-based video streaming input. Using the Filter Graph Manager, we have no need to worry about the format or the source of the media. Filter Graph performs at the device driver level in order to stream multimedia data through the media system. The filter graph provides a structure for multimedia filters used specifically by the automotive platform. The filter graph is constructed of 3 filter types, which are source filter, decoder filter and the render filter. Those 3 filters perform as low level media driver to receive, process and provide the same data format for all media to the output level. Our Image Acquisition component is in charge of calling the filter graph, grabbing the single frame from the video stream, and buffering each single image to the memory storage.

3.2.2 Image Enhancement

We first experimented with a couple of algorithms in order to improve our image quality to process in the next steps, such as noise reduction, image smoothing and so on. But the experimental result came out not very well, because all those methodologies were time consuming. So we have cut off some operations, which are not useful to our analyzing process. The remaining are 2 operations, which are Image Scaling and Gray Scaling.

Image Scaling is used in order to provide the possibility of having the various sizes of input formats. Understanding the format of the images helps us to determine the time that will be used to process each single image and display to the output device.

Regarding to the variety of input format, color is one of the key factors, which have a great impact on the system. The image color in each input format can be up to 36 millions colors and that means difficulty of the analyzing process. To reduce this difficulty, Gray-Scaling has been brought to the process. Making the colored image to be the gray level image means that we have cut off the number of million levels of colors. Images with 36 million-color levels can be transformed into 24 levels of colors without losing the abstraction.

3.2.3 Image Segmentation

For this operation, we are talking about image segmentation for the moving vehicle. To segment the moving vehicle from the images sequence, we have decided to use the image differentiation approach. Regarding the image enhancement process, all images in the image sequences must pass through the image enhancement, which means all that those images are the gray-scaled images. The first image from gray-scaled image sequences has been selected as the reference frame. Next step is to subtract all images in the sequences with the reference frame we have chosen. The result of subtraction gives us that there are the movements in the binary image form. Our approach to determine the vehicle position is to find the biggest area in the vertical space. We are declaring the biggest area in vertical as the prospective vehicle entry point. From the newly discovered entry point, the region-growing method has been applied. The region-growing method gives us the area of the real vehicle. The area of vehicle will be saved into the memory data structure called vehicle coordinate.

3.2.4 Image Analysis

Image Analysis process is responsible for finding the position of mark-points in the reference frame. The gray-scaled reference frame, which has been received from the image enhancement process, is used as the input of this process. Refer to the framework in Figure 1(a) and Figure 1(b), the mark-point must be in the dark shade line, so that the image thresholding method can be used to distinguish the mark-point from the background. After the thresholding process has been applied to the reference frame, we will have the binary image containing only two mark-points in the black color with white background. The binary image in this step will be inverted and sent to the image segmentation process to find the boundary of the vehicle itself. The result of the segmentation process will be the 1st mark-point, because the segmentation will determine the biggest area in the vertical space as the vehicle coordinate. So the next step that needs to be performed is to populate the new image without the 1st mark-point. The newly populated image will be sent to the image segmentation process to find the 2nd mark-point. When both mark-point positions have been received from the image segmentation process, the process will decide which is the starting point and end point. The result of the process will be the position of starting point and ending point, which will be used in the speed detection.

3.2.5 Speed Detection

From the previous processes, which have already provided us the position of each single vehicle in the image frame and also the position of mark points found in the reference frame. The speed of the vehicle in each image will be calculated using the position of the vehicle together with position of reference points and the given time stamp. From each calculation that we have proceeded, the summary will be made as almost the final step to give us the average speed of the vehicle since it first appears between the 2 mark points until it moves out of the range. Figure 3 shows more a visual explanation on the algorithm for finding the vehicle speed.

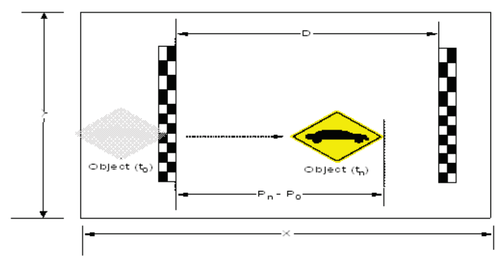


Figure 3. Diagram displaying all the variables used in the speed detection process

Based on the diagram to calculate vehicle speed in Figure 3, we can write the equations to find our vehicle speed as shown below.

Distance between vehicle and starting point measured in kilometer

$$\text{Distance} = Df * (D / D_x) * (P_n - P_0) \qquad \ldots(1)$$

Time that vehicle spent in order to move to P_n in unit of hour

$$\text{Time} = Tf * (t_n - t_0) \qquad \ldots(2)$$

Vehicle speed measured in format of kilometer per hour

$$\text{Speed} = \text{Distance} / \text{Time (Kilometer per Hour)} \ldots (3)$$

WhereD is the real distance between two marking points (start point and end point) measured in meter

D_x is the distance between two marking points measured in pixels

X is the width of the video scene measured in pixels

Y is the height of the video scene measured in pixels

P_0 is the right most of the vehicle position at time $t = 0$ measured in unit of pixels

P_n is the right most of the vehicle position at time $t = n$ measured in unit of pixels

t_0 is the tickler (timestamp) saved at time $t = 0$ measured in unit of milliseconds

t_n is the tickler (timestamp) saved at time t = n measured in unit of milliseconds

Df is the distance conversion factor from meter to kilometer, which is (1.00/(1000.00*60.00*60.00))

Tf is the time conversion factor. In this case, the conversion is from millisecond to hour, which is (1.00/1000.00)

3.2.6 Report

Report process is the last process, which provides the end-user readable result of calculation. The format of output can be either the text description or the chart displaying the speed of the vehicle when it passes the mark point.

IV. EXPERIMENTAL RESULT

In this section, the experimentation result will be presented in order to prove whether vehicle speed detection from a video scene system is applicable. We first present the experimentation result, which demonstrates how to use our system to capture the speed of the moving vehicle in video scene. The next part intends to demonstrate the effectiveness testing of the system, which will show how accuracy is provided by the system. Finally, we end up with the performance test to report how fast the system can perform.

4.1 Usability Proof

This experimentation begins with the computer software analysis window. The screen shows a list of image frames captured from the video scene. Our input data in this experimentation is the radio-controlled toy car, which moves from the left to right side of the scene. Figure 4 represents the moving vehicle in frame number 9th when it first appears in the scene until it reaches the ending mark point. For every single frame, the vehicle position has been detected together with the frame timestamp. With this information plus the position of the starting mark point and ending mark points, simple manual calculation can be made in order to find the vehicle speed on each frame. Table 1 demonstrates the video frame number with the timestamp and car speed in each frame. The final line of the table shows the average speed of a car.

4.2 Effectiveness Test

This stage, the effectiveness test, will be done under the same infrastructure as the usability proof. But the result of experimentation is changed to more focus on the correctness of the result. Our experimentation has been made under the different scenarios. We have created the different testing scenarios by summarizing the list of the factors, which we have considered it as the factor that can have an impact on the system correctness, such as the image resolution, size of the vehicle per size of the whole image frame, the movement of the vehicle recorded by the camera and the complexity of the background.

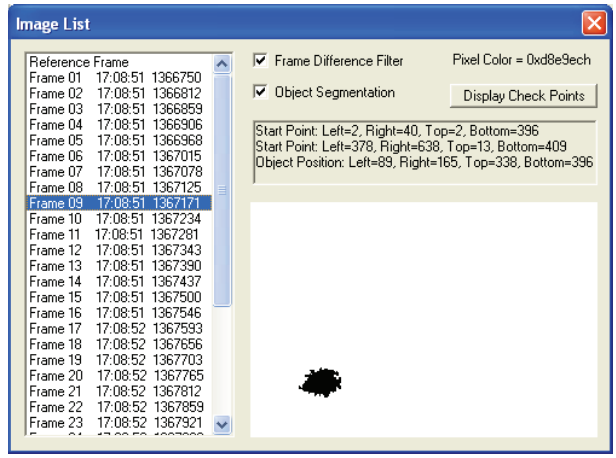


Figure 4. The captured screen of the 9th frame

Table 1 Display the result of programmatic detection of a 640 X 480 resolution data, containing the moving toy car

Programmatic Detection							
Frame Number	Screen Shot	Resolution 640 X 480 / Object Type : Car / Motion: Normal					
		Position (Pixel)				Time Stamp (Milliseconds)	Speed (Km / Hrs)
		Left	Right	Top	Bottom		
1	A1.1.1	2	41	355	386	7351250	0.00
2	A1.1.2	2	71	345	399	7351296	3.92
3	A1.1.3	2	94	338	431	7351343	3.43
4	A1.1.4	21	112	339	423	7351390	3.05
5	A1.1.5	41	142	339	433	7351453	2.99
6	A1.1.6	119	245	195	319	7351500	4.90
7	A1.1.7	41	214	327	439	7351546	3.51
8	A1.1.8	121	240	342	455	7351593	3.49
9	A1.1.9	136	288	331	457	7351656	3.66
10	A1.1.10	232	345	158	320	7351703	4.03
11	A1.1.11	248	430	119	327	7351750	4.68
12	A1.1.12	284	390	339	471	7351796	3.84
13	A1.1.13	294	454	344	478	7351859	4.08
14	A1.1.14	367	503	347	478	7351906	4.23
15	A1.1.15	379	520	146	372	7351953	4.10
16	A1.1.16	402	590	83	311	7352000	4.40
17	A1.1.17	523	638	355	478	7352062	4.42
18	A1.1.18	539	638	256	478	7352109	4.18
19	A1.1.19	583	638	374	468	7352156	3.96
Average Speed (Km / Hrs)							3.73

Table 2 Show the result of performance using moving car scene for each resolution

Resolution	Background Type	Processing Time (Milliseconds)		
		Turn Around Time	Detecting Marking Point	Time Per Frame
640 X 480	Plain Background	~ 781,000	~ 4,500	~ 43,000
320 X 240	Plain Background	~ 78,000	~ 1,100	~ 5,000

4.3 Performance Test

In this stage, our main concern about the performance test is the execution time of the system, while performing the automatic analysis process. With the same idea as we have presented in the previous section, the testing process will be done under the different circumstance regarding the different factor that we have considered it as the cause of performance impact. For convenience sake, we have used the same factors and scenarios, which have been used in the effectiveness test. Table 2 shows the result of performance test.

V. Conclusion

Based on the previous section, our experimentation has been made to achieve 3 objectives. For first objective, which is usability test, we can obviously say that the system can absolutely qualify this goal. The system is capable of detecting the speed of the moving vehicle in a video scene. Our concerns in order to improve the system are the remainder of 2 objectives, which are the performance and effectiveness of the system.

Based on the experimental results, the correctness of the system is still based too much on the form of the data. At this point, we have analyzed the experimental result in order to consider the important factors, which can affect the system correctness, as shown below.

The complexity of the background - We have defined this issue as our specification. But in the real-life application, the video scene cannot be fixed. The system has to be able to process on any kind of the background, even the non-static background.

Size of the video scene - One of the important factors, which can have effect an on the effectiveness of the system, is the size of the video scene. The larger image provides more processing information than the smaller one.

Size of the vehicle – with regard to our approach to determine the position of the vehicle, we are using the image differentiation to differentiate the vehicle from the static background. This is working well as long as the size of the vehicle is not too small. A very small vehicle can cause the system to be unable to differentiate between the vehicle and noise. When this happens, the detection process can be wrong.

Fixed characteristic of the marking point - Marking points are something very important to the speed calculation process. To give the wrong characteristic marking points, the system may not be able to recognize the correct position of the marking point.

Stability of the brightness level - To process the video scene under unstable brightness level means that we are working on the different images and backgrounds in every sampling image. The result of doing that may be an unexpected error on the detection process.

Number of colors from the input video - The Gray Scaling process is using just a simple algorithm. This means the Gray Scaling process is not designed for too many color levels like 1.6 million-color image.

The direction of the moving vehicle - Based on the experimentation result, we have tried to move the vehicle to reverse direction. The result of doing this is that the detection process is given the negative number of vehicle speed.

Limitation of the number of the vehicles in each scene - We have proposed this as the limitation in the specification. The system has been implemented to support only the single moving vehicle in the video scene. To have more than one vehicle moving in the same scene can cause the system to provide an erroneous result.

Stability of the camera - This is the limitation that we have proposed as our specification. But in reality, there are still some risks that the camera can be shaken or moved for many unexpected reasons. For this current system, if some of these errors happen, the system can give the wrong result.

Speed of the vehicle - The speed of the vehicle that we want to detect is based on our hardware speed. To capture the fast-moving vehicle, this definitely requires faster hardware speed.

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