INFRARED-BASED SYSTEM FOR VEHICLE AXLE COUNTING AND CLASSIFICATION

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Abstract- This paper presents infrared-based system developed for vehicle axle counting on the basis of axle-wise vehicle direction detection at toll-ways and check-post. Many times vehicles at Toll-ways are waiting in queue for fare payment, partially moves vehicle in forward and reverse direction resulting mismatch of actual results with the automatic vehicle classification. Complete vehicle reverse and forward movement disturbs sequence of vehicle classes in database queue. The solution to this problem statement is to detect the vehicle direction on the basis of vehicle axle. The system consists of infrared transmitter and receiver paired sensor array that is mounted vertically and horizontal on toll-ways. Vehicle side profile is obtained on receiver side Infrared LED pulse is transmitted sequentially at counter time and captured at receiver sensor to generate an array pattern. Vehicle axle count and direction can be accomplished on basis of type of pattern generated by vehicle wheel movement.

Keyword- Axle counting, vehicle classification, side profile, infrared transmitter and receiver.

I. INTRODUCTION

Toll-ways is facing problem for number of actual vehicle axle counting done by toll collectors and automatic system is not satisfactory. Since maintaining the actual vehicle queue with pre-classification database queue is not accurate, when motorizes entered into toll lane is sometime found conjunction, so to find out another way motorized roll back and moves to the another lane where conjunction is less as compared to previous, these creates discrepancy for the pre classification automatic system. Solution for these is vehicle classification on basis of axle counting in combination with direction which can carried out in 4 cases: complete forward, partial forward, complete reverse and partial reverse. Classification is categorized at toll-ways such that car/jeep, lower class vehicle, truck/bus and multi axle vehicle. In this context, a variety of solution are been proposed exploring different technologies as wireless magnetic loop based, image processing [1-4], microwave radar or infrared and ultrasonic sensors [5]. User needs for particular scenario and classification conditions can require the use of a specific solution.

In this work we present an infrared-based system developed for vehicle axle counting and classification for toll-ways. In our system, infrared technique is used in transmitter (Tx) and receiver (Rx) paired array that is mounted vertically and horizontally as shown in “Fig. 1”, in which infrared pulse is transmitted at particular counter time and captured at receiver end within that particular counter time. When a vehicle approaches towards Tx and Rx tower raw data is formed as per blockage of the sensors for that particular timer, all similar pulse cycle collectively generate patterns of a axle which is helpful for vehicle axle counting. We show that by comparing with the collected axle pattern database vehicle axle counting and direction can be obtained. [1]

This paper is organized as follows: the system architecture is described in section II. Feature extractions of the system are shown in section III. Results of the field tests are in section IV. The conclusions in section V.

III. ELECTRONIC SECTION OF THE SYSTEM

In “Fig. 2” the system architecture of the vehicle axle counting and direction detection is shown. The proposed system consists of magnetic loop, infrared pulse driver, pulse capturing system, Tx and Rx synchronization and RS-485 driver.

Fig.1: System overview
Infrared-Based System for Vehicle Axle Counting And Classification

1. Magnetic loop:
   Magnetic loop, more precisely referred to as an induction-loop based. Induction-loop detectors sense the presence of a conductive metal by inducing electrical currents in the object. The induced current decreases the loop inductance, which is sensed by the inductive-loop electronics unit. The electronics unit interprets the decreased inductance as vehicle detection and sends an appropriate call to the controller. As shown on “Fig. 3” magnetic loop laid down on at the center of Tx and Rx tower having dimension of 2000 X 600 mm. A 45° crosscut is across the loop corners to reduce the chance of damaging of the loop cable at right angle corners. The Nominal slot depth of 30 mm to 50 mm and width 5 mm.

2. Transmitter
   Infrared LED emits light at peak wavelength of 940 nm emitting diode in GaAlAs/GaAs technology with angle of half intensity $\phi \pm 25^\circ$, high radiant power molded in a blue-gray plastic package resulting in an illumination area with diameter of 2.5m. Rise and fall time of 800nsec. “Fig. 5” shows 50% duty cycles train of pulse are generated by microcontroller with reference to receiver receipt able 38 kHz frequency. As shown in “Fig. 4” the synchronization signal is acknowledged by Tx controller, then it starts the driving pulse sequence. Driver is transistorized switching circuit which is capable to transmit the train of pulse at individual level. In similar fashion remaining infrared LED’s is pulse transmitted sequentially with certain time delay. Infrared LED’s is mounted in such a fashion that single LED pulse will target only five receiver sensors aligned in opposite direction to maintain 1 : 5 ratio.

3. Receiver
   The functional block diagram of the IR receiver modules can be seen in “Fig. 6”. The infrared signal generates an equivalent photo current in the photo PIN diode. A PIN diode and a preamplifier contain an IR filter. The demodulated output signal is directly connected to a microcontroller for decoding. It is optimized to suppress almost all spurious pulses from energy saving lamps like CFLs.

   The digital output signal has an active low polarity and consists of an envelope signal of the incoming optical pulse, without the carrier frequency. These sensors are directly connected to controller which is capable for reading the particular sensors output at that infrared LED firing sequence.

   As shown in “Fig. 7” controller collects all sensors output, validate on it and sends data via RS-485. Tx and Rx controller is synchronized so that transmitting pulse timing and pulse capturing timing should be matched. Synchronization is carried using RS-485 so that maximum distance can be covered between Rx and Tx tower at toll-ways.
IV. FEATURE EXTRACTIONS

Features using for axle counting and classification are vehicle detection, axle counting and vehicle classification.

A. Vehicle Detection

Vehicle detection is performed by magnetic loop. Since, the magnetic loop has limitation on computation and resources, only the earth magnetic field in z-axis is used for vehicle detection. In normal situation, earth magnetic field variation has very small change, however, when a vehicle is present, the magnetic field will be disturbed and results in noticeable large changes. If the magnitudes of earth magnetic field comparing to base line of both sensors are greater than the threshold $t_h$ for certain period of time $T$, it is considered as vehicle arrival. Otherwise, it is considered as noise. Let’s $z$ be z-axis magnetic time series observed by sensor. [2]

$$z_n = z\text{-axis magnetic field at time sample n},$$

$$b_i = \text{magnetic base line of sensor } i,$$

$$|z_n - b_i| \geq t_h \quad (1)$$

The vehicle departure is detected as same as the arrival except of the earth magnitudes to base line of the both sensors are less than the threshold $t_h$ for a certain period of time $T$. Otherwise, it considered that the vehicle still is present on the sensor.

In “Fig. 9” 20 milliseconds (ms) samples are collected is shown for determining presence of vehicle on induction loop. When vehicle arrived on magnetic loop low to high signal is sent to Rx controller and for vehicle departure from loop high to low is sent. [2]

$$|z_n - b_i| \geq t_h \quad (2)$$

![Vehicle Detection and Event Triggered Signal](image)

**Fig.9.** Vehicle detection and event triggered signal

B. Vehicle Axle Counting and Classification

Vehicle side profile is generated from two vertically mounted towers having 1:5 ratio between receiving and transmitting sensors, “Fig. 10” shows the sequential process set for generating side profile, which consists of transmitting pulse captured at certain timing and sensors data collection which is sent via RS485. Synchronization signal is reference time for both Tx and Rx circuit so that firing pulse and pulse capturing timing is matched.

“Fig. 11” shows sample frames sent via RS485 with start character 7B and end character 7D.

![Sample Frames](image)

**Fig.11.** Sample frames

Axle counting is done on the basis of wheel direction of moving vehicle. Complete vehicle direction detection can be done by checking the direction of each transit wheels passed through sensors. In this Tx and Rx infrared sensors are horizontally mounted with 4 sensors count having 1 : 1 ratio between Tx and Rx. On the basis of vehicle detection signal vehicle arrival is recognized and unknown objects filters out like movement of human near mounted system. On this acknowledgement vehicle axle counting is initiated.

As shown in “Fig. 12” assuming that vehicle wheel is arrived from forward direction 1st sensor is blocked while rest other 3 sensors are unblocked, similar fashion when same vehicle wheel approaches to 2nd sensor, 1st and 2nd sensors is blocked while rest of the sensors is unblocked, sequentially wheel blocks 1st, 2nd and 3rd sensors, while 4th unblocked, when these pattern is formed in consecutively way it can be concluded that vehicle axle is detected in forward direction.

As shown in “Fig. 13” assuming that vehicle wheel is arrived from reverse direction 4th sensor is blocked while rest other 3 sensors are unblocked, similar fashion when same vehicle wheel approaches to 3rd sensor, 4th and 3rd sensors is blocked while rest sensors is unblocked, sequentially wheel blocks 4th, 3rd and 2nd, while 1st unblocked, when these pattern is formed in consecutively way it can be concluded that vehicle axle is detected in reverse direction.

![Vehicle Axle in Forward Direction](image)

**Fig.12.** Vehicle axle in forward direction

![Vehicle Axle in Reverse Direction](image)

**Fig.13.** Vehicle axle in reverse direction
In “Fig. 14” side profile generator is shown which sequentially feeds received data in visual chart to create the graphical side profile of a vehicle and stored in database for comparison. In similar fashion jeep, LCV, Bus, truck and multi-axle vehicles profiles is stored in database for comparison. Figure shown is side profile of the car moving at the speed of 40 to 50 Km/h.

V. RESULTS OF THE FIELD TESTS

Field test were performed exploring different shapes and size of vehicles. The tests consist of the passage of vehicles, at constant speed, in the coverage area of the equipment. Vehicles profiles were optioned for each vehicle at speeds of 10 Km/h, 20 Km/h, 30 Km/h, 40 Km/h, and 50 Km/h, 60 Km/h. Vehicle detection is performed on the earth magnetic field used for vehicle detection. When a vehicle is present on magnetic loop which results in noticeable large changes in the magnitudes of earth magnetic field, comparing to the magnitude found greater or lesser than the threshold \( t_h \) for certain period of time, it is considered vehicle arrival and vehicle departure, these combination results to giving 100% vehicle counting accuracy. Wheel axle counting done on the basis of wheel direction of moving vehicle. Checking the direction of each transit wheels passed through sensors give results in two ways: complete forward and complete reverse with 95% to 98% accurate. The profile generated depends on number of sensor count mounted on Rx side that is delivering highly dense side profile of the vehicles. The classification done purely based on vehicles shape and height regardless of any fixed parameters. When vehicle arrival event triggered by vehicle detector, vehicle side profile capturing is initiated by system, system stops capturing when there is departure event is found from vehicle detector. Extracted side profile of vehicle is compared with the stacked database for further classification of the vehicle.

CONCLUSION

Low cost infrared based system for vehicle axle counting and classification has been presented. The beamed infrared light pattern generated. We have developed a side profile database for passengers of various types we have shown that on basis of database comparison classification can be done. An infrared-based vehicle classification system applied for other vehicle types such as car, bus, truck and multi axle truck is currently under evaluation.

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REFERENCES