TRAFFIC DATA COLLECTION: QUALITY ASPECTS OF VIDEO DETECTION

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ABSTRACT

Because of continuous increasing traffic volume and complexity, traffic managers worldwide are faced with an increasing demand for **state-of-the-art intelligent traffic information**, mainly for traffic management and for safety issues.

Quality is fitness for use. Different detection technologies show different characteristics and prove to be successful in different application areas. Traditionally, inductive loops provide ample information to direct traffic flows and assemble statistics. However the information produced by inductive loops are too limited for several more complex applications such as incident detection, hard shoulder monitoring, pedestrian detection, etc. Current complex traffic situations need more extensive information.

This paper is based on the report of the “Traffic Data Quality Workshop” for the federal Highway Administration (FHWA). This report defines traffic data quality as follows:”Data quality is the fitness of data for all purposes that require it. Measuring data quality requires an understanding of all intended purposes for that data. The following data **quality measurement parameters** are recommended: accuracy, completeness, validity, timeliness, coverage, accessibility. In this paper we analyse each of these parameters linked to video detection for traffic measurement.

INTRODUCTION

The collection of traffic data in urban areas, on highways, bridges and in tunnels is essential for decent traffic and incident management. It is also important make the right infrastructure decisions

NEW DETECTION TECHNOLOGIES HAVE ARRIVED

The oldest of all traffic surveillance technologies are **inductive loop detectors**. Loop detectors are placed in the subsurface of the roadway and when utilized can provide real-time traffic information on that point of the road. However, it has been noted that the cost of installation and maintenance of loop detectors can be prohibitively high. Thus the quest for more cost-effective alternatives was soon made. Other technologies, such as video, radar, microwave, ultra-sound and acoustic, came to the market. These alternative technologies provide not only cost-savings but also have the ability to obtain a broader variety of traffic and incident-related data.

Video detection has now been available commercially for several decades and is gaining acceptance as a more effective technology than the conventional inductive loop-based technology. Why is that?

Traffic detection using **video image processing** has several distinct advantages over the inductive loop-based technology. Inductive loops are only capable of gathering traffic flow data at a certain point. Video image technology can provide a wide range of standard traffic data information about traffic flow at one point, but it has also the capability to monitor larger areas. Some of the newer detection technologies also monitor a larger area, but video has actually the largest control area. Another unique feature of video detection is the capability of sending over real time images to a control room and thus providing extra information to the control centre

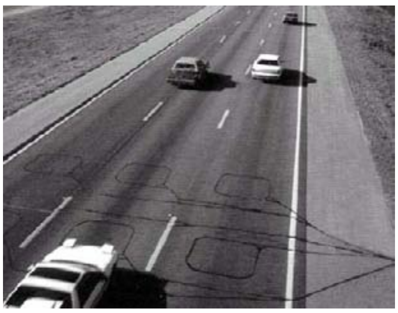

Fig. 1: Inductive loop detectors

Fig. 2: Video Image Processing detectors

TRAFFIC DATA QUALITY: DEFINITION AND ASPECTS

DEFINITION

The Federal Highway Administration defines 'data quality' as follows: "Data quality is the fitness of data for all purposes that require it. As a consequence, measuring data quality requires an understanding of all intended purposes for these data."

The FHWA report states that there are 3 types of "user groups" for traffic data:
1. Real time traffic data collection and dissemination
2. Historical data collection and monitoring
3. Other industries such as data warehousing, management information systems, and geospatial data sharing

ASPECTS

The FHWA report recommends the following parameters to be considered when measuring traffic data quality: accuracy, completeness, validity, timeliness, coverage, accessibility

Accuracy
= The degree of agreement between the measured data by the installation (detection system) and the correct traffic data.

Very often this comparison is calculated as the difference between the known standard measuring device and the device under test. This definition is generally used when the known device is calibrated and is an order of magnitude.
The required accuracy is strongly related to use and budget. For example if the data are used for traffic monitoring, than a degree of accuracy with errors less than 5 to 10% is more than sufficient. Other applications such as tolling systems will require more exact data.
The accuracy can also be function of the type of traffic. For example during traffic jams, most systems will have problems to count exactly the number of vehicles. When you then have a model to calculate the travel time based on this parameter, the error for the calculated travel time will be significant. But if you use a model based on "space mean speed", your predicted travel time will be more correct because the "space mean speed" can still be measured under these conditions.

Completeness
= The degree to which data values are available via the attributes and the amount of events available.

There are many traffic or vehicle attributes that can be measured by different means: as individual vehicle data or as traffic data over a sampling period. **Individual vehicle data** can be used for evaluation of traffic models or law enforcement, but are of no value for traffic monitoring.

Traffic Data (These are collected during the sampling period)	**Individual Vehicle Data**
• Volume • Speed • Class • Occupancy • Density • Headway • Presence	• Counts • Speeds • Length, class, type • Headway • Position • Height • Tracking • Weight

Table 1: Detection systems deliver two types of data: traffic data and/or individual vehicle data

Validity

= The percentage of records passing the quality control checks

An important aspect of the validity is the total expected on time per year of the measuring device. Another important aspect is the effect and frequency of adverse circumstances that affect the measuring quality of the device. A useful tool is the availability of a data quality monitoring system in the measuring device that allocates a quality factor to different attributes.

Timeliness

= The degree to which data values or a set of values are provided at the required or specified time.

Similar definition is applicable for 'event detection': what is the required or specified time between detection of the event and presentation to the operator. This factor depends on the speed of detecting and collecting and also on the quality of the whole communication network

Coverage

= The degree to which data values in a sample accurately represent the whole network that is to be measured.

Here again it is necessary to know what the data are used for and how they are used. For example if you have a traffic model that performs well using punctual data from sensors every mile, your coverage for the available data will give you 100%. But if you want to detect individual stopped vehicles with a camera system covering 300m per camera and you have one camera every 1000 m, your coverage will only be 30%.

Accessibility

= The relative ease with which data can be retrieved and manipulated by data users to meet their needs.

The accessibility is dependent on the decision of the data owner as to how he will distribute his data to potential users. Some data are not at all available for third parties; other traffic centres have active websites where all data on actual traffic, expected travel times and historical traffic can be retrieved. Some have also real time images available. This allows road users a better planning of their trip which eventually will lead to an improvement of the total activity on that particular road section.

Fig 3. :Navigator project: gathering information about traffic events via website.
http://www.georgianavigator.com/

EXTENDED TRAFFIC INFORMATION (EVENTS)

Besides standard traffic data (such as volume, speed, class, occupancy), many traffic management or control centres also wish to be informed about traffic events such as those listed in Table 2:

List of Traffic Events:
▪ Stopped vehicle ▪ Departing vehicle ▪ Inverse direction ▪ Fallen objects on the road ▪ Pedestrian on the roadway ▪ Smoke (in tunnels) ▪ Lane changes ▪ Queues, different levels of service

Table 2: Enhanced traffic event information collected by video image processors

For these types of events, different detection quality criteria such as d**etection rate and false detection frequency per Km per day** can be used.

All of the above events can be collected by different types of sensors. **However it is the user who has to decide which data and events he ultimately needs**. All additional data and events that are collected but not used are extra overhead and add extra complexity simply making the system less user-friendly. Lack of easiness and user-friendliness often is considered as a negative quality aspect!

TRAFFIC DATA QUALITY: VIDEO DETECTION ASPECTS

The most commonly used detection system in the world is still based on inductive loops embedded in the road. This made the loops the de facto reference for all traffic detection systems. Most traffic operators have a long experience with loops, most of the classic traffic monitoring systems are still based on the use of loop data. For example one of the travel time prediction algorithms is based on the use of single loop data that give only counts and occupancy. This algorithm normally works within the 5-10% error margin, which is sufficient in most cases. The only problem arises with stop and go traffic where the results are no longer useful.

Since loops were the de facto reference all new detection systems were first compared with loops and the loop characteristics, thus neglecting the real potential of other detection systems.
Some radars and laser systems can give better results in speed measurements. Some ultra sonic detectors will perform better for occupancy. Video detection with its wide area possibilities will create a lot more possibilities (e.g. for automatic incident detection) but sometimes is still not well understood with respect to the different applications that require different cameras and different camera positions. Automatic Incident Detection projects require a complete different camera position than sites that are equipped with cameras for traffic data collection.

A camera for number plate reading is not the same as a camera for wide area incident detection, and this is not the same as the camera position for counting and classification of the traffic flow. Sometimes we can use one camera for different purposes and thus take a position that will work for different functions, but this can reduce the quality of one of these data detection sets.

Quality is fitness for use. Since there are different type of users and an immense variety of traffic applications, the criteria for quality of the traffic data will differ from case to case. **There is no such thing as the single best quality of traffic data.** Quality of traffic data depends on the type of application and is also influenced by budget. For example if the data are used for traffic monitoring, then a degree of accuracy with errors less than 2% is more than sufficient. Other applications such as tolling systems require more accurate data.

Accuracy

Accuracy of traffic data when using video detection

The accuracy of the traffic data collected by video based systems is influenced by the selection of the camera and camera position. One of the problems of video detection is that there are no standard cameras. There are also no standard camera positions, no standard roads, no standard weather and no standard illumination. Although it might seem that video detection for traffic applications is a difficult art, practice shows that good results can be achieved with video detection technology. However, it is necessary to inform that each detection technology, including video detection, has to be used correctly and for specific applications. Camera type and camera position is of vital importance for having a video detection system that fulfils customer requirements. Different applications require different cameras and different camera positions.

Fig. 4: Good camera position, camera over the road

For ‘**volume**’, current video detection systems give accuracies of more than 99.5 % in all weather conditions, day and night. Results on ‘**Speed**’ accuracy depend on good calibration. Normal expected accuracy is more than 95% for individual measurements (within a 3 % error margin). ‘**Occupancy**’ is certainly influenced by camera position and camera angle (and for some systems still by trailing shadows). A similar effect is seen with inductive loops, giving different occupancies as a function of their size, their sensitivity and the metal content of the vehicle. ‘**Classification**’ accuracy with video detection is currently only measured based on the overall length and form. The classical classification based on axles is not possible using single cameras. For the classification at tolling systems, a laser beam system is therefore a better solution as it will deliver a very fine profile of the vehicle. For normal traffic management, the requirements are to be able to make a classification between trucks and passenger cars. Here video detection technology shows a classification accuracy of more than 95%. Calculating “**headway**” accuracy using video is done as a function of time and speed or by directly measuring the distance between two vehicles. This method will depend on the use of this element and on the camera position. When using video and a good camera position, results of more than 99.5 % for “**presence detection**” and a very low false detection rate can be obtained.
Normal single camera systems will not measure the “**height**” of the vehicles. There is some research done in this area but there are no commercial systems currently available. ‘**Weight**’ can only be measured using weigh-in-motion or static sensors.

Other traffic events such as stopped vehicle; inverse direction; fallen objects; pedestrian crossing; smoke; fog; lane changes; speed drops; traffic jams can also be detected with video. The quality criteria here are based on **detection rate and false detection frequency** per Km (mile) lane. Some people still use as definition for ‘false detection rate’ the relation between false detections and true detections. This criterion is very dangerous because you measure the relation of two completely non-related factors! This gives a nearly random result.

Completeness

Completeness of traffic data when using video detection:

Of all existing detectors, **video detection has the largest scope for traffic data and events**. Again, we must inform that the accuracy of some of the detectors will be influenced by the camera position! For classical traffic data collection, a camera mounted over the road looking about 45° down will give the best results. But for large area covering purposes such as ‘automatic incident detection’ or ‘lane change detection’ the camera must be looking over a larger road stretch thus giving less accurate flow data. Similar effects will occur when the camera is on the side of the road which will cause occlusion problems due to larger trucks that are occluding smaller cars behind them. Here the effects will depend on the density of the traffic.

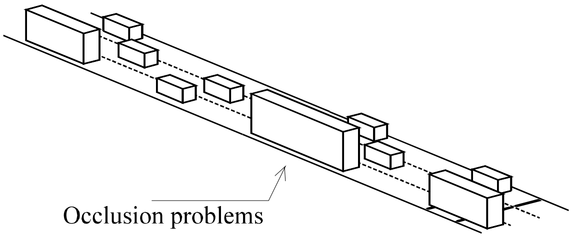

Fig. 5: Occlusion illustration

Validity

Validity of traffic data when using video detection:

The validity of traffic data using video is mainly dependent on the **visibility attribute of the CCD camera**. The main obstacles will be weather conditions linked to the cleanliness of the camera (lens). In case of foggy weather and a visibility of approx. 20 m, a camera used for normal traffic data acquisition and mounted above the highway will not be influenced by this fog. If the camera is looking over a stretch of 300 m, then the validity of the data will be restricted to the zone of visibility. Rain and snow will only have minor effects for the short range view when the camera is mounted in a position where there is no direct spot light on the snowflakes close to the camera. Same scenario with a dirty lens. A camera mounted sufficiently high will receive less dirt from traffic than a camera mounted close to the vehicles (e.g. in a tunnel). Finally, a video detection system also includes confidence or quality levels making sure the user is warned when data are doubtful.

Timeliness

Timeliness of traffic data when using video detection:

The Mean Time Between Failures (MTBF) of video detection systems is extremely high (more than 20 years for all Traficon material). The main problems that appear arise from lightning effects striking the camera. Since the whole installation is off-road, the reliability is very high and will not be influenced by road works or cracks in the road breaking the connections with the detection device.

For tunnel installations we sometimes install a fully redundant system where each zone is covered by 2 cameras and all other functions are built in a fully redundant manner.

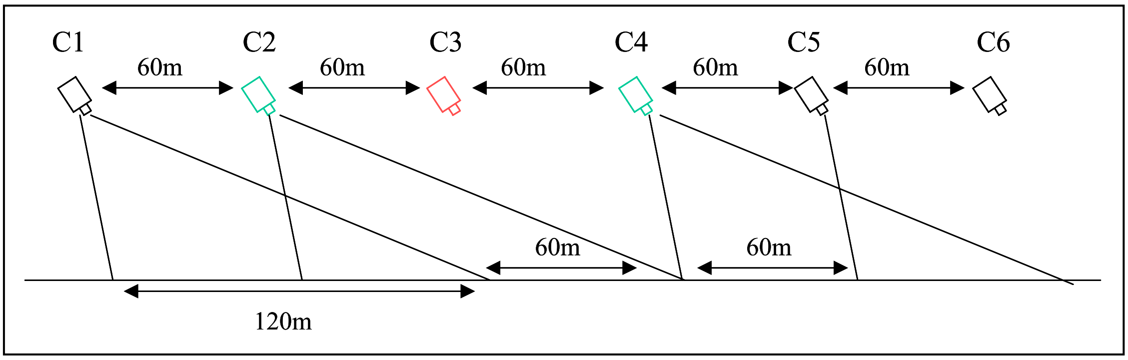

Fig. 6: Fully redundant system

Coverage

Coverage of traffic data when using video detection

Since video detection can cover wide area zones, this normally results in the most cost-effective coverage of tunnels, highways, bridges and larger intersections. A video detector can cover up to 100 different zones when needed. Video detection in tunnels is just limited by available camera mounting height or curvature or up and down grades. A second advantage is that with recent systems, also Pan Tilt and Zoom cameras can be used for incident or traffic verification.

Accessibility

Accessibility of traffic data when using video detection

Accessibility of traffic data depends on the decision of the information provider. With video detection, the user not only receives simple data but of course also useful visual information (e.g. for pre-and post incident analysis). The improved image compression techniques (MPEG4) and the available communication bandwidth and channels create new opportunities for improved accessibility of the traffic information.

Fig. 7: Via the web, road users can view the traffic situation

MEASURING TRAFFIC DATA QUALITY

TESTING OF TRAFFIC DATA

When testing quality of traffic data there must be made first a difference between numerical traffic data used for monitoring traffic, events derived from these traffic data via diverse algorithms (incl. evaluation quality of the algorithm) and direct detection of traffic events.
Currently, there is no standardized, uniform way or tool for testing traffic detection devices because all sensors are influenced by several different parameters: the position of the sensor versus the car, environmental effects, type of traffic (traffic jams, stop and go, tailgating), etc. It's like comparing apples with pears! To address this need, video image processor manufacturers have realised that it is of primary importance to have a tool for automated quality control of video detection algorithms. Traficon for instance developed a unique framework, called **ADEPT (Automatic Detection Performance Test)** that allows an **objective and automated evaluation of the performance of video detection products.** Important is that the system contains different test scenarios for a variety of realistic traffic conditions and under different conditions such as camera position, weather, day night dense traffic and traffic jams. Nowadays, video detection is the only technology where one can evaluate the detection quality of different algorithm's using the same video recordings of a traffic scene. This tool measures exactly the amount of detection progress that is made between different software versions or algorithms. As such this ADEPT software tool is able to define an objective and detailed answer on the quality of the video detection system.

METHODS FOR VIDEO DATA ACCURACY MEASUREMENTS.

How to test the quality of traffic data gathered by a video detection system?

First of all, since video detection is based on the use of video signal, it is very important to have **video sources that are as equal as possible as the sources in the field**. Here a problem arises because some video image processors are directly connected to the camera; some are connected over a larger distance with video amplifiers in between and some use video over twisted pair, over fibre or over IP.

In a first phase when developing ADEPT, all sequences were collected and digitised on DVD (since digital video is the most stable source of video), with some time synchronisation for verification. Afterwards, the DVD's were analysed manually for all important data such as time of arrival, time of departure , class of vehicle ,speed and others. The selected sequences were of 10 minutes on different moments of the day (and night), under different traffic situations, and with a normal camera position.
Currently, the Traficon library exists of dozens of different sequences including simulations of all normal expected images useful for verification of the measurement performances. This video library is now used to evaluate the detection performances of the traffic data algorithms.

Fig. 8: Via ADEPT, different software versions are compared which makes it possible to conclude if there is improvement in the quality of the presence detection

TRAFFIC EVENT DETECTION PERFORMANCE USING VIDEO

How to test the quality of traffic events gathered by a video detection system?

The problem with traffic events is that they do not occur regularly. The simulation of a stopped vehicle in an empty tunnel during system installation tests (over different distances and with different light levels, headlights, flashing lights, etc) is completely different from detecting a stopped vehicle on the hard shoulder in a real-time situation.
The same problem is noticed with the event 'inverse direction'. For instance: inverse direction shadows on the opposite lane. All various "weather" effects can occur which makes it harder to record this event in all possible variations. The main task therefore for all video detection manufacturers is to have an extensive library containing hundreds of hours of video to have a significant amount of traffic events under different situations.
Because customer requirements become more and more demanding, video image processing manufacturers must prove that the video detection system will detect 99.9 % of the events under normal traffic flow conditions. Having a tool for automated quality control of video detection algorithms is thus an absolute must.

CONCLUSION

Quality is fitness for use. Different detection technologies show different characteristics and prove to be successful in different application areas. **There is no such thing as the single best quality of traffic data.** Video detection technology has proven to be very reliable for traffic data collection and for automatic incident detection. Various data and reports support that using video signals for detecting traffic data and incidents is a reliable and cost-effective solution.

Traffic managers nowadays want proof of the quality of the traffic data, delivered by various detection systems. This will influence their final decision on what system to use for their specific application. Tools, such as **ADEPT** and others, .assist in evaluating the quality of traffic data generated by a video detection system.

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