Chapter 10

Non-Intrusive Technologies

10.1 Introduction

Non-intrusive technologies include video data collection, passive or active infrared detectors, microwave radar detectors, ultrasonic detectors, passive acoustic detectors, laser detectors and aerial photography. All these technologies represent emergent fields that are expanding rapidly with continuing advances in signal processing. At present time such technologies are used to provide supplemental information for selected locations or for specific applications (e.g., queue detection at traffic signals). Most non-intrusive systems are operationally and somewhat visually similar, consisting of small electronics unit mounted in a weatherproof housing placed in various locations, as shown in Fig. 10:1.

The first type of non-invasive detectors are roadside mast-mounted. The detector possesses a field-of-regard covering an oblique area upstream or downstream of the unit. There are also multiple zones of detection defined within the overall field of regard, or the overall zone of detection same as the field of regard, depending on the specific detector type and technology. Obscuration problems occur when high-sided vehicles screens lower vehicles from the detector or the field-of-view being too large, leading to detection of vehicles outside the desired lane. The second type of non-invasive detectors are mounted on gantries or bridge undersides, with field of regard directly below, or at a slight oblique to the unit. Finally, some units, such as open-path pollutant monitors are mounted road side at ground level, firing a beam across the road. Such units are subject to side-by-side masking and hence most suitable for only single lane, unidirectional flows.

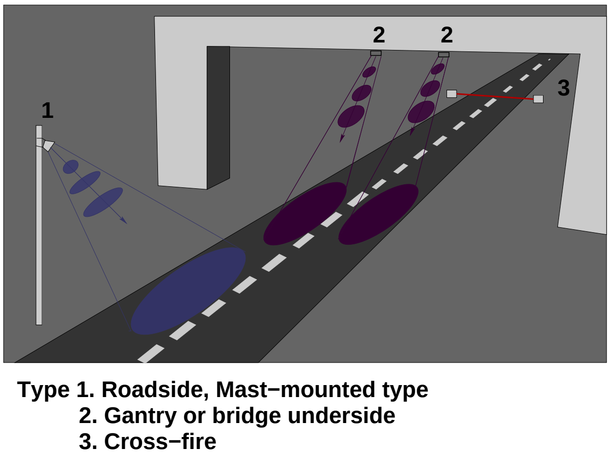

Figure 10:1: Typical non-intrusive technology configurations

10.2 Video image detection (VID)

The traffic parameters are collected by frame-by-frame analysis of video images captured by roadside cameras. The following parameters are collected: Depending on the processing methodology almost all traffic parameters are captured from video analysis. Simple video systems often collect flow volume and occupancy. More complex systems allow the extraction of further parameters.

Advantages
Possibility to capture all desired traffic information, including some parameters that are not readily obtainable using other types of detectors Possibility of a permanent visual record of the traffic flow that reviewed and analyzed by a human operator.

Disadvantages
VID systems are susceptible to obscure issues, as with other non-intrusive detectors. Performance of VID systems might be degraded in bad weather or low light conditions.

1. **Video Image Processor**
   A video image processor (VIP) system typically consists of one or more cameras, a microprocessor-based computer for digitizing and processing the imagery, and software for interpreting the images and converting them into traffic flow data.

2. **Principles of Operation**
   Video image processor systems detect vehicles by analyzing the imagery from a traffic scene to determine changes between successive frames. VIP system typically consists of

one or more cameras, a microprocessor-based computer for digitizing and processing the imagery, and software for interpreting the images and converting them into traffic flow data.

The algorithms are designed to remove gray level variations in the image background caused by weather conditions, shadows, and daytime or night time artifacts and retain objects identified as automobiles, trucks, motorcycles, and bicycles. Traffic flow parameters are calculated by analyzing successive video frames. Color imagery can also be exploited to obtain traffic flow data. However, somewhat reduced dynamic range and sensitivity have so far inhibited this approach. Traffic flow parameters are calculated by analyzing successive video frames. Color imagery can also be exploited to obtain traffic flow data.

Three different types of VIP systems are available; they are tripline, closed-loop tracking, and data association tracking. Fig. 10:2 shows tripline systems which operate by allowing the user to define a limited number of detection zones in the field of view of the video camera. When a vehicle crosses one of these zones, it is identified by noting changes in the pixels caused by the vehicle relative to roadway in the absence of a vehicle. Surface-based and grid-based analyses are utilized to detect vehicles in tripline VIPs. Tripline systems estimate vehicle speed by measuring the time it takes for an identified vehicle to travel a detection zone of known length. The speed is found as the length divided by the travel time.

Closed-loop tracking systems are an extension of the tripline approach that permits vehicle detection along larger roadway sections. The closed-loop systems track vehicles continuously through the field of view of camera. Multiple detections of the vehicle along a track are used to validate the detection. These tracking systems provide additional traffic flow data such as lane-to-lane vehicle movements. These have the potential to transmit information to roadside displays and radios to alert drivers to erratic behavior that can lead to an incident. Data association tracking systems identify and track a particular vehicle or groups of vehicles as they pass through the field of view of camera. The computer identifies vehicles by searching for unique connected areas of pixels. These areas are then tracked frame-to-frame to produce tracking data for the selected vehicle or vehicle groups.

3. **System Design**

Figure 10:2: Video Image processing by tripline detector system, source

System design consist of following four stages, construction of background image, detection of frame features, matching of detected frame features and refining matched vehicle features. Creating a background image (an image representing the scene without moving vehicles) using a computer is a difficult task. The reason is that a computer, unlike humans, is unable to distinguish background and vehicles by considering a single image. The number of frames improves the quality of background images, it increases the time consumed in creating them. This is caused by the large number of mathematical instructions required to construct a background image.

In the second stage it analyzes each frame in the sequence and detects features that correspond to moving vehicles in the scene. Depending on the method used, several types of features can be highlighted to represent moving vehicles. In the second stage apply background subtraction on each frame to remove the static background of the scene. The resulting image consists of *blobs* (collections of pixels with non-zero values) corresponding to moving vehicles. These blobs are enhanced by processing further and detected as the main feature. Several attributes about the blobs are recorded in memory for processing in the coming stages.

Also, there are *false blobs*, not corresponding to any moving object. Such blobs are present because of excessive noise in the image or poor quality of the background image. Such features need not be processed further for estimating traffic flow. Therefore, these features are identified from the input features and discarded. Now, the remaining features can be considered as vehicle features. In third stage by matching the features detected in

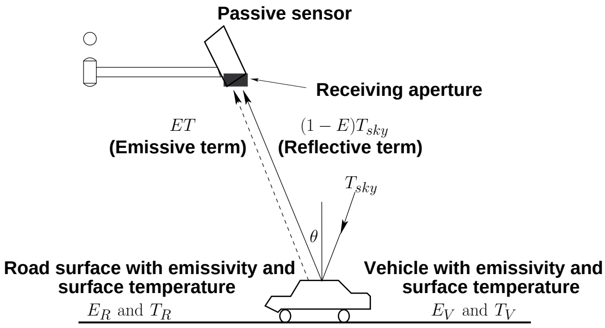

Figure 10:3: Emission and reflection of energy by vehicle and road surface. (Source: FHWA vehicle detection manual)

previous frames with those from the current frame, vehicles can be tracked. In the final stage matched vehicle features can be refined to correct features in the frames. However, this is a complex task, as most of the information in the image has been lost after labeling. Therefore, it is necessary to extract information from original frames to perform this task. All these system design process are done by different algorithms.

10.3 Infrared Sensors

The sensors are mounted overhead to view approaching or departing traffic or traffic from a side-looking configuration. Infrared sensors are used for signal control; volume, speed, and class measurement, as well as detecting pedestrians in crosswalks. With infrared sensors, the word detector takes on another meaning, namely the light-sensitive element that converts the reflected or emitted energy into electrical signals. Real-time signal processing is used to analyze the received signals for the presence of a vehicle.

1. **Passive Infrared (PIR)**
   Detection of vehicle based on emission or reflection of infrared (electromagnetic radiation of frequency $10^{11} - 10^{14} Hz$) radiation from vehicle surface, as compared to ambient levels emitted or reflected from the road surface shown in Fig. 10:3. The PIR system collected following parameters: Flow volume, Vehicle presence, and detection zone occupancy. Speed with unit with multiple detection zones.

   Advantages

   (a) Relatively long wavelength of light used in PIR systems makes them less susceptible to weather effects.

Disadvantages

(a) Accuracy of speed information is poor with low resolution sensors. Vehicle length determination is highly problematic for the same reason.

2. **Active Infrared (AIR)/Laser**
Low power LED or laser diode fires a pulsed or continuous beam down to road surface as shown in Fig. 10:4. Time for reflection to return is measured. Presence of a vehicle lowers the time of reflection. High scanning rates provides a detailed profile for classification determination. Use of Doppler frequency shift from moving object allows for very accurate speed determination. The AIR system collected following parameters flow volume, speed, classification, vehicle presence, traffic density.

Advantages

(a) Very accurate flow, speed and classifications possible.

(b) Laser systems work in day and night conditions.

Disadvantages

(a) Active near-IR sensors adversely affected by weather conditions.

(b) Laser systems impeded by haze or smoke.

(c) Some problems with tracking small vehicles reported.

(d) Relatively high costs compared to other units. Precise, but limited zone of detection require additional units over other systems.

10.4 Microwave - Doppler and Radar

Low energy microwave radiation (2.5 to 24 GHz) is transmitted into the detection zone. Objects within the zone reflect a portion of the radiation back to a receiver. Doppler units use the frequency shift of the return to calculate speed as shown in Fig. 10:5. It cant detect the stationary objects. The microwave system collected following parameters.

Doppler - Flow volume and speed;
Frequency-Modulated, Continuous Wave (FMCW) - Flow volume, speed and presence;
Microwave - Flow volume, speed, presence, possibly classification;

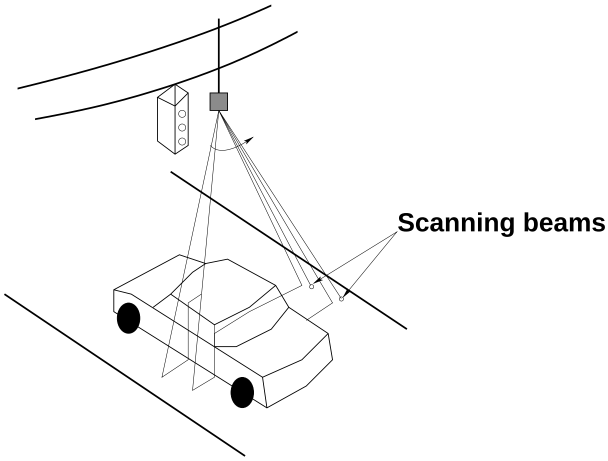

Figure 10:4: Laser radar beam geometry. (Source: FHWA vehicle detection manual)

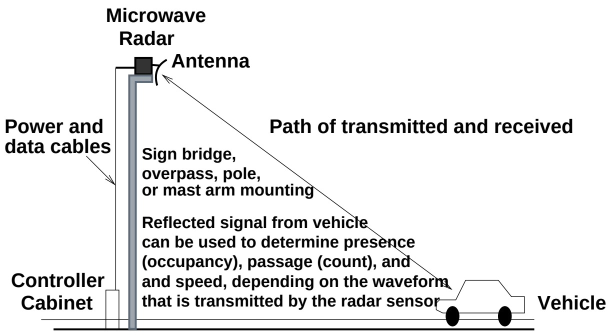

Figure 10:5: Microwave radar operation. Source

Advantages

1. Very accurate. Easy to install, long ranged.

2. Multiple detection zones possible.

3. Day or night operation.

Disadvantages

1. Possible sensitivity to spurious returns from adjacent objects

2. Restrictions on use due to electromagnetic interference with other electronics.

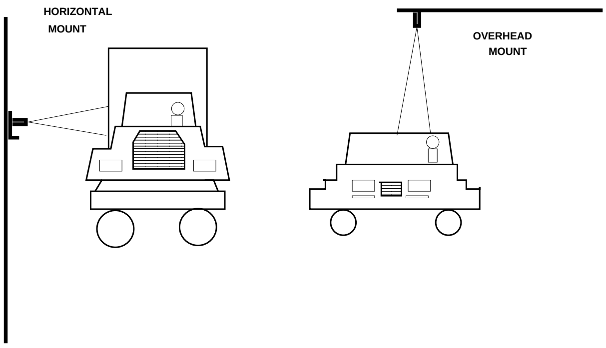

Figure 10:6: Ultrasonic range-measuring sensors, source

10.5 Pulsed and Active Ultrasonic

Ultrasonic sensors transmit pressure waves of sound energy at a frequency between 25 and 50 KHz. Pulse waveforms measure distances to the road surface and vehicle surface by detecting the portion of the transmitted energy that is reflected towards the sensor from an area defined by the transmitters beam width. When a distance other than that to the background road surface is measured, the sensor interprets that measurement as the presence of a vehicle as shown in Fig. 10:6. The received ultrasonic energy is converted into electrical energy that is analyzed by signal processing electronics that is either collocated with the transducer or placed in a roadside controller. Vehicles flow and vehicular speed can be calculated by recording the time at which the vehicle crosses each beam.

Advantages

1. Highly accurate.

Disadvantages

1. Environmental effects affecting sound propagation degrade performance.
2. Pulsed units with low sampling rate miscount or misclassify fast moving vehicles.

10.6 Passive Acoustic Array Sensors

An array of microphones is used to detect the sound of an approaching vehicle above an ambient threshold level. Time lags and signal variations between microphone positions are used to determine vehicle location relative to the array as shown in Fig. 10:7. Further processing

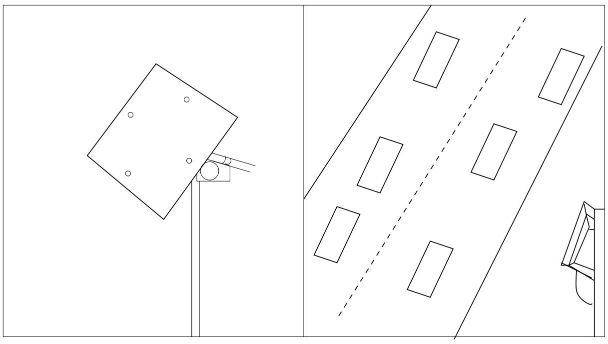

Figure 10:7: Acoustic array sensors, source

of signal yield to speed information and possibly engine type classification. It collected flow, speed, occupancy, possibly classification.

Advantages

1. Completely passive system
2. Direct speed measurement.

Disadvantages

1. Environmental effects affecting sound propagation degrade performance
2. Low accuracy in busy locations due to interference from adjacent sources.

10.7 Summary

A non- Intrusive technology is very effective compared to the Intrusive technologies.

10.8 References

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