A study of Vehicle Detection technologies for use in Car Park Space monitoring system

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AIM: This project involves study of several technologies that use different methods in vehicle detection giving an idea of its pros & cons, difference between each of them, cost effectiveness, efficiency & also reliability. The project also involves literature reviews on the present technologies being used along with survey on some of the car parks in operation. Further this project proposes an efficient design which is implemented & tested on hardware.

Keywords- Vehicle Detection Technologies, Car Park Space Monitoring

I. INTRODUCTION

The vehicles are detected using several types of sensors available in the market, whose primary function is detection of any change in physical phenomenon. Accordingly in the present scenario it’s the detection of the vehicle. This detection sensed by the sensor is transmitted to the data processing devices between which the data is converted into electrical signal by signal processing device. The processing device in here is nothing but any hardware devices which are capable of performing certain actions or processes on the data obtained e.g. the hardware which recognises any moment or locks down the target in video surveillance is regarded as the data processing device. These devices sometimes may also be an integral part of any sensor.

TYPES OF VEHICLE DETECTION TECHNOLOGIES & THEIR WORKING PRINCIPLE:

There are mainly two ways to place any sensors for detection one is IN-ROADWAY & other is OVER ROADWAYS. Embedding the sensors on the pavement or in the sub grade of the road or attaching it to the surface of the road is called as IN-ROADWAY Sensor. In the other type, the sensors are either placed above roadway or alongside of the roadway at some distance from the nearest traffic lane.

Some of the important surveillance technologies available commercially are listed below

- Pneumatic road tube
- Inductive loop
- Piezoelectric cable
- Magnetic sensor
- Video Image processor
- Microwave radar
- Laser radar
- Passive infrared
- Ultrasonic &
- Passive acoustic array

The sensors such as pneumatic road tubes, piezoelectric cable, inductive loop detector, magnetic sensors are some of examples of IN-ROADWAY sensor technology which need to be embedded or buried under the surface

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of the road to collect the required data. The sensors which are either mounted over a separate pole or any other platform i.e. above the ground level are considered to be OVER ROADWAY sensors like Video Imaging, passive infrared, Laser radar, Microwave radar etc.

**PNEUMATIC ROAD TUBE:**

In this type of system a hollow rubber is mounted on the surface of the road which is approximately 1cm in diameter. This tube is connected to a box at one end which contains a membrane with an electrical switch connected to it & the other end is a small opening to avoid reflection of the air wave. Whenever a vehicle passes or is stopped on the tube, it causes the air inside the tube to move which in turn causes the membrane to vibrate & this switch activates the electrical switch in the box. This engagement causes the system to get a count.

The main disadvantage in this system is that as the tubes are directly exposed on the road, the life of tube is very less as high risk of wearing due to the movement of the vehicles upon it is observed. The pressure box & electrical switch is susceptible to the pollution.

![Figure 1 Pneumatic road tube with the box (Fs.fed, n.d.)](image1)

**INDUCTIVE LOOP:**

A preformed or a saw-cut loop is used in this type of systems where loop is formed using a continuous wire which starts & ends from the same point & this connects to the extension cables which in turn connects any device which is intended to detect the vehicles. The whole device is buried under the road surface with the detector being installed somewhere out of road as it could be easy for maintenance. The power is provided to the loop which causing the magnetic field in the loop area, when a large metal body like vehicle is passes on it there is an increase in the resonant frequency which can be sensed. So in this way the detection of the vehicle can be done. Loop to be installed is as shown below.

![Figure 2 Loop detectors embedded on the road (The vehicle detection clearing house, 2007)](image2)
2.2.3 PIEZOELECTRIC CABLE:

Here a coax cable is used to monitor the presence or movement of the vehicle on the required area. A coax cable with the piezoelectric properties is used on the road surface to detect the pressure. When a vehicle is passed on the cable due to its weight deformation can be observed which causes the molecular structure change & this result in the change of the electrical charge. The change in electric charge is measured each time & it’s changed is regarded as the count of the vehicle. For the detection of the vehicle, the weight of the parked vehicle does the work of changing the molecular structure of the cable resulting in the small electrical charge, which could be used for the presence of the vehicle.

![Piezoelectric cable installation on road](Mtehelp.tech-metrocount)

2.2.4 MAGNETIC SENSORS:

In this type of system a magneto resistive sensor is used to detect an object where the magnetic field of the earth is taken as the bias field. When a ferromagnetic object is present, the systems magnetic field differs accordingly with respect to the bias field & this presence of the ferromagnetic object signifies the detection of the object which here is a vehicle. So in this type of detection the energy required is very less so very less energy to be emitted which decreases the energy consumption & electromagnetic interference as well. The parts in the vehicle such as axle, engine, gearbox, driveshaft etc which forms the ferromagnetic components play a major role in the deflection of the magnetic field lines & this deflection is detected by the magneto resistive sensor, which is made to trigger required signal if observed. A 2-D simulation was done to see the

![Simulation of the deformation of the earth's magnetic field by a car](Joerg wolff et al. N.d.)

2.2.5 VIDEO IMAGE PROCESSOR

In this type of system the operation is carried out by using cameras as sensors to collect the data about the parking lots available for the parking. Cameras are placed in different locations of the parking arena where the monitoring is required

These systems have cameras to detect the free space available. All video processing is performed on the base station, and results from object detection and tracking are assembled into symbolic data packets and transmitted back to the operator control workstation using a radio Ethernet connection (Scholar.google, n.d.). The main advantage in this type of systems is that, in case of any theft the recorded video can be used to find out the thief which could solve the problem with the safety of the car park.
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On the other hand using the video surveillance for the parking facilities needs huge initial investments as a part of system installation & also to its maintenance. The system software which runs the system is more complex compared with the regular sensor based systems as there will be need of the image processing requirement for the video being recorded.

Figure 5 Camera for Video Image processing (D. Gibson, Milton K P Mills, L A Klein 2007)

2.2.6 MICROWAVE RADAR:

There are two different types of microwave radars mainly used the first one works on the principle of Doppler Effect by emitting a continuous electromagnetic energy, which can only be used in finding the speed of the vehicle. This type of radar cannot be used to determine the stopped vehicle such as vehicles at the signal lights or the parking areas.

The second type of Microwave radar is the one which uses saw tooth continuous waveform for the transmission which is also known as frequency modulated continuous waveforms changes its frequency continuously with time. This type of radar is such that the stationary vehicles can be detected by calculating the distance between the detector & the vehicle, not only the stationary vehicle but this system can also be used to detect the speed of the vehicle by measuring the time taken by the vehicle to move between two marked points which represents the known distance for the radar.

Figure 6 Microwave Radar mounted as a Video camera on a pole near to traffic lane (D. Gibson, Milton K P Mills, L A Klein 2007)

2.2.7 PASSIVE INFRARED WITH ULTRASOUND SENSORS:

One of the other types of sensors used in common is the passive Infrared with ultrasound sensor which is capable of providing Vehicle count, passage of vehicle & also the presence of the vehicle. It uses combination of both infrared & Ultrasound to detect vehicles & its movement. This type of sensors is usually mounted on the pole nearest to the traffic lane focusing on the lane from its positioned place. The detection in Passive infrared is done by absorbing the energy which is emitted from any objects like road surface, vehicle & also from other objects but the element itself never emits the energy. When using Non imaging passive infrared sensors for the traffic management applications has one or several (usually less than five) are used to detect the energy omission from the objects which is available in the sensors premises. The detector used non-imaging sensors do generally have a large field view. The field view of the instantaneous values is equal to the angle, which are in the x-y plane & are subtended by a pixel. Objects within the scene cannot be further divided into sub- pixels or objects of it’s working with this device.
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Figure 7 Infrared-Ultrasound Sensor (The vehicle detection clearing house, 2007)

Below table compares the different technologies used with each other, their bandwidth limitations, and type of output obtained like detection, passage of any vehicles, counting etc.

<table>
<thead>
<tr>
<th>Sensor Technology</th>
<th>Output</th>
<th>Multiple Lane, Multiple Detection zone</th>
<th>Communication Bandwidth</th>
<th>Sensor Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>Speed</td>
<td>Occupancy</td>
<td>Classification</td>
</tr>
<tr>
<td>Pneumatic Road tubes</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Low to moderate</td>
</tr>
<tr>
<td>Inductive loops</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>Low to moderate</td>
</tr>
<tr>
<td>Piezoelectric cables</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td>Low to moderate</td>
</tr>
<tr>
<td>Magnetic Sensors</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Video Image Processor</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓</td>
<td>Low to high</td>
</tr>
<tr>
<td>Microwave Radar</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>moderate</td>
</tr>
<tr>
<td>Passive Infrared With ultrasound sensor</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓</td>
<td>Moderate to High (£3500-£17500)</td>
</tr>
</tbody>
</table>

Table 1 Traffic output data communication bandwidth & its cost comparison (adopted from Nmsu.edu, 2007)

**OPTICAL CHARACTER RECOGNITION SYSTEM**

Here the system uses the RFID technology to assist the drivers to park their vehicle in the parking area. The one need is that the cars coming to be parked needs to have a RFID card attached & these cards are read by the RFID reader when the car comes at the entrance of the parking arena. This read RFID card will be having a barcode which is recognised by the reading system & this system displays on the LCD screen attached on the special & accessible place of the parking area where the required information about the parking spaces will be provided for the individual drivers. This system just tells the drivers about the free spaces available in whole of the parking area but not the exact locations of it. The used RFID detector are mounted on the wall or with any other platform at the entrance & exit within 5-7 meters of the ticket issuing areas as to clearly read the barcode.
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This type of system is best suited for the indoor parking as to lessen the manpower. The system gives a 100% success rate as mentioned by the authors of the design.

THE WYSIWYAS CAR PARK NAVIGATION SYSTEM

This system is specifically designed to assist the drivers to park their vehicles on the empty space on the parking lot. Here the system used a new concept called WYSIWYAS (What You See Is What You Are Suggested) navigation system. This system was based on a special sequential investigation called M-CubITS (M-Sequence Multimodal Markers for Intelligent Transport Systems) which uses markers painted on the road within the parking area. The free space available in the parking lot is found in the database of the system, which in turn is fed to the database through ultrasonic or any other type of sensor accordingly. So, the free & occupied spaces in the parking lot is stored in the database, this information is used when a new driver drives in at the car park & asks for the free space to the parking database.

The query by any new driver is taken by the database & based on the spaces available in the area the data is sent back to queried system. Thus acquired data from the parking database is utilized by system on board to calculate the shortest distance to the free space. Then by using the images from the on board camera the system estimates the exact position of space with the help of M-CubITS. Now, with the help of markings on the road the exact location of the free space is calculated by board system, which is read through on-board camera. The marking on road is read accordingly to give direction for the exact location of available free space for the driver. This direction is displayed to the drivers through on board display unit. This system not only gives the direction but also instructs the drivers through the audio messages similar to that of the GPS systems used in car like TOMTOM.

CONCLUSION & FUTURE WORKS

Different types of vehicle detection have different advantage & disadvantage respectively. This chapter unfolds the technologies available & their pros & cons, its clear form this chapter that the system which has good stability doesn’t make a good choice in robustness for example considering pneumatic road tubes forms a good choice for vehicle count for most less quotes but its robustness is the least because of its direct exposure on the road. In the similar way video image processing is good reliable technology for vehicle detection, count, speed detection etc but it is one of the high priced technology & also is the most complex technology as it requires designing of image processing. In the similar way piezoelectric cable are robust & have long life but this technology requires road pavement cut in order for installation.

On the other hand inductive loop is most matured & understood technology with high trustable result but even this technology requires road pavement cut also the maintenance cost is high as it requires closure of the road it is installed in. Whereas passive infrared sensors have good performance under normal climate
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condition with lots of features like vehicle counts, distance measurements, speed detections etc but it comes at high cost & is not suitable if the climate is bad. Magnetic sensors are rigid, reliable & accurate but its cost is in medium range compared to induction loop, pneumatic road tubes which are low & video image processing & passive infrared sound sensor so comes at a moderate price.

From the survey it was revealed that magnetic sensor had upper hand advantages compared with other technologies few of them to be mentioned are:

- Moderate price
- Power consumption is less compared to piezoelectric cables & video image processing system.
- Installation cost is less if system is needed to be installed on existing car park system.
- Less affected to climatic conditions.
- More accurate & fast reflections to the vehicle movement.

Thus from the above conclusion & reviewing several literatures Magnetic sensor was chosen to be used as detection paradigm for my proposal of ‘Car Park Space Monitoring System’. Further on, a system using magnetic sensor will be designed & a proto-type of the same will be developed for further testing’s, which will be presented in other paper.

Reference


