

Intelligent Traffic Lights

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Abstract

Traffic signal systems have been employed since the early twentieth century. Since then, many different signal systems have been implemented to minimize the waiting time and most importantly deadly accidents at dangerous road intersections, streets on which schools are located and bad curves. Optimizing the traffic systems in real-time based on the vehicle flow and adapting accordingly is a challenging problem; mainly because as the size of the road increases there is a continuous increase of traffic congestion. This in-turn increases the total travel time and ultimately cost of travel. This project aims to address the issue and implement a method which can effectively reduce travel time, and thus, the cost of travel.

Introduction

The current state of traffic signal ecosystem comprises of variety of different control systems ranging from clockwork mechanism to computerized control that self-adjust to minimize delay to people using the road. This project falls under the category of computerized control. With the

advancement in computer vision the computerized control can be given the ability to see and analyze traffic to self-adjust based on the traffic at a particular signal. When waiting for a traffic light, the driver loses time and the car uses fuel. Hence, reducing waiting times can save society billions of dollars annually. Here is small fact to support the statement, based on the review and research, if travel time is reduced by 30-40% then the travel costs reduces by 15-20%. This is for one vehicle, so collectively 253 million cars and trucks on U.S. roads could easily save billions of dollars.¹

Local time based signal controllers are among the most fundamental traffic signal system component. This often results in delay at red lights, when we have to wait while no one is using the green. Traffic signal control is an important practical problem. A recent study in the USA indicates that travel delays due to traffic congestion caused drivers to waste more than 3 billion gallons of fuel and kept travelers stuck in their cars for nearly 7 billion extra hours – 42 hours per

¹ <http://www.latimes.com/business/autos/la-fi-hy-ihs-automotive-average-age-car-20140609-story.html>

rush-hour commuter. The total nationwide wasted money amounts to \$160 billion, or \$960 per commuter.² Moreover, since this wasted fuel and time leads directly to the percentage of time drivers spend in traffic; there are additional negative impacts on environmental conditions. The problem is so bad that most intensive exposure to air pollution happens at traffic junctions. It is mainly due to the 'stop and go' nature of the traffic flow. This severely affects the health of the people which may also lead to major respiratory problems. With the invention of computers, traffic lights started to become computerized. We all remember those days when a man stands at the center of a junction and controlling traffic at that junction. Since humans have the capability of looking and understanding the traffic issue this was probably the best implementation to control traffic. But, Over time computers improved, and the traffic lights subsequently improved, and they could now monitor traffic and change lights accordingly. Based on the software, the traffic of a city could now be predicted and accordingly controlled.

But the computerized approach still does not provide the human power of looking at the traffic, analyzing and acting accordingly. Our project aims to provide a simple approach to resolve unnecessary waiting time at traffic signal by providing vision to traffic

system and an algorithm that can effectively control traffic.

Related Work

While there has been a lot of work in the areas of vehicle detection using computer vision techniques, successful implementations of these algorithms in real time problems like traffic control, speeding detection etc. is still very limited. The subsection provides a survey of the literature related to traffic light systems.

➤ Queue traffic light model ³

The queue traffic light model was developed in traffic engineering studies. Vehicles arrive at an intersection controlled by a traffic light and form a queue. Many researchers evaluated the queue lengths in each lane using different techniques depending on street width and the number of vehicles that are expected at a given time of day.

➤ Knowledge based traffic light models ⁴

Knowledge based systems are artificial intelligent tools that work in a narrow domain to provide intelligent decisions with justification. For example, Findler and coworkers (1997) described a

² <https://mobility.tamu.edu/ums/media-information/press-release/>

³ Fathy, M. and M. Y. Siyal. 1995. "Real-time image processing approach to measure traffic queue parameters." Vision, Image and Signal Processing, IEE Proceedings - 142(5):297-303

⁴ Findler, Nicholas V., Sudeep Surender, Ziya Ma and Serban Catrava. 1997. "Distributed intelligent control of street and highway ramp traffic signals." Engineering Applications of Artificial Intelligence 10(3):281- 292.

distributed, knowledge-based system for real-time and traffic-adaptive control of traffic signals. The first of a two-stage learning process optimizes the control of steady-state traffic at a single intersection and over a network of streets. The second stage of learning deals with predictive/reactive control in responding to sudden changes in traffic patterns

➤ Traffic light models using an extension neural network (ENN)⁵

The extension neural network (ENN) consists of extension theory and a neural network that uses a modified extension distance (ED) to measure the similarity between data and a cluster center. ENN is another traffic light control system developed to deal with object recognition in outdoor environments. Kuie et al. (2008) and chao et al. (2009) have presented an intelligent traffic light control method based on extension theory for crossroads. First, the number of passing vehicles and maximum passing time of one vehicle within the green light time period are measured in the main-line and sub-line of a selected crossroad.

⁵ Kuei-Hsiang, Chao, Lee Ren-Hao and Yen Kun-Lung. 2008. "An intelligent traffic light control method based on extension theory for crossroads." In Machine Learning and Cybernetics, 2008 International Conference on.

➤ Vision traffic light models⁶

Video sensors have become particularly important in traffic applications, mainly due to their fast response and easy installation, operation and maintenance. They also have the ability to monitor wide areas. Serrano et al. (2005) designed, constructed and tested an artificial-vision controlled traffic-light prototype to rule and regulate intersections. Methods, algorithms and automations were created to provide analysis of images and decision making in real time.

On exploration, we've come across vehicle detection using Haar Cascades, Background Subtraction (BGS) etc. This project explores the potential of automating traffic control by building an algorithm using the aforementioned methods.

Traffic signal control algorithm

The control problem is at a single intersection and the objective is to make the best local decisions possible, given the information that is locally available. The adaptive methods for optimization, based on dynamic programming, have been used for controlling a single intersection.⁷

⁶ Serrano, Ángel, Cristina Conde, Licesio Rodríguez-Aragón, Raquel Montes and Enrique Cabello. 2005. "Computer Vision Application: Real Time Smart Traffic Light." In Computer Aided Systems Theory – EUROCAST 2005.

⁷ S. G. Shelby. Single-intersection evaluation of real-time adaptive traffic signal control algorithms.

Implementation

Our algorithm involves two high-level steps; detecting the traffic flow in both the lanes, switching the signal green/red based on the inflow of traffic in both directions. For traffic detection in each lane, two different approaches were tried out. These are

1) Using Haar-cascade classifier

Haar-cascade classifier can act as effective tools for object detection.⁸ A cascade function is trained (supervised) on a lot of images, containing positive and negative instances of the object. It is then used to detect the object in new images. In our case, vehicles are the objects based on which the cascade is trained. Training a cascade requires a lot of pre-labeled data. Also, there are a lot of vehicle-based trained cascades available online. We've used the available trained classifier for vehicle detection.

2) Using Background Subtraction

Background subtraction is a widely used technique in vehicle detection.⁹ This identifies the static background (in our case,

road, lanes etc.) to detect the moving/non-static objects (vehicles). This method is more generic and can be applied to varied scenarios.

Once the vehicle detection is live, the inflow of traffic in both directions is recorded. We pick a block of each lane near the intersection to observe the. A 'patience' is assigned to each of the lanes indicating the flow of traffic. For every frame without vehicles, patience is incremented by 1. It is reset to zero every time there is a vehicle detected. That is, zero patience indicates inflow, while high patience indicates no inflow. Therefore, patience keeps increasing when there are no vehicles coming in. We set a threshold to the patience (for example, let patience = 150 frames; this corresponds to 12.5 seconds considering 12 frames per second). If the green lane patience threshold is overtaken while the red lane patience is zero, green and red are switched, thus avoiding traffic congestion. If the patience on each direction is 0 (traffic in both lanes), the signal switch is by the default switch time.

Results

The experimental results observed with Haar-cascade and Background Subtraction is compared. While Background subtraction has 100% accuracy of detecting vehicles as foreground, there is a lot of noise being detected from the video (figure 2).

Transportation Research Record, 1867:183–192, 2004. <https://doi.org/10.3141/1867-21>

⁸

<https://www.cs.cmu.edu/~efros/courses/LBMV07/Papers/viola-cvpr-01.pdf>

⁹

https://docs.opencv.org/3.2.0/d1/dc5/tutorial_background_subtraction.html

The detected noise interferes with the patience calculation. In the case of Haar-classifier, the detection is more accurate with our video as there is no noise to take care of. Here the vehicle detection is 100% but there are a few cases of false positives on some lane videos. So we compare the accuracy of each approach using the false and true positives of each approach.

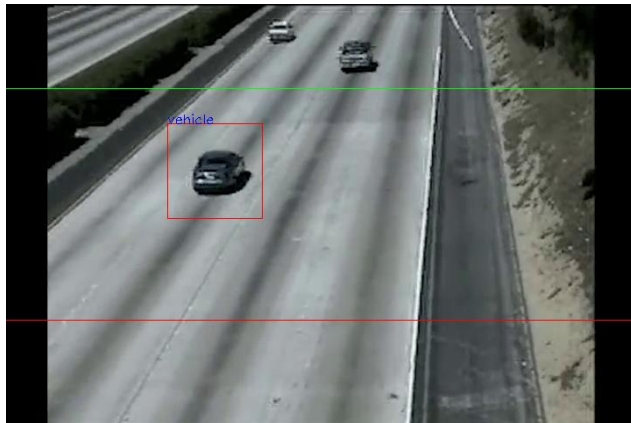


Figure 1: Vehicle detection using Haar-cascades



Figure 2: vehicle detection by background subtraction

| Total vehicles = 70 | Haar-cascade | Background Subtraction |
|---------------------|--------------|------------------------|
| False positives | 9 | 17 |
| True positives | 70 | 70 |

Conclusions & Future Work

With the advancement in machine learning and neural networks, Convolutional Neural Networks can be used to improve the accuracy. Also, we have noise in background subtraction output, different image noise reduction techniques learnt in class can be used to extract clear image.

Since, we now have a POC on traffic light system a future road map would be of implementing and analyzing the system evaluation on live feed and improve the system. As we have cameras installed at every intersection, it would be relatively easy to implement our system. With this implementation we can then widen our application domain to detect speeding vehicles; number plate detection for automated tolls and traffic rules violation ticket. Given the scope of computer vision domain, there are many other problems that can be solved with vision machines. Improving traffic light systems has huge economic value via reducing wastage of fuel due to unnecessary waiting times at intersections and eventually saving time and money.