A Comparative Study of Sensors for Road Traffic Density Measurement

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Abstract— Sensors plays a vital role for measurement of traffic density on road. To acquire the traffic data from road various sensor were used. Different sensors have their own advantages and limitation in terms of accuracy in measurement. However a sensor varies from parameter to parameter i.e range, location of installation, power consumption, number of scanned lanes, features etc. This paper describes about the conventional sensors that were used for traffic density measurement in automatic traffic control system. Also the comparison between different sensors has been discussed in this paper.

Key words: IR sensor, ultrasonic sensor, radar, microwave detector, pressure tubes

I. Introduction

Researchers now are so much interested in automatic real-time traffic congestion estimation tool as it is the most significant factor on which intelligent transportation systems are based. Some of the researchers have focused in their work on traffic flow estimation. It is measured as the rate at which vehicles pass a fixed point (e.g. vehicles per minute). They used spot sensors such as loop detectors and pneumatic sensors to quantify the traffic flow [1]. However, the sensors are very expensive and need a lot of maintenance especially in developing countries like Egypt because of the road ground de-formations. In addition, metal barriers near the road might prevent effective detection using radar sensors [2]. It is also found that traffic congestion also occurred while using the electronic sensors for controlling the traffic. In contrast, video based systems are much better compared to all other techniques as they provide more traffic information and they are much more scalable with the progress in image progressing techniques [3]. This is the main reason for the motivation to develop vision based tool for traffic light control in this work.

II. Related work

In recent years, traffic flow or traffic density estimation, has attracted the attention of many researchers. The value of traffic density measures only the ratio between the density of the vehicles and the total density of the road. So based on this measure, the traffic control system will compare between different roads in the intersection to take the decision for the traffic light and the time interval given. However, most of the previous vision based monitoring systems suffered from lack of robustness on dealing with continuously changing environment [4] such as lighting conditions, weather conditions and unattended vehicles. All these mentioned factors considerably affect the traffic density estimation. Changes in lightening conditions and weather conditions have been tackled in many of the previous approaches [5] and they are going to be considered also in our proposed approach, but the problem that has never been addressed before and has a significant effect on the traffic pace is the stationary vehicles, specially the unattended ones. The problem with the traffic density measurement is that the traffic density of a road with stationary or unattended vehicles is the same as the traffic density of a road with no stationary vehicles. Traffic flow counts the number of vehicles that passes through the frame during a certain time interval. However, it may give an empty road a higher priority than a congested road, because fewer vehicles are passing though the given point in that empty road. Therefore, we will concentrate on the detection of the delayed and unattended vehicles in the proposed approach for computing more informative metric about the traffic congestion in order to have more effective way of traffic light control. This metric is very similar to the traffic density, but with taking the traffic flow into consideration. So it can be considered as a combination of both traffic density and traffic flow.

III. Conventional sensors

The Conventional automatic traffic light controllers were used the following sensors:

A. *IR Sensor:*

Infrared sensor detect energy from two sources: (1) energy emitted from vehicles, road surfaces, and other objects in their field of view and (2) energy emitted by the atmosphere and reflected by vehicles, road surfaces, or other objects into the sensor aperture. The energy captured by passive infrared sensors is focused by an optical system onto an infrared-sensitive material mounted at the focal plane of the optics. Real-time signal processing is used to analyze the signals for the presence of a vehicle. The sensors are mounted overhead to view approaching or departing traffic. They can also be mounted in a side-looking configuration. Infrared sensors are used for signal control; volume, speed, and class measurement; detection of pedestrians in crosswalks; and transmission of traffic information to motorists

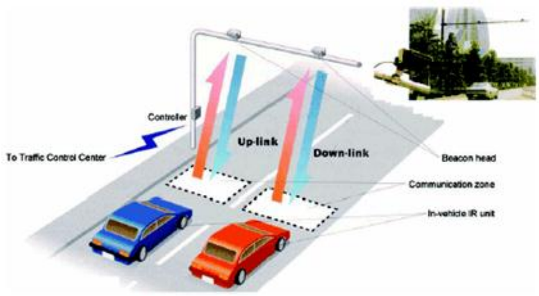

Fig. 1: IR sensors for Traffic Control System

There are two types of infrared (IR) detectors; these are the active and passive type detectors. Active infrared sensors operate by transmitting energy from either a light emitting diode (LED) or a laser diode. A passive infrared system detects energy emitted by objects in the field of view and may use signal-processing algorithms to extract the desired information. All objects emit some form of energy, which is in the form of heat or thermal radiation, this radiation most often falls in the infrared spectrum. This radiation cannot be seen by the naked eye, but can be detected by an infrared sensor that accepts and interprets it. In some infrared sensor like motion detectors, radiation enters the front and reaches the sensor itself at the centre of the device. This can be a system consisting of one or more individual sensors, each one being made from pyroelectric materials, these materials mat be natural or manmade. These are materials that generate an electrical voltage when heated or cooled.An experimental infrared optical system has been designed to detect and monitor vehicular road traffic. The principle of an infrared vehicle sensor is: the thermopile element is used as a sensor which detects the temperature of the object situated within a sensing area. This element generates thermo-electromotive force which is dependent on the temperature [6]. The setup of sensor pair across road in our system uses 802.15.4 radios which have a spread propagation model, instead of ray propagation model of infrared. This makes our technique robust to noise and thus suitable for disorderly road conditions.

B. Ultrasonic Sensor:

Frequencies above 20 kHz are considered to be ultrasonic. The speed of ultrasonic waves varies with air temperature and can be calculated as follows:

Ultrasonic speed = 331.5 m/s + (0.61 × temperature)

The dissemination angle of an ultrasonic sensor depends on the ultrasonic frequency. As illustrated in Figure 2.10, for instance, the dissemination angle θ increases as the ultrasonic frequency decreases. Figure shows. Mount positions of an ultrasonic sensor. (a) Overhead mount; (b) top side mount: (c) side mount. These characteristics of ultrasonic waves must be considered when designing vehicle detection systems. The variation of ultrasonic speed with air temperature influences the detection interval of an ultrasonic sensor, and the angle between the sensor and detection object influences its installation position.

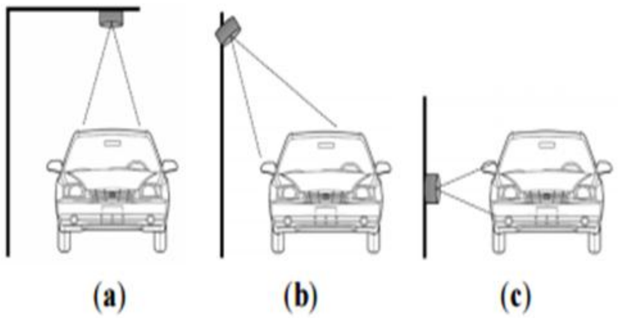

Fig. 2. Ultrasonic Sensors for Traffic Control System

C. Radar:

For accurately measuring vehicle speed. Doppler Effect is well-known phenomenon in physics which enables detection moving at a high speed. When a moving object approaches or recedes from the source of signals, the frequency of signal received back from moving object will be different from the frequency signal emitted by source object.

D. Microwave detector:

These are usually mounted on a bridge or gantry such that they point vertically down over a lane of traffic. The device emits microwaves which are reflected from the road surface and bounced back towards the sensor. A vehicle passing under the sensor will cause interference to the reflected microwaves which enables the vehicle to be detected.

E. Pressure Tubes:

A rubber tube affixed to the road surface across the width of a lane of traffic forms the basis of this sensor. One end of the tube is closed and the other is connected to a pressure sensor. As each wheel of a vehicle runs over the tube it causes a pressure fluctuation inside the tube which is detected by the pressure sensor. Each pressure fluctuation represents one axle of a vehicle passing over the sensor. Tubes count the number of vehicle axles which pass a particular point on the road allowing vehicle count, vehicle length and class to be deduced as shown in fig. 3.

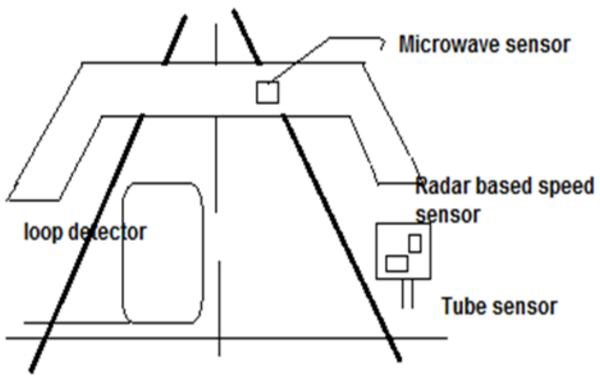

Fig. 3: Tube Detectors for Traffic Light Control System

F. Traffic loop detector:

These consist of a large coil of wire buried just below the road surface. As vehicles pass over the coil, the inductance of the coil changes and the vehicle can be detected. From this range of sensors, loop detectors are the most prominent and are used almost universally in traffic light systems. Although an individual detector merely signals the presence or absence of a vehicle, the outputs of several detectors may be collated to deduce information such as vehicle speed, length, flow rates and density. There are several disadvantages in using such sensors. As they are only capable of detecting vehicles directly overhead, a typical road junction requires the installation of many sensors in order to cover all entry/exit points. They are highly inflexible, once installed they may not be moved. Installation is costly and disruptive. Loop detectors are vulnerable to resurfacing or road works, in the USA 30% are out of operation at any one time. Computer vision based monitoring systems will overcome many of these disadvantages.

IV. MAJOR PROBLEMS ENCOUNTED IN CONVENTIONAL SENSORS

Following problems are identified in response for measurement of traffic density on road when sensors are installed on roads:

A. Problem 1:

If the position of vehicle does not come in alignment of infrared rays then IR/ultrasonic sensor would not give response.

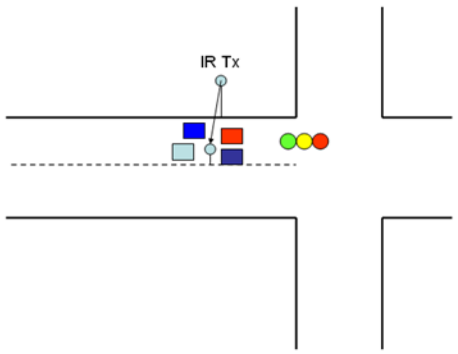

Fig. 4: IR Rays out of Range of Vehicle

B. Problem 2:

If the vehicle stops (due to technical/human problem) in the range of IR/ultrasonic rays then the response given by IR sensor would not be accurate.

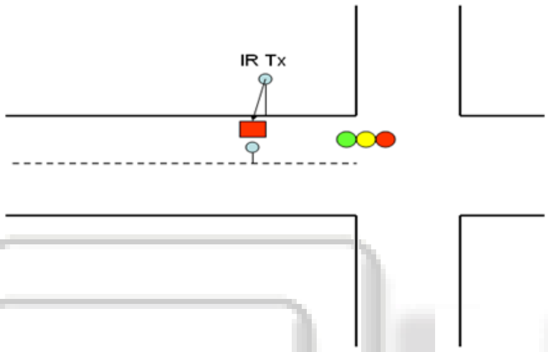

Fig. 5: Stationary Vehicles Due to Fault

C. Problem 3:

Conventional controller will take more time to decide the timing of signals as large time is taken by sensor(s) to collect the information regarding density then give that information to controller.

V. Comparison of Conventional Sensors

S.No	Sensor	Advantages	Limitations
1	IR sensor	Low cost, easy to install, low power consumption	Poor response, scan only 1 lane , low power consumption
2	Ultrasonic sensor	Good response, 2-4 lanes can be scanned with ultrasonic sensors,	Installation cost is high, speed varies with air pressure
3	Radar	Response is good for moving vehicle, not fit for stable vehicle	High cost and high power consumption
4	Microwave detector	Response is quite good	Consumes high power
5	Pressure tube	Response varies due to variation of weight of vehicle. Maximum 2 lanes can be covered by sensor unit.	Installation is costly and complex
6	Traffic loop detector	Response is quite good. More than 2 lanes can be covered by sensor unit	Complex in installation, installation cost is high

Table 1: Comparison Table of Sensors

VI. Conclusion and Future Scope

In real world application, it is very hard to implement the automatic traffic control system as there are so many parameters which disturb the response of traffic control system. After study of conventional sensors that were used in dynamic automatically traffic control system, it is found that traffic loop detector gives comparatively good response in terms of accuracy in measurement. In pressure tube, response varies due to variation of weight of vehicle. Maximum 2 lanes can be covered by sensor unit. Radar is very costly for this type of application.

These above limitation can be overcome with the help of vision sensors i.e camera. Information collected from road with the help of camera gives better response among all discussed sensors in this paper.

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