REPORT OF RESEARCH RESULTS

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Real-Time Traffic Light State Detection and Prediction for Driver Assistance

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Summary

Safe driving is the most-wanted and effective action to prevent road accident. Recent figures reveal that in Thailand 2016, there were totally more than 400000 road accidents so far. The accident investigation concluded that traffic light is one of the most important factors. To prevent a road accident due to sudden change of traffic light state without countdown timer, this study aims at developing an effective algorithm to detect traffic light and predict its state changes. We combined several image and video processing techniques including edge, shape and color detection, and mean-shift algorithm to localize traffic lights. Then we implemented Hidden Markov Model to predict the traffic light state. Experimental results revealed that the real-time detection rate is around 88% and the prediction rate reaches 91.41%.

Aim of Research

The major objective of this study is to develop an efficient technique and system to detect and predict traffic light state changes. It would help alert drivers during risky driving situations i.e. traffic lights turning suddenly from green to yellow and red so that the drivers could decide to decelerate in time. Figure 1 demonstrates this situation when rapid change of traffic light could trouble drivers and could lead to accidents due to rear hit or red light violation.

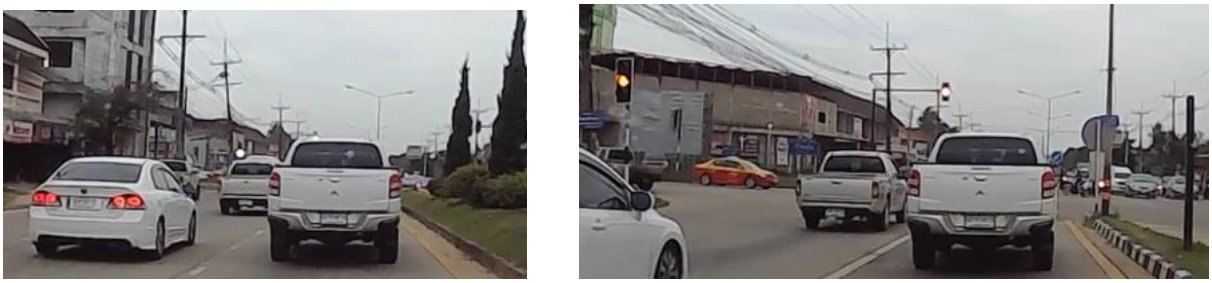

Figure 1 Cars approaching green traffic light (left) and sudden change to yellow light state (right)

There are two main research questions in our study. One is how vehicles could detect the traffic light location and position while approaching junctions. Another is how to predict the incoming traffic light state to warn the driver if necessary.

Method of Research & Progression

The research methodology comprises of four main phases: data collection, equipment preparation, traffic light detection and traffic light state prediction.

a) Data Collection

We performed manual data collection for around 200 traffic lights at junctions of primary (main) roads and secondary roads. For each junction we mark the location of traffic lights using GPS

and collect times of traffic light's state i.e. red, yellow and green lights. In addition, we also counted the number of cars passing by the traffic light at different light state for probability calculation later.

b) Equipment Preparation

Firstly we started using a mobile phone as a tool thanks to its complete specification as we required i.e. camera, location detection (GPS), sound and processing power. Unfortunately after some experiments we found that the mobile device has a major limitation which is the heat of its camera after long exposure.

Therefore we looked for an alternative to overcome this trouble and finally chose a single board computer i.e. Raspberry PI 3 model b. We attached necessary components including camera, display, sound, GPS and battery modules as Figure 2 and install this equipment on a car's console.

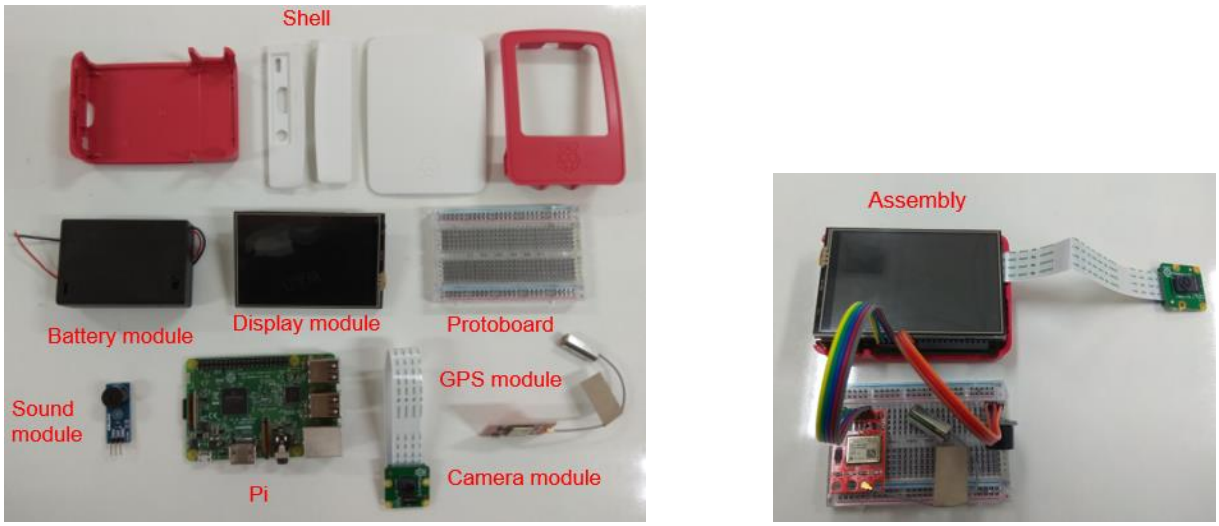

Figure 2 Single board computer with modules (left) and its assembly (right)

c) Traffic Light Detection

Localization of traffic light is a difficult task due to some limitations such as car speed, various traffic light positions, and brightness of traffic light state as well as processing power of our equipment. We decided to choose fast and efficient image and video processing algorithms including a) consider a region of interest (ROI) to be only the middle part of video frame where normally the traffic lights are detected b) use edge detection to extract edge features c) apply Hough line transform on the edge features to detect the traffic light position and d) filter the extracted traffic light image using color in HSL (Hue-Saturation-Luminance) domain to detect its state i.e. red, yellow or green. Finally we implement mean-shift algorithm to track the traffic light in each video frame.

d) Traffic Light State Prediction

Prediction of traffic light state is rare in the literature. It is the tough research issue based on the question that how could we predict the light state in a very short time with limited prior knowledge. To do so we gather as much as junction information in advance including location of traffic light, light duration and car speed. However, these are not sufficient for prediction. We collect another statistic which is the number of cars passing through the junction at two light state changes i.e. green to green and green to yellow. Then we input all these prior information to Markov Chain and calculate the probability of a situation where a driver could face yellow light on the condition

that the previous light is green. This is the dangerous situation and if its probability is higher than a threshold, we set the equipment to beep for warning the driver.

From initial experiments we found that the prediction accuracy was average. Therefore, we observe the drivers' behavior and notice that another interesting factor to help decide whether to stop at the traffic light is the front car. A car ahead could also guide drivers to continue or brake. Thus we try to detect another factor which is the front car's rear view and use it as a hidden input to Hidden Markov Model (HMM). By doing so the prediction accuracy increases and is very promising.

In summary, the overall scheme of our proposed methodology is presented in Figure 3. Video input from our equipment is processed frame-by-frame to detect the traffic light and its state and the front car's rear view. Then HMM is used to predict the next light state and alarm the driver if necessary.

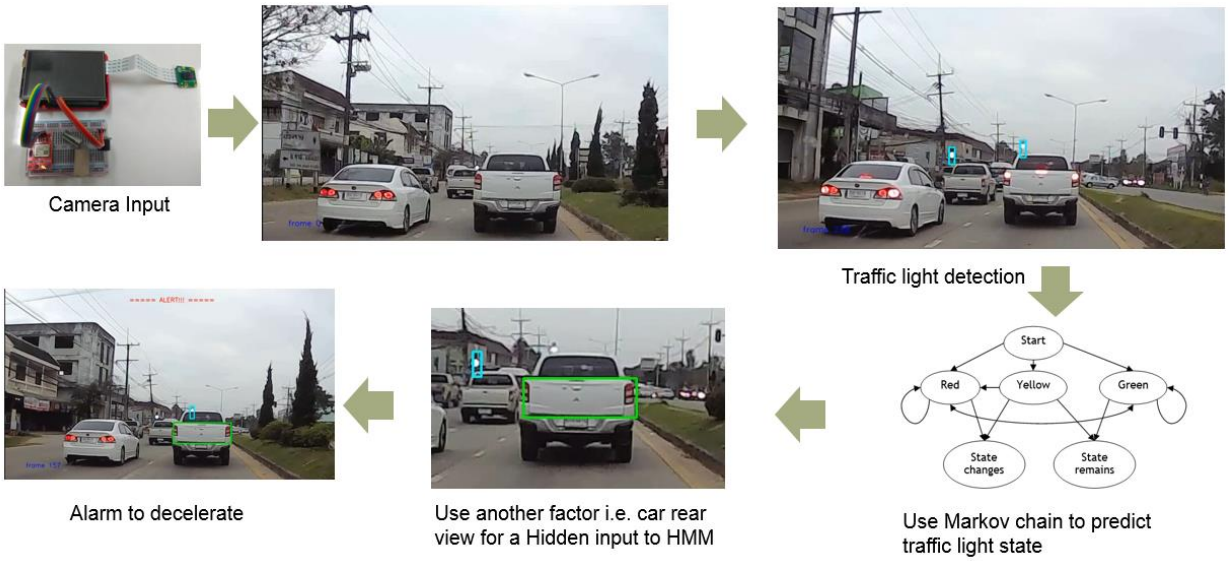

Figure 3 Overall scheme of the methodology

Results of Research

The results are twofold; observation result and experimental result.

a) Observation Result

After field collecting data in local area, we noticed that less than 30% of observed traffic lights are attached with timer. The green light's duration varies from 15-120 seconds. Around 20% and 35% of red light violation are found at the primary direction and secondary direction respectively. In addition, interview with police officers revealed that red light violation was often observed and some resulted in car accidents. Considering the light state, the yellow light duration is too short to be significant while the green light state is the main focus.

b) Experimental Result

More than 150 drive tests with the developed equipment in daylight. The driving speed is around 60-110 kmph. Only 80 experiments were selected at different junctions where the initial traffic light state is green. Among 80, 40 cases were green to green states and other 40 cases are green to yellow and red states. Figure 4 illustrates two cases of true positive prediction when our

algorithm alert correctly for the case that the driver should stop and another case that the driver could keep on.

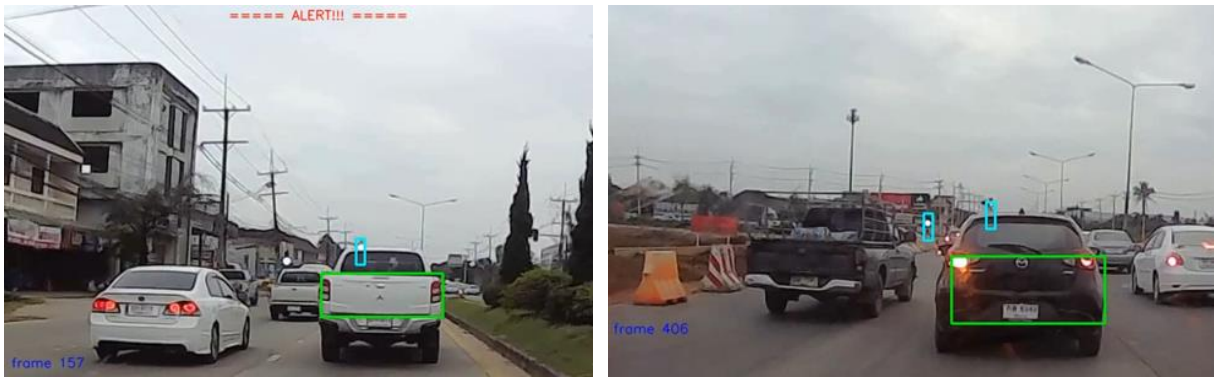

Figure 4 Two examples of experimental results: alert case (left) and no alert case (right)

For detection result, in 71 from 80 experiments (88%), the traffic light and state were correctly detected. 9 missing cases were mainly due to the low ambient light condition, the high driving speed and the camera performance.

For prediction result, in 71 experiments where the traffic lights were detected, there are 37 green to green and 34 green to red. 35 from 37 (94.59%) is true negative while 30 from 34 (88.23%) is true positive. The prediction accuracy is presented in Table 1. Note that the local accuracy refers to the accuracy regarding that all traffic lights are previously detected. While the global accuracy takes into account both prior detected and non-detected traffic lights.

Table 1 Prediction accuracy

State	Warning	Not Warning	Local Accuracy	Global Accuracy
Green to green (37/40)	2	35	94.59 %	87.50 %
Green to red (34/40)	30	4	88.23 %	75.00 %
Average			91.41%	81.25%

It is worth noting that the prediction rate is better than the detection rate. The local accuracy of the prediction is promising while the global accuracy of the prediction is satisfied but should be better if we can improve the detection rate.

Future Areas to Take Note of, and Going Forward

The research is still in an initial phase. We found that traffic light detection and prediction is a challenging issue due to incomplete inputs and a real-time processing on limited-resource equipment. Getting car numbers through a junction could be done automatically via image processing or another traffic measurement device to lessen the burden of manual counting. Further research could focus on improving detection and prediction accuracy as well as testing on different machine learning algorithms. Detection and prediction of traffic light state during night time is also challenging.

Means of Official Announcement of Research Results

Currently we are preparing the manuscript to submit to International Joint Conference on Computer Science and Software Engineering JCSSE2018 (http://jcsse2018.ict.mahidol.ac.th/) and Information Technology Journal (http://ojs.kmutnb.ac.th/index.php/joit).