Imaging Red Light Runners

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Abstract

Traffic lights are routinely ignored by Thai drivers, so we designed a system that allows a single camera attached to a simple PC to monitor a controlled intersection and sends images of vehicles violating traffic lights to a police post further down the road. This allows police to instantly stop motorists, fine them if appropriate but, more importantly, educate them on the importance of following road rules - for the benefit of all drivers. We demonstrated that our system performs with two types of cheap, consumer cameras: it is simple to setup, does not rely upon accurate intersection delineation and can be deployed on intersections that are not well marked. It can view red light runners from the side or rear view thus the only constraint on the camera position is the ability to view the whole intersection and at least one controlling traffic light.

Keywords: visual object tracking, traffic safety

Introduction

Thailand has a very high rate of road accidents: it has been ranked as high as third in the world on a per head of population basic by statistics from the World Health Organization[1]. Road traffic accident have many causes: statistics from the Thai Traffic Police rank the causes of the accident as

1. Highway speeding,
2. Tailgating,
3. Unsafe overtaking and
4. Running a red light[2].

Although running red lights only causes _ 10% of accidents in Thailand, this represents _ 2000 deaths (and many more accidents) annually[2]. However, this problem is international: Retting et al. reports that in the US, 260,000 crashes and 750 fatalities annually were attributed to red light running[3]. Crashes involving red light runners have greater impact than other crashes causing occupant injuries in 45% of crashes, compared to 30% in other crashes[4]. Internationally, the economic and social cost of road accidents remains high, even in countries with much lower per capita accident rates than Thailand. For example, in Victoria, Australia, with only 5.4 fatalities per 100,000 head of population, the economic cost is estimated at $ A4 billion perannum[5] in a total population of 5.8 million (2014 census), thus the cost in Thailand with 17 fatalities per 100,000[1] the economic cost must be significantly greater. This makes no account of the social cost of deaths and injuries. Despite some campaigns from several sources in Thailand, the accident rate is not decreasing. Thus any system which increases awareness of road hazards will have enormous benefit for the country.

Previous work

Many systems have been developed to monitor traffic violations. Early systems were usually attached to the traffic light control systems, e.g. Abbas and Li used a combination of a PC104 which takes data from the traffic cabinet and cameras storing images with a commercial video capture loop[6]. Other systems, mostly involving cameras linked to traffic cabinets and inductive loop detectors, have been surveyed by Yung and Lai[7]. Washburn and Courage used a commercial video

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recorder with some sensors on the light power cables. Signals from these sensors were encoded on the audio channel of the recorder for later outline

Analysis: the acquired data was used for traffic analysis and was not used for enforcement or education of drivers themselves[8]. Many of these use camera and image processing techniques to assist law enforcement and improve safety as well as improve traffic flow. Klubsuwan et al. used image processing alone to detect traffic light violations without the help of other systems[9]. They correctly detected 80% violations. Several commercial systems are also now available, but they are mainly suited to the well-controlled intersections in western countries[10]. One full system developed in Thailand has been reported, but does not appear to have been widely adopted: cost may be a factor as it includes license plate detection[11].

1. Extent of the problem

To confirm the extent of the problem of running red lights locally, we made a simple count of the rate of red traffic light violations. On one major highway T-junction in Mahasarakham (a small city in NE Thailand, pop 250,000), we counted the number of vehicles going through traffic lights in light traffic conditions (12 noon on a Sunday): in a one hour period, with 26 light changes (one for each of 3 directions), we noted 79 cars and trucks and 28 motorcycles that did not stop for a traffic light over the three intersections in the T-junction, ie on average one car or truck for every light change and one motorcycle every three changes. This showed that traffic lights are routinely ignored locally and that an automated system that assisted police to detect and educate drivers could make a significant impact on accidents and their cost. We also hypothesized that educating drivers to obey one road rule might encourage them to follow other rules also and reduce accidents from other causes too.

Our system

Our system consists of a single camera attached to a PC which was positioned to monitor a controlled intersection. It monitors the traffic lights themselves and does not require assistance from the traffic controlling hardware and associated road loops. When it detects a red light violation - a vehicle moving through the intersection when the light is red - it captures images of the offending vehicle and transmits a set of images to a police post which can be several hundred meters down the road. This component of the system was designed to follow the very common current Thai police practice of establishing partial road blocks to check vehicles, thus it will require minimal changes to current practices. Our design is also easily adapted to a variety of situations: it can be set up in a few minutes at a new intersection. It just requires a suitable position for a camera mount and a casing for the PC and battery[1]. The wireless connection needs a line-of-sight link to the monitor post, say 500m away[2].

1. Operation

1.1 Setup

Traffic Light Detection initially, the operator needs to place the camera in a stable location so that it can view the intersection and at least one light controlling it. The software detects traffic light candidates which can be anywhere in the field of view and asks the operator to indicate when the correct light has been detected[3]. Steps in the light detection algorithm are:

1. Identify `red' areas by comparing high intensities in the red channel of the image with intensities in the other two channels. Typical traffic scenes contain large white areas which show high red intensities, so these are eliminated. Unfortunately, scenes often contain several red patches (red cars seem to be very popular!), so we did not attempt to fully automatically identify lights: previous efforts, e.g. Sooksatra and Kondo[12], found less than 90% correct detections in fairly ideal conditions, as might be expected due to the likelihood of round and red objects appearing in a typical scene[4]. traffic light, false color optical flow map (green indicates highest speed), flow map contour

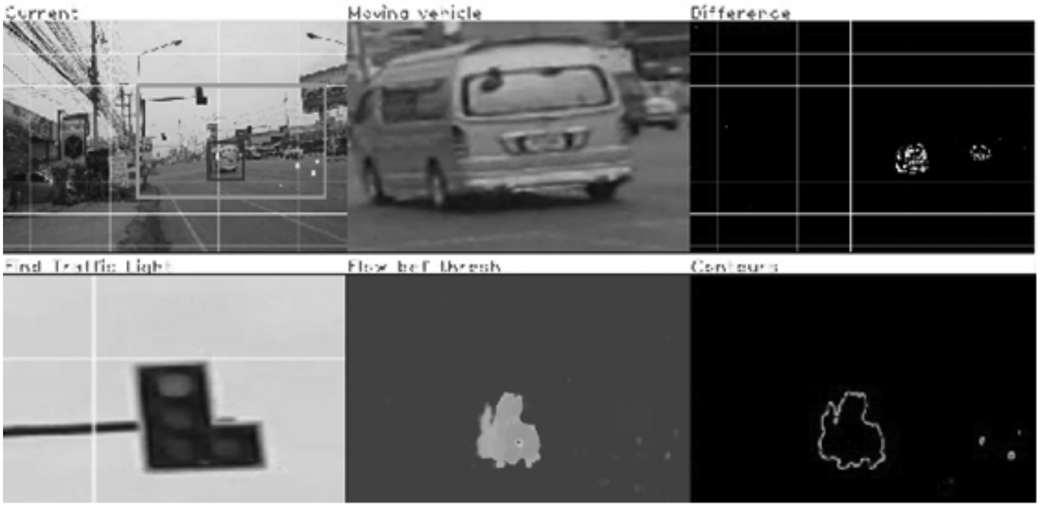

Figure 1 Screen shot after detecting a red light runner using 1280 720 pixel small consumer camera (Canon IXUS 155) Top row: marked up intersection image, vehicle passing red light, difference image; Bottom row:

2. Select red light candidates by shape and size.

3. Present candidates to the operator, one-by-one

4. Terminate when the operator accepts a candidate or repeat on another image.

Traffic Light Detection The operator then identifies the `forbidden region' - the area which must not be entered after the light has turned red. Observation showed that many intersections were poorly marked - with markings absent or badly worn - and therefore likely to defeat an automated system. However, an operator can quickly (two mouse clicks) identify the forbidden region - see blue outline in the top left of (Figure 1).

Link to monitor post Then the operator aligns the link between the intersection camera and the monitoring post computer. A reasonable height above ground for the antennae at both ends will ensure trouble-free transmission. Even in quite crowded city areas, transmitters and receivers about 2-3m or more above ground will suffice. Software will verify that significant bandwidth to transmit images of the red light runners is available[5].

1.2 Automatic Monitoring In monitor mode, the program uses optical flow to detect moving objects in the exclusion zone when the traffic light is red. Candidate algorithms for this are frame differences and optical flow.

1.3 Frame differences This is very fast and meets any real-time constraints, but is susceptible to interference from moving objects (trees are a particular concern, but even traffic lights are affected by the wind. Some examples may be seen in the top panel of (Figure 2) which shows trees and power wires clearly showing up - `speckle' in the Top row: marked up intersection image, vehicle passing red light, difference image; Bottom row: traffic light, false color optical flow map (green indicates highest speed), flow map contour

background. Even the `pick up' appearing as a large white area in the difference map is a complex shape with several black `holes'. So the difference images need considerable intelligent processing to remove noise and non-vehicle movements and we rejected it in favor of optical flow techniques. Although it is not used for primary vehicle movement detection, occasional system artefacts (probably mainly vibrations in the camera base) cause poor frame-to-frame registration, affecting optical flow, which detects anything moving in the scene, and leads to poor discrimination between moving and background objects. So we simply reject frames which are poorly registered: typically more than 30 frames are captured for a red light runner, so this has negligible effect on overall detection.

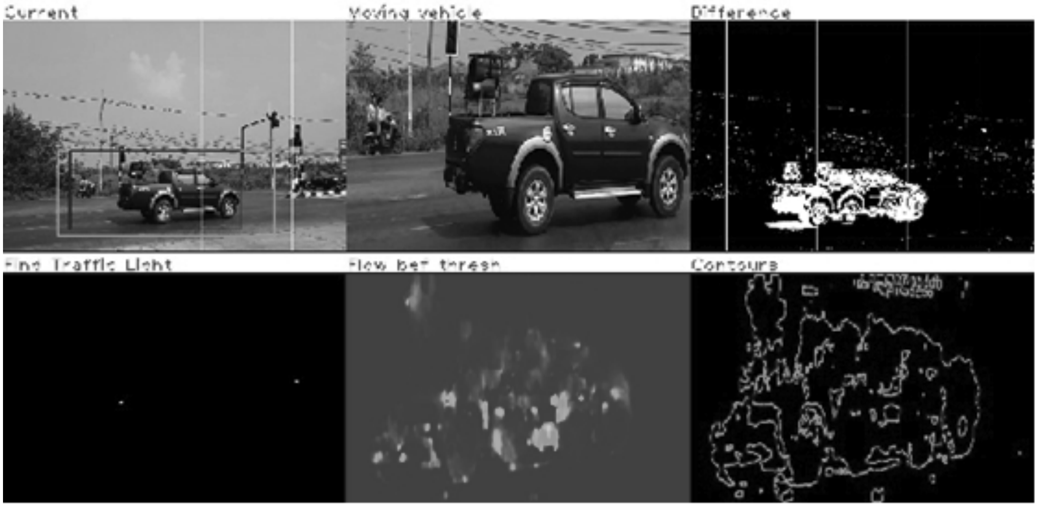

Figure 2 Screen shot after detecting a red light runner using hand held 1900 _ 1080 pixel cell phone camera (Samsung Galaxy Grand Prime)

1.4 Optical flow

Optical flow is unfortunately computationally complex on the high resolution images that are now available. Selection of the forbidden region assists by reducing the area that must be processed. Optical flow images also allow the speed and direction of the moving vehicle to be determined, allowing rejection of vehicles stopped unintentionally in the forbidden region, e.g. blocked by other traffic. We used the Farneback optical flow routine from the Open CV library[13]. In separate trials, we have used the total linear variation algorithm (from Open CV[14]) which produces slightly better results but is approximately three time slower. On the bottom middle panel of (Figure 1), a false color map showing which pixels are moving from frame to frame.

Greenish colours encode faster moving pixels. A contour is drawn around the fast moving pixels: small areas are rejected (wind or vibration generated noise) and regions large to represent a vehicle (or motorcycle - the commonest offenders are some intersections) and an image of the offending vehicle extracted from the current scene image for transmission to a monitoring post. For the higher resolution images of (Figure 2), the optical flow algorithm fails to cleanly assign every pixel of the vehicle to a uniform velocity (as seen in the lower middle false colour image of Figure 2), but the moving vehicle is sufficiently correctly identified to allow a complete and clear image of the red light runner (upper middle panel of Figure 2).

Results

Preliminary results for our system have been tested with several video cameras - including one in a cell-phone - have shown that the system reliably detects red light runners. A screen shot from the running program is shown in (Figure 1). Using a Canon IXUS 155 camera (1280_720 pixel resolution), clear images of the red light runner were obtained in typically 300 _ 230 pixel colour images which can easily identify a vehicle. These _ 24 Kbyte images are rapidly transmitted to a monitor post which can capture a short video of the runner.

False detections from low moving and small objects and noise were readily eliminated. Currently the system is being tested using IP links over the cell-phone network, which may prove satisfactory (and considerably cheaper!) in the long run: we note that a red light runner travelling at 60 km/hour needs 30 s to reach a monitoring station 500m down the road and a communications latency of much less than that is readily achieved. A frame rate as low as 10 fps requires a bandwidth of _ 0:25 MB/s to capture 30 frames of a red light runner at 60 km/hour: so a clear picture can still be obtained if many frames are dropped. There is also considerable potential to use higher resolution images but seemingly no need to increase frame rates.

We observed that automatic number plate recognition (as provided in the Smart Vision Technology system[11]) would require higher resolution and also restrict position of the camera to be almost directly behind the moving vehicle, but there are only weak constraints of the current system: it can be rapidly set up and only needs a clear view of the intersection and a controlling traffic light. We have tested it successfully from several view-points in different intersections.

Conclusions

This work was designed to develop a simple and robust system that was suited to Thai conditions and procedures. It is characterized by a flexible fast setup and thus can be readily redeployed to a new location. Rapid movement may be a key factor in the electiveness of this system: fixed red light camera locations are widely publicized in several countries, mitigating their electiveness, but the wide availability of rapidly deployed systems may substantially enhance electiveness. Tests at several intersections with different camera capabilities have suggested that the system has significant potential to detect traffic light violations in less than ideal conditions with simple set-up procedures and contribute to the serious problems referred to in the introduction that currently exist on all Thai roads. We thus see strong justification for further work to improve its robustness and reliability.

Future work

Robust estimation of the object shape and size from optical flow data needs further study. Further tests in a variety of weakly controlled environments, e.g. partially visible traffic lights, and situations where several competing traffic flows can be observed. Although the system is designed to provide traffic light violations to a human operator and therefore occasional failures are tolerable, confidence and effectiveness of the systems will be improved if its correct behavior is known - and approaches 100%. Statistical analysis of detection accuracy is also required: we have not yet investigated situations where several vehicles run the red light at the same time.

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