A survey on acquiring vehicle traffic congestion information*

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1 ABSTRACT

With the number of vehicles growing rapidly in the world. A need for a form of congestion or traffic control is formed. This paper reviews some literature in the space of traffic control, vehicle communication, and various different methods of achieving them. I provide a survey on the recent works within this sector and compare and contrast the benefits as well as the costs of the different methods. I discuss and explain the various different methods of attaining information about the number of vehicles on the road, as well as an algorithm that hopes to avoid congestion all together.

2 INTRODUCTION

A study by the Maryland Department of Transportation showed a relationship between accident frequency and congestion on both freeways, through roads, and intersection density. Reducing the congestion on the road is good not only for the average commuter, but can lead to safer roads overall. Various different methods exist to collect, analyze, and utilize the data from an ongoing stream of vehicles. With a widely heterogenous vehicle deployment, with some cars on the road currently not even having air conditioner. Vehicle to vehicle congestion mitigation solutions may not be enough until the future. Existing technologies already exist that can help solve this issue by creating a smart intersection with sensing capabilities surpassing what we currently have.

In order to sense vehicles at an intersection we need one of two things, we either need a smart infrastructure, like an equipped stop light, or a smart vehicles on the road that communicate with each other or said infrastructure. There are several techniques to achieve this, but the most widely adopted an soon to be deployed potential solution is known as Dedicated Short Range Communication, or DSRC for short. This is a very hot topic research nowadays, with many papers focusing on collision avoidance utilizing this system. This system works in both freeways, roads, and intersections. However, there are many drawbacks.

Another potential traffic congestion mitigation solution comes in the form of a smart infrastructure that can sense and make decisions like triggering a green light. The way to collect information from the road can vary greatly as well. From solutions that implement an IR sensor to count the amount of traffic, to a more complicated computer vision based approach.

3 SMART INFRASTRUCTURE

The idea behind a smarter infrastructure is to use the existing infrastructure more efficiently without having to add more lanes. Current implementations of traffic lights work based on a hard-coded time slotting technique that is independent of the flow of traffic. This is often detrimental because congestion changes throughout the day. We need a system that manages the flow well through peak hours. A smarter traffic infrastructure is necessary to handle the increase of drivers on the road while maintaining efficient and adaptive use of the traffic lights currently in place. This leads us to need a lot of descriptive and thorough traffic information. I will explore two existing solutions, and discuss their benefits as well as their drawbacks. The two approaches in question are a simple IR tripwire sensor and a more complex vision based approach. Regardless of the technique used, they need to both confine to very strict criteria:

(1) Work well with the heterogeneity of road vehicles.

(2) Work well under different traffic conditions.

(3) Work well in different lighting and weather conditions.

(4) Work in real-time.

This smart vehicle/infrastructure problem can be broken down into several subpart. See figure 1, this figure shows a break down of a system life cycle within smart vehicle. However, this can be further generalized to incorporate the lifecycle of a system powering a smart infrastructure node like a traffic light. The base of the solution has to be built on detecting the actual vehicles, After this, we can get more useful information like position and other kinematic information. With this information, we adjust the behavior of the traffic signal.

3.1 IR Tripwire Approach

In this simple trip-wire method. A trip-wire is canonically a wire or laser that is placed perpendicular to any path, anything that passes through the path will then trip the wire and set something off. For vehicles, you need something that is able to let things pass through unobtrusively, is able to handle multiple cars, and will not be a potential distraction. In order to adapt this method for the streets, infrared technology is used. This works by using a an IR sensor, and an IR diode in unison. Infrared sensors are normally used to measure heat, or infrared radiation which is invisible to the human eye. However, you can also use a laser diode to emit this radiation which is then read by the sensor unless something blocks it's path. Its invisibility makes it perfect for this application. IR transmitters and sensors are employed on opposite sides of the road right before a traffic signal. When a vehicle passes through, it trips the IR sensor and a counter is incremented. The counter information for all of the crossroads in the intersection is aggregated and analyzed in order to dynamically adjust the green light delays. This IR system in question also has the added ability for emergency vehicles to send "warning" signals to the receiver. This then triggers a sequence of traffic lights to provide a special and speedy route.

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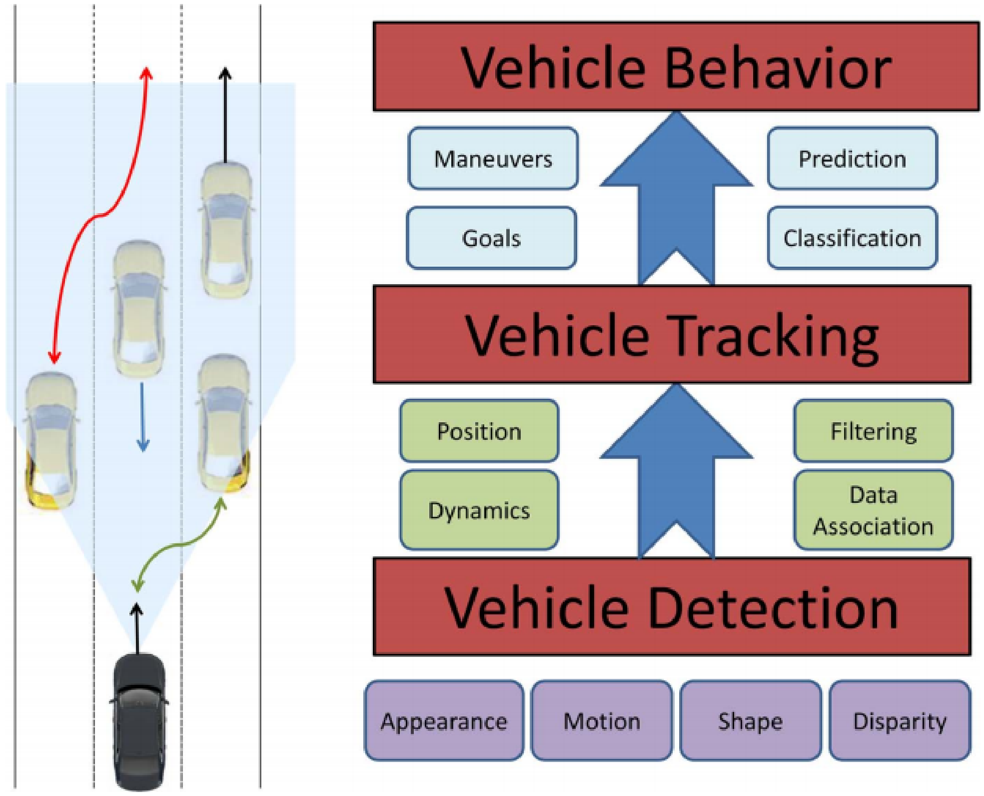

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Figure 1: This figure is taken from an academic paper that surveys computer vision usage in smart vehicles. For smart intersections, we are focused primarily on the bottom two categories: Vehicle tracking and detection.

This method works well with all the criteria above. For one, since the basis for the readings are just trips of the IR sensor, it can handle any road vehicle regardless of the shape. One issue might be small motorcycles with lots of holes in the frame. Traffic conditions are irrelevant because the count inherently handles the traffic density by a simple counter. Although, IR light can be affected by fog or rain, the distances are small enough, 30 ft for a road, where this is negligible for normal roads. Unfortunately, this can be an issue for larger roads with lots more lanes; since the basis of this work is congestion mitigation, larger roads are often the issue. So I feel like the assumption that IR is not affected for the purposes of this experiment are not justified. This system is also real-time, since the collection portion is simply increasing a counter that can then be sent off at a moments notice.

Each smart stop light has to be be equipped with a microcontroller pair, and the sensors. For example, one possible set up could be as follows; A PIC 16F877A microcontroller acting as a traffic master controller, which is responsible for changing the lights and receiving the information. Then it another PIC 16F877A microcontroller is used as a portable device reading and transmitting the information from the IR sensors. [3] These type of systems keep the cost down by using common off the shelf components and a simple idea. Some research even add a bit of complexity when they allow for important or emergency vehicles to have a special control over the the intersections.

While I see the assumptions made by using this type of system as valid under normal operation conditions. I believe the trade off of a low cost, doesn't justify using such a rudimentary technique. I see three main issues with this design. one being about it's robustness, another about it's potential incompatibility with newer cars and another being a potential security flaw with the emergency vehicle mode.

If you see figure number 2, the proposed design would use only one IR setup per road. Normally roads are two-way, meaning that they are a lot wider than one way roads. Overlooking the fact that roads are normally two-way, let's assume each direction is equipped with an IR sensor and emitter pair. You lose a lot of useful information when trying to determine congestion. You have no idea if the car in question is going to turn (where it might not add to the congested load of the intersection), or stop at the light. This lost information might lead to a lot of false positives at lights where it's

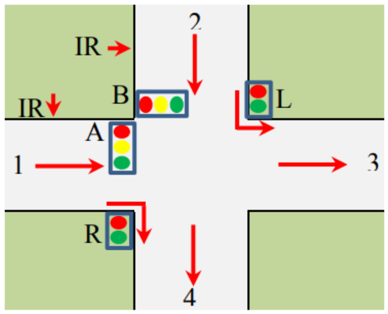

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Figure 2: This figure is taken from an academic paper that wishes to solve traffic congestion with an IR approach. This is a typical set up if the intersection is a cross of two one-way road. This can be generalized further to larger two-way roads if you use double the sensors and receivers.

more popular to turn than to continue straight.

Newer vehicles now come equipped with an increasing number of sensors, specifically cameras littering the outside. If you have ever pointed a remote control at your own phone camera you notice something interesting, they IR blasted out of your remote is picked up easily by your phone camera! This is because IR is easily read by normal cameras, they can see further into the infrared spectrum than our eyes. With this system, there will constantly be a huge stream of IR being blasted across the road to the receiver on the other side. This might cause non-deterministic behavior on cars equipped with with systems that dynamically brake, or actively avoid collisions. There was been a lot of work in recent years to determine just how many pixels need to be changed in order to fool a smart vehicle into misreading the road or traffic signs and it doesn't take much! This system as it stands would cause a lot noise in the camera as it passes through the beam.

For the paper being surveyed specifically, I view their decision to add a special mode for emergency vehicles as a security hole. The implementations boils down to a portable device that has two buttons, one to switch the signal into a special mode that alters the traffic flow in the emergency vehicles favor, and one to switch it back to normal mode. If the emergency vehicle fails to switch it back once it has cleared the signal, it has an automatic timer that switches it back to normal mode after four minutes. I see four minutes as a long timer. This would mean that any potential cross traffic would have to wait for four minutes in the case the special mode is inplace for other lanes. Regardless of this, it opens up a potential avenue of abuse. A potential attacker can spoof the same signal from the device and cause great levels of congestion, or game the system so he never has to stop at stop lights. If congestion is mitigated well, I see no need for a special emergency vehicle mode, especially since they already have sirens and lights to let other drivers know to move to the shoulder and let them pass.

3.2 Vision Based Approach

Most comercial systems that use video image processing currently work based on the trip-wire approach. As discussed above, this is a simple solution that only detects a vehicle passing. A selected region of the frame is specified from the beginning and the system just listens for intensity changes within that region. Similar to the IR tripwire approach, you have no idea how many vehicles pass if they overlap, and it does absolutely no tracking. One solution is the use of a camera sensor with complicated computer vision algorithms to obtain the vehicle flow, velocity, trajectories, and position. For a good vehicles video processing system, it needs to meet the criteria stated above, as well as:

(5) Automatic vehicle-background segmentation, so that each vehicle is independently known.

The system in question needs to automatically distinguish between the vehicles and that background. It also needs to differentiate between all the different cars on the road. This is a difficult task because the vehicles are only stopped for a very short time, so it needs to quickly identify the vehicle(s) on the road. There is difficulty when creating a system that can detect and segment car frames. this is because vehicles come in all different shapes and sizes. You need to be able to count not only civilian vehicles, but also busses, motorcycles, large hauling trucks, etc. On caveat of a smart infrastructure, is that it experience largely different traffic loads. From high congestion, to low traffic density. The system needs to be adaptable to each scenario and make specialized decisions. Since this system is placed outside, it is susceptible to all sorts of different lighting conditions. It needs to work as well at night, as it does during the day. Weather also affects visibility so regardless of the weather, the system needs to be robust.

One of the most robust approaches to achieve all five goals using a combination of image reasoning with a special corner tracking algorithm. These systems typically region off the image via the the different lanes. As you can see in figure 4. This is done in order to have a good context for the flow of each lane and not lose any information about vehicles wishing to turn either left or right. This allows for a better precision when tuning the traffic light delay. See figure 3. The system then uses some corner or feature detecting algorithm, like Harris or Shi-Tomasi to find good features to track. These features are then clustered together to isolate the features for each specific car. After, these clusters can be followed and a flow is then created for each independent vehicle.

What is novel about this approach is that instead of tracking an entire vehicle image, it simply tracks points on the vehicle. This allows for a more robust tracking overall since it's not hindered by low light. In the case of low-light, the tracking points become the car headlights and the algorithm works as expected.

4 CONCLUSION

In this paper I provided on two techniques for acquiring knowldege about vehicles in a traffic congested environment. The two main approaches are a trip-wire approach and a vehicle tracking approach.

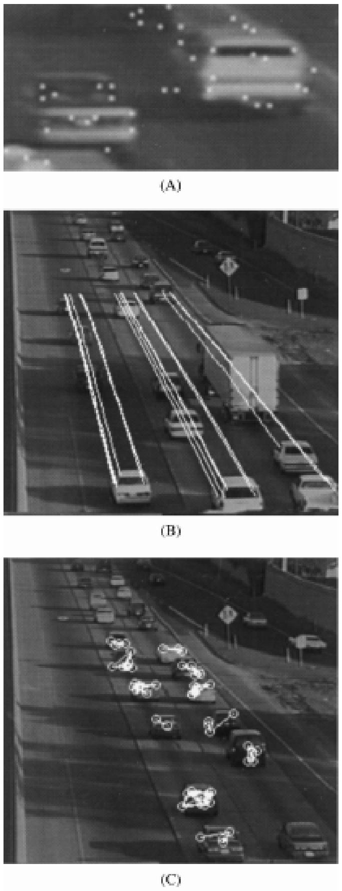

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Figure 3: This figure is taken from an academic paper that wishes to solve traffic congestion with computer vision approach. A) Vehicle tracking points identified. B) Vehicle tracking point's flow through time. C) Clustered vehicle tracking points.

While both have their benefits, the tracking based approach provides a more robust method of collecting this information and also outputs a richer set of kinematic data points for each vehicle. This a finer granularity in dynamically changing the stop light delay time, either based on how many vehicles are present or how fast a group of vehicles are approaching the stop. This will remain to be a hot research topic in recent years due to its ability to be onboard the vehicle. This brings about all sorts of processing and real-time issues not discussed in this paper. The future for vehicle tracking is barely in its infancy but both topics discussed remain relevant even with new and richer sensor types like lidar and RGBD (red, blue, green, depth) cameras.

REFERENCES

[1] Bilal Bhazal, Khaled Elkhatib, Khaled Chahine, Mohamad Kherfan. *"Smart Traffic Light Control System"*.

[2] Benjamin Coifmana, David Beymer, Philip McLauchlanb, Jitendra Malikb *"A real-time computer vision system for vehicle tracking and traffic surveillance"*

[3] Sayanan Sivaraman, Member, IEEE, and Mohan Manubhai Trivedi, Fellow, IEEE *"Looking at Vehicles on the Road: A Survey of Vision-Based Vehicle Detection, Tracking, and Behavior Analysis"*

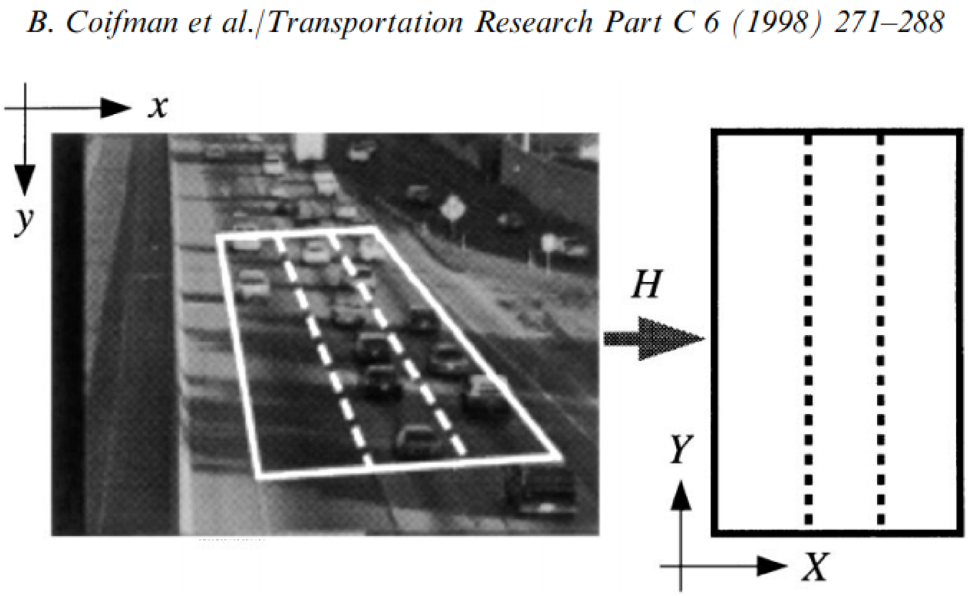

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Figure 4: This figure is taken from an academic paper that wishes to solve traffic congestion with computer vision approach.