TRAFFIC LIGHT CONTROL SYSTEM SIMULATION THROUGH VEHICLE DETECTION BY IMAGE PROCESSING

Mac Michael B. Reyes and Dr. Eliezer A. Albacea

***Abstract*— Traffic Light Control System Simulation Through Vehicle Detection By Image Processing is a system designed to control the state changing of a traffic light using image processing. Road traffic image sequences are processed and analyzed, producing a result that is used by the system to create an output simulation of traffic light control system.**

***Index Terms*— Traffic light, image processing, vehicle detection**

I. Introduction

A. Background of the Study

Traffic problems nowadays are increasing because of the growing number of vehicles and the limited resources provided by current infrastractures. On intersecting roads, huge number of vehicles lead to congestion and heavy traffic. Traditional traffic controls (warning signs, stop signs, etc.) are used in most areas but these are sometimes inadequate to address the problem. Traffic lights are installed in urban places to minimize the problem.

A traffic light has three main lights: red, green, and yellow. Each light represents a traffic signal; red means ”stop”, green means ”go”, and yellow means ”slow down” or ”prepare to stop”. There are different ways of controlling a traffic light for it to change phase. The simplest way uses timer for each phase. Others use electronic sensors in order to detect vehicles, and produces signal that cycles. Some of the latest traffic light control systems use video cameras on intersections since it can accurately detect vehicles than using sensors.

B. Statement of the Problem

The problem with a pre-timed traffic light is that it remains green until the time expires even if there are no more vehicles waiting to pass the intersection, while the vehicles on different route still wait for their turn. This problem is solved by using electronic sensors to detect vehicles on the road. Sensor-based systems use coils of wires embedded in the road’s surface. However, by using this system, small vehicles like motorcycles and bicycles may not be detected because of their low metal content. Thus, signaling the traffic light to change state despite the latter’s presence. Additional problem is that when the loop wires become damaged, the signal controller of the system sometimes interprets damaged wires as presence of vehicles.

A new system for controlling the traffic light by image processing is the main goal in this project. The system will detect vehicles through images instead of using electronic sensors embedded in the pavement. A camera will be installed alongside the traffic light. It will capture videos and convert them to image sequences. The image sequence will then be analyzed using digital image processing for vehicle detection.

C. Significance of the Study

While waiting for the traffic light to change phase, motorists lose time, and vehicles consume more fuel. The system can reduce the waiting time of motorists since it minimizes (if not totally avoids) giving a green light to an empty road. It can also detect all kinds of vehicles in a more accurate basis.

The traffic monitoring agency will also benefit because the system will lessen their expenses (Example: Instead of embedding electronic sensors under the pavement, only a video camera will be installed at the road side.).

D. Objectives of the Study

The study generally aims to create a system that would process road images during daytime only, and signal the result to a simulated traffic light system.

Specifically, it aims to do the following:

1) distinguish the presence and absence of vehicles in road images;
2) signal the traffic light to go red if the road is empty;
3) signal the traffic light to go red if the maximum time for the green light has elapsed even if there are still vehicles present on the road.

II. Review of Related Literature

As traffic volumes increase beyond the capacity of lesser controls (traditional traffic signals such as warning and stop signs), there may be a necessity to install a traffic light. There are, however, established minimum criteria that must be satisfied before installing one. Some factors that must be satisfied before installing one. Some factors that must be considered include the following: (1) the amount of vehicular and pedestrian traffic, (2) the need to provide interruption to

Presented to the Faculty of the Institute of Computer Science, University of the Philippines Los Baños in partial fulfillment of the requirements for the Degree of Bachelor of Science in Computer Science

the major street for side street vehicles and pedestrians, (3) special conditions such as hills and curves, (4) the accident history of the intersection, and (5) the proximity of schools.

When a traffic light is justifiably installed, signals offer a maximum control at intersections - they relay messages of what to do and what not to do. However, an unjustified traffic light cause an increase in accident frequency, excessive delay, disobedience of signals, and diversion of traffic to residential streets.

Traffic in a city is very much affected by traffic light controllers. When properly timed, a traffic light increases the traffic handling capacity of an intersection. But a traffic light that operates on timer causes the traditional problem of no matter what time of the day it is, there is going to be a lot of traffic. As a solution to this problem, detectors are used. Traffic lights with detectors may detect when a vehicle arrives at an intersection, or when too many cars are stacked up at an intersection. There are all sorts of technologies for detecting vehicles. By far, the most common technique is the inductive loop. An inductive loop is simply a coil of wire embedded in the road's surface. To install the loop, they lay the asphalt and then come back and cut a groove in the asphalt with asaw. The wire is placed in the groove and sealed with a rubbery compound.

There is also the single-axis magnetometer. It looks for changes in only the vertical component of the Earth's magnetic field to indicate vehicle arrivals and departures. These devices are installed in the street and run via wire and conduit to the traffic control box. The detector must then be calibrated back at the control box. Because they only utilize the vertical axis, single-axis magnetometers are prone to double counting of a vehicle (detection on the front and rear axles).

There are some techniques, however, that is used in vehicle tracking but has not been used in traffic light systems. Oliveros (2005) used Radio Frequency Identification (RFID) technology in vehicle tracking which gathers data from specific tags using a transceiver, even without coming into contact with a scanning device.

Another technique is by image processing. Aerial images along the road directions where cars appear as small objects can be used for car detection. It may be easier to detect a car using this approach but the constraint lies on the difficulty of the viewpoint.

More about image processing, it has already been used in many systems. Zapata (2001) created an application that detects human in a video sequence specifically in a basketball game.

The reviewed literatures gave the author a motivation to develop a system that would control traffic light through vehicle detection by image processing.

III. Theoretical Framework

Computer Vision, as a scientific discipline, is concerned with the theory and technology for building systems that obtain information from images or multi-dimensional data (Wikipedia 2006). The specific implementation of a computer vision system is very dynamic that it depends on if the system's functionality is pre-specified or it can be learned or modified during the development of the system.

1) Image acquisition. One or several image sensor produces a digital image. The image may be 2D or 3D from depending on the type of sensor used. Image sensor types include light-sensitive cameras, renge sensors, tomography devices, ultra-sonic cameras, etc.
2) Image Segmentation. In the analysis of the objects in images it is essential to distinguish between the objects of interest and "the rest". This latter group is also referred to as the background. The pixels in the image will be converted into a series of 0's and l's. This can be done by getting the grayscale value of a pixel and comparing it to a certain pixel value. Segmentation lessens the area of concern and makes the system run faster.
3) Motion Tracking. Can be off-line or real-time. In off-line, the entire image sequence is stored. The tracking uses frame differencing algorithm to generate a motion map.
4) Background Subtraction. The process of finding the transient objects by comparing the current frame to the background image.
5) Morphological Operations. (i) Opening: Removes foreground details that are smaller than the structuring element. It is also used as a noise removal operator; (ii) Closing: Removes background details–holes, gaps, inside corners, etc.–that are smaller than the structuring element. It is also used to link components (i.e., broken lines) that should be connected.
6) Image Correlation. The process of computing the correlation for each region of interest (ROI) of the current image to the ROI of the background image.

IV. Methodology

The system has three main phases: (1) Input generation, (2) Processing part, and (3) Output generation.

A. *Input generation*

This phase includes the whole data gathering part (video shooting up to input preparation). After shooting and collecting traffic videos, they are prepared and converted to image sequences for the system to be able to take them as input. Virtual Dub v1.6.16 is used to convert video files to image sequences.

B. *Processing part*

The overview of the system is illustrated in Fig 1. And the flow of the processing part is shown in Fig 2.

C. *Output generation*

After executing the processing part, the system creates a sequence of image processed output containing the results of the processing part and the simulation of the traffic light system as well. The generated image sequences are again converted back to video files. Virtual Dub 1.6.16 is again used for this process.

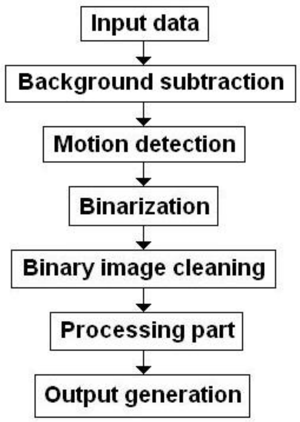

Fig. 1. System Overview

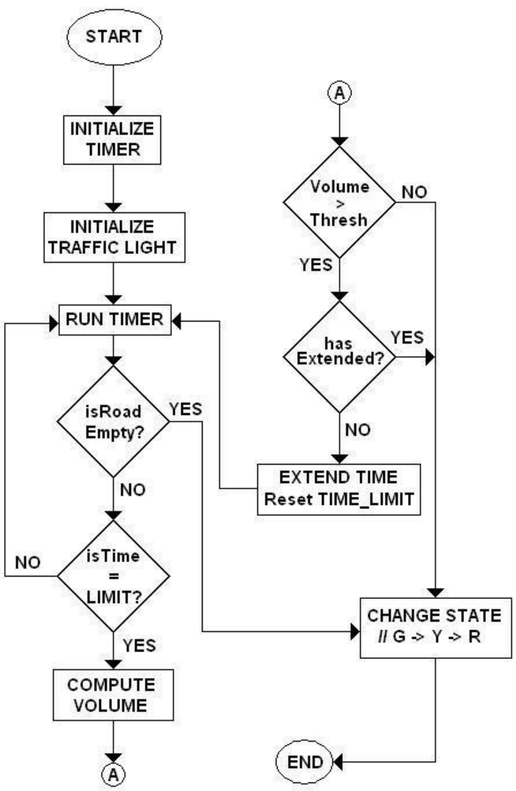

Fig. 2. Flowchart of the processing part

V. Results and Discussion

The dimension of the input video is 320 x 240 pixels. The system produces an output image with 6 frames, each frame having the 320 x 240 pixel dimension.

Each frame in the output image represents a result of a step in the processing part. The first frame contains the result of binarizing and cleaning of the input. The frame below that, (2nd row, 1st column), contains the result of the motion detection algorithm. The frame at the first row of the second column displays the original image input. The frame below it contains the original image with their division being marked with different colors according to region of interest (ROI). The last two frames contains the traffic light and the timer for the whole image sequence, and the data of vehicle volume per ROI written in percentage. A sample image output is shown in Fig 3.

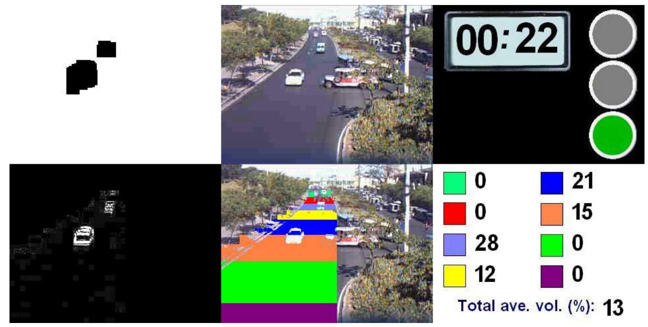

Fig. 3. Sample image output

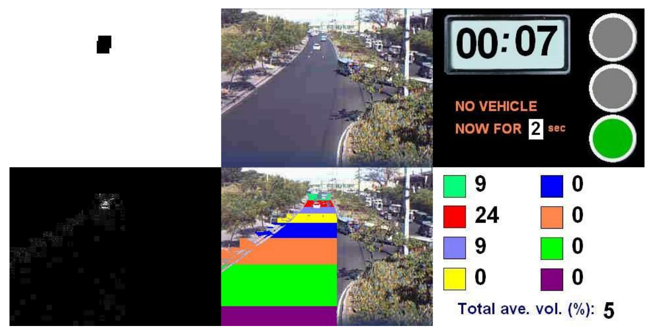

Fig. 4. Sample image output for case 2

Fig. 5. Sample image output for case 3 (before extension is made)

The system was able to produce results for different scenarios.

1) Case 1: Normal case. Time for the green light elapsed, the traffic and vehicle volume is normal.
2) Case 2: No vehicle on the road during a green light. The ROI here is the first three regions in front. Idle time of three (3) seconds is set before the traffic light changes state. It is shown from Fig 4 that the first three ROI of the image is empty (no vehicle presence detected) and there is still seven (7) seconds left in the timer. It is also shown in the frame containing the statistics of vehicle volume (last frame). With the case being this, the traffic

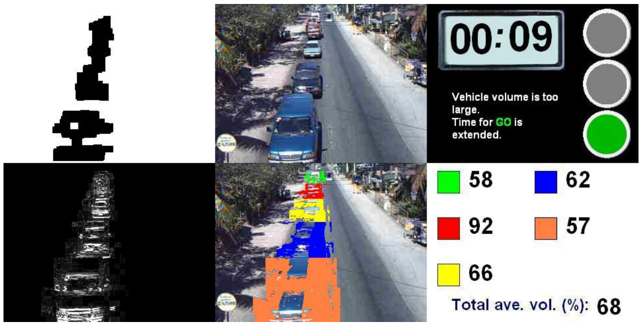

Fig. 6. Sample image output for case 3 (time extended)

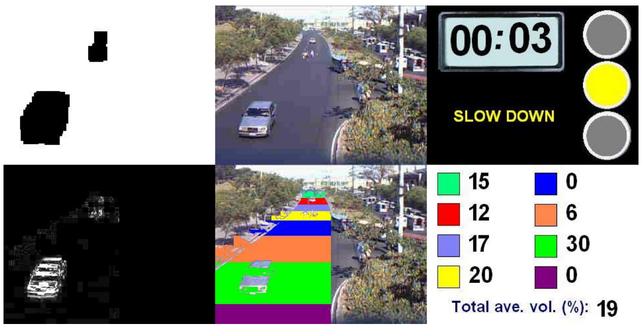

Fig. 7. Sample image output for yellow state

light will change state from green to yellow after the three (3) second idle time has elapsed even if there's still plenty of time before the actual time for the traffic light state change. Eventually, it will turn red after a few seconds.

3) Case 3: The time for the green light has elapsed but the vehicle volume on the road is too dense (see Fig 5). The timer will extend the time for the green light. The extension depends on the level of vehicle volume density. Fig 6 shows the extension made by the timer after the scene on Fig 5.
4) Other cases: These are just variations of the first three cases, having different volume of vehicle on the road and different time limit for the traffic light. The system works the same as it does in the previously described scenarios. Fig 7 shows the output when the state of the traffic light is set to yellow. Fig 8, state is red.

VI. Summary and Conclusions

The study showed that image processing is a better technique to control the state change of the traffic light. It shows that it can reduce the traffic congestion and avoids the time being wasted by a green light on an empty road. It is also more consistent in detecting vehicle presence because it uses actual traffic images. It visualizes the reality so it functions much better than those systems that rely on the detection of the vehicles' metal content. Overall, the system is good but it still needs improvement to achieve a hundred percent accuracy.

VII. Recommendations

It is recommended that the study like this be done using an advanced high-resolution camera. With that, vehicle detection

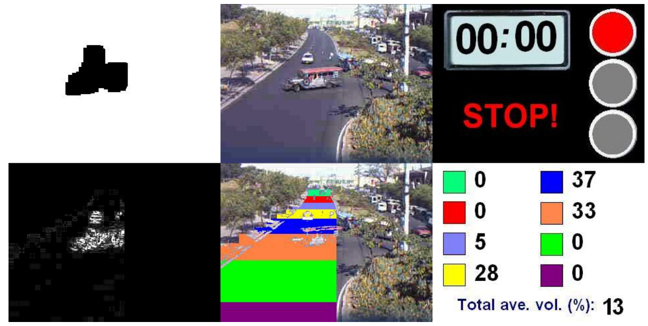

Fig. 8. Sample image output for red state

and tracking will be more accurate, thus leading to a more efficient traffic light control system. It is also recommended that this study be extended to work during the night time because it is also important to have this kind of systems at night. A new algorithm is needed. Also, the use of actual traffic light device is recommended. Government support for financing is needed.

VIII. Acknowledgments

The author would like to thank the following people who helped in making this study possible: Dr. Eliezer Albacea, Dr. Vladimir Mariano, the UPLB COSS (LAKAS!), and the astig Pearl street boys. Also, Siena and Jew for the videos. He is dedicating this work to his family (kuya, ate at kuya denden, tin, mac), especially to his parents (I love you very much!).

References

[1] Oliveros, M.K.V. 2005. *Vehicle tracking using radio frequency identification (RFID) technology*. Undergraduate Special Problem. Institute of Computer Science, University of the Philippines Los Baños.
[2] Zapata, I.R. 2001. *detecting humans in video sequences using statistical color and shape models*. Graduate thesis. University of Florida.
[3] *"How does a traffic light detect that a car has pulled up and is waiting for the light to change?"* http://auto.howstuffworks.com/question234.htm
[4] *VEHICLE DETECTION GOES WIRELESS*. http://www.imsasafety.org/journal/jan12002.htm
[5] Transportation and Public Works Department, Texas. *Traffic light* http://www.fortworthgov.org/tpw/TrafficSignalsAllAbout.htm
[6] Wiering, M. *Intelligent traffic light control.*. http://www.ercim.org/publications/ErcimNews/enw53/wiering.html
[7] Wikipedia. 2006. *Traffic light*. http://en.wikipedia.org/ wiki/TrafficLight
[8] *Comm shop info: Traffic light*. http://www.ci.missoula.mt.us/trafficservices/
[9] Mariano, V.Y.M. *imagelab. Library for image processing.*. Institute of Computer Science. University of the Philippines Los Baños.

Mac Michael B. Reyes is an undergraduate BS Computer Science student of the University of the Philippines Los Baños. He is a member of the UPLB Computer Science Society. His interests include Image Processing, Database Systems, and Web Development. He likes to pursue a career in Software Development upon graduation.