Research on the characteristics of traffic flow with the use of video registration

I. CELIŃSKI
SILESIAN UNIVERSITY OF TECHNOLOGY, FACULTY OF TRANSPORT, Kraszyńskiego 8, 40-019 Katowice, Poland
EMAIL: ireneusz.celinski@polsl.pl

ABSTRACT
The article outlines the video registration method as well as research based on obtained video footage of the characteristics of traffic flow. The method is flexible and makes it possible to research various traffic characteristics. The article presents the method’s assumptions and the manner in which traffic flow characteristics were measured. The method of registering traffic flow parameters on video was implemented in 2012 in selected sections of Katowice’s road network. An important feature is the possibility of traffic flow parameterization with the use of popular camcorders. The thus-obtained footage is processed using so-called open library vision graphics procedures in order to establish traffic flow characteristics in near real-time.

KEYWORDS: image processing, vision processing, road network, video registration, traffic detection

1. Introduction
Traffic flow video registration along road networks has been successfully utilized for the past dozen or so years [1,2]. Research on determining traffic flow characteristics in real-time, however, has a much shorter history, mainly due to computer calculation requirements and capacity of storage devices required for this type of data processing [3]. The video registration technique suggested in the article allows users to parameterize traffic flow in a flexible manner. Unlike classic detection systems, this method makes it possible to determine a wide spectrum of traffic characteristics. Traffic flow video registration is currently the most flexible solution for control over various traffic characteristics. Significantly, it is also the least invasive as far as research impact on traffic flow parameters is concerned.

The suggested method utilizes popular PAL standard video registration devices (camcorders) to measure the characteristics of traffic flow. Video registration device installation takes place along a cross-section of a road lane, at various heights over the lane, perpendicularly to the section being measured. Traffic flow is registered from a certain height, at an angle (see below). Collected footage is processed using standard open libraries for processing moving objects (open vision graphic libraries). The manner in which footage is processed has been described in section two (Traffic Flow Video Registration). Currently image processing takes place in a laboratory and not the road itself. Ultimately, the method will allow for the construction of an integrated circuit system (camera-FPGA module), and thus create universal traffic detectors generating advanced traffic characteristics in real time directly on roads (roadside).

2. Traffic flow video registration
Traffic flow video registration should be carried out on characteristic (specified) road sections. In places: where queues form, conflicting traffic flows intersect, etc. For the needs of the method characteristic road sections were defined along Katowice’s...
road network, i.e. so-called reference points (sections, ca. 50 points). Next, video registration of images of actual traffic flow was conducted in these sections. In each network it is possible to identify reference sections which can potentially constitute its bottlenecks, queue etc. Infrastructure elements (its parameters) along the sections should make it possible to register traffic flow images (usually one or more streams), from a certain height (over the road). To do so it is possible to utilize: traffic signs on transmission towers, viaducts, bridges, pedestrian overpasses, trees etc. Reference sections should make it possible to record traffic flow using typical camcorders situated approx. 4.5-7 meters over the road (the typical range of heights of viaducts, overpasses and bridges). Footage can be recorded in PAL standard or higher like HD (PAL, codec H.264 was chosen for research purposes). The choice of higher recording standards makes it necessary to utilize computers with higher calculation capacity and devices with larger storage capacity during subsequent data processing. This is not always necessary for the purposes of basic traffic flow parameterization and in case of planned FPGA implementation with the use of the method it may even pose a problem.

In the course of research carried out in the abovementioned manner, footage a few dozen seconds in length was taken in selected sections of the road network in Katowice (reference point). The research focused on measuring one parameter: disruptions in traffic flow. The uncharacteristic for flow detection processes parameter was chosen on purpose – to demonstrate the method's universal potential. The identification of this parameter using current motion detectors is highly problematic. Moreover the definition of disruption is also highly problematic and most discussed in literature [4]. This remarks applies to both road and rail.

Road sections with expected higher number of disruptions were selected for research purposes (based on preselecting data) [5]. A description of the characteristics of flow disruptions goes beyond the subject matter of this article [4]. In short, disruptions were defined as changes in speed (to a certain extent) accompanied by a series of other factors: lane changes, route changes, etc. Disruptions in traffic flow can be registered on intersections, service roads, etc. Fig.1 shows an example of a basic measurement station used to register traffic flow using typical camcorders situated approx. 4.5-7 meters over the road (the typical range of heights of viaducts, overpasses and bridges). Footage can be recorded in PAL standard or higher like HD (PAL, codec H.264 was chosen for research purposes). The choice of higher recording standards makes it necessary to utilize computers with higher calculation capacity and devices with larger storage capacity during subsequent data processing. This is not always necessary for the purposes of basic traffic flow parameterization and in case of planned FPGA implementation with the use of the method it may even pose a problem.

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The method is also validated. To validate data, the number of disruptions obtained based on processed video footage of the road network is compared with an analogical value obtained on the same road section using a micro-simulation model (this model include 400 000 OD flows) [7]. To do so, a micro-simulation model was created of the road network in Katowice. Model was built in the VISSIM program [8,13,14].

In order to determine the number of disrupted vehicles on registered video footage (in registered traffic flow conditions), the footage must be preprocessed [6]. First, the video images are cropped in order to pinpoint the virtual measurement section of strictly defined dimensions. The dimensions correspond with the width and length of the selected measurement section (from a certain camcorder perspective). During the filming process it is necessary to pay attention to the camera's location in respect to the road being filmed. The author's program crops every frame of registered footage to capture the predetermined measurement section (every frame in the same manner – the operation is carried out “on-the-fly”). Tests revealed that image processing libraries used by the method do not require video filtering with the use of popular filters (a lapse of a few milliseconds was registered). Often initial image filtering speeds up and simplifies processing. In the example outlined in the article, the color-image processing algorithms carried out on readily-available desktop computers (popular) and work very quickly (processing unit: Intel Celeron® G540, at speed 2.5 GHz, RAM: 4GB, Windows 32-bit OS).

If more than one traffic stream requires registration (a few lanes), the camera is positioned at -90 degrees, which later requires a +90 degrees rotation during processing (also doing by “on the fly” operation but the length of section is decreased). Generally all initial processing operations on registered footage are carried out “on the fly” (in near-real-time). Initial video image processing and later phases of the analysis carried out to determine flow parameters are shown on Fig. 2.

The effect of the abovementioned operations, presented on Fig. 2, is a space-time graph. The graph depicts movement of registered vehicles along the measurement section throughout the observation period. Fig. 3 shows a path-time graph for one of the analyzed reference sections of Katowice's road network (superposition as assembling n-th frames of footage).
When analyzing the traffic flow image presented in the form of a graph on Fig. 3 it is possible to use a series of fixed values. We can see that the registered footage has identical image frame sizes. In reality (following processing) frame dimensions correspond in height and width with the measurement section (the perspective depends on the position of the camcorder). When processing video footage (with the use of image processing), every recognized moving object (within its scope) gets assigned on the camera’s focal plane to x and y coordinates (respectively height and width variables on frame). The time-space graph presented on Fig. 3 is not “typical” diagram. There is no closed-form time axis - the image is a superposition of the actual space-time graph (from n-th frames). Time on the graph is not shown as a constant variable but as a step variable (numbers on film frames, each frames as time increment). The image of the traffic flow on Fig. 3 is also distorted due to the value of the angle between the focal length of the video camera and the plane of vehicle movement. For the space-time graph to depict the image well, the camera would have to be situated at a substantial distance over the road axis being registered (which is often difficult to implement).

The camera parameters can be set using the computer programs available on the market such as VideoCAD [15]. Programs of this type have the option to set the geometry of the camera. When entering data on the size of the CCD sensor (e.g. 1/3”), the camera focal length (2,9), minimum and maximum dimension of registration objects (0-3 m, traffic structure) you can specify an geometries camera. This allows you to accurately set camera tripod using a protractor (in degrees).

The graph shown on Fig. 3 is a type of “imprint” of the vehicles’ trajectory on the camera’s plane (CCD, CMOS converter). The space-time graph, distorted in the manner described above (superposition with hidden dimension of time), is then mapped to obtain a typical SVT (space-time) graph. Mapping consists of decomposition of data from individual frames in a sequence in accordance with the flow of time on the video footage. A typical space-time graph of the analyzed road section is shown on Fig. 4. The area with the arrow on Fig. 3 corresponds with a current position of a vehicle on the video frame (in the measurement section). A series of thus-marked points creates the vehicle’s trajectory within the measurement section (a path-time graph for the vehicle as depicted on the frames). The time-space graph also shows static visible on the footage (e.g. vibrations of the viaduct from which footage was taken, wind, air vibrations, fauna flying past, etc.). Further processing eliminates such noise, to a certain extent, via filtration.

Fig. 4 shows a comparison of the space-time superposition with an image of actual traffic flow (for the needs of providing a comparison, a frame-by-frame analysis was carried out for a short period of time). The configuration of lines on Figure 4 depicts the trajectories of individual vehicles (each separately curve). The figure also shows frequent lane changes (often observed on this section of the road) and shorter distances between cars. Figures 5 to 11 show the interface of the author’s software, used to parameterize traffic flow on the road network.

The program shown in the Fig. 5 is designed to cut out of the frame depicting the measuring section (red rectangle). Each video frame is cut identically.
Fig. 6. Filtering program

In filtering program (above) are embedded the most popular image filters (grayscale, Wiener, Gauss, Laplace’a, Roberta, Sobel etc.) found that match the data reduction.

Fig. 7. Image superposition representation program

Consecutive numbers of the fields mean: 1- original footage, 2-space-time diagram, 3- footprint (superposition), 4-6 distortion removing procedure.

Fig. 8. Noise and contour analysis program

Fig. 9. Moving object identification program

Fig. 10. Program for the analysis of an image’s statistical parameters

Fig. 11. Analysis program, other (flat space-time diagram)

Fig. 4 shows a vision processing. In this program, moving objects are detected in the analyzed image (each single frame). These objects represent moving vehicles. Number of points on the vehicle depends on the settings examining procedures.

Figures 6-9 show (in the form of screenshots) the various programs used to parameterize registered traffic flow: a program for cropping the measurement section from the camera’s frame, image filtering, superposition of the image of traffic flow (transformation: image from camera SVT), detecting moving elements on the image. Figures 10 and 11 show a program used for the statistical analysis of the layout of the number of interferences in the measurement section. Apart from the final program, all shown programs are strictly linked with a field of computer graphics: moving image processing [6]. The process is carried out based on available standard open libraries (for example: Open Source Computer Vision Library and many others). The image processing libraries are used solely in order to construct a time-space graph, in accordance with observed physical parameters of registered traffic flow. Processing of traffic flow images is carried out in real-time.

The presented method of traffic flow video registration has strictly defined technical limitations. The precision of the measurement method mainly depends on the number of frames registered per second, video standard used by the camcorder and used codec. Precision also strictly corresponds with vehicles’ speed and camera’s location (foreshortening depends on the height of the camera’s location over the road). As an example, for a vehicle travelling 10 km/h, it is possible to register changes in location with a precision of less than 0.1 meters (registration speed: 25 fps). At a speed approaching 110 km/h, precision of registering vehicle location
 decreases, at the end of the measurement section, to approx. 1 meter. In addition, in conditions of higher movement intensity the method will require segmentation of video footage due to the size of data being processed (large files >100MB). Vehicle succession within the limits of 4÷5 sec. causes points to layer one on top of the other on the traffic superposition image (during the analysis period, t=1'). This makes it necessary to position the camera at the highest possible height over the measurement section (sometimes difficult to find the good location). In practice, placing the camera at a height of approx. 7 meters rendered it possible to register an approx. 100 meters-long section in the presented case (scale: 1.7:10). The final phase of traffic footage processing is a statistical analysis of the path-time graph (see: Fig. 10 and 11). Initially, processing the path-time graph makes it possible to calculate vehicle succession times and distances between vehicles. The final product of these types of transformations and calculations is shown on Fig. 12.

Fig.12. Result of the decomposition of an SVT graph

Fig.12, on the SVT graph (on the left), also includes information concerning the location of vehicles on particular traffic lanes along the analyzed measurement section (small shifts in levels between points on the superposition of vehicle location). Parameters of succession time and gaps between vehicles observed on the road then undergo a statistical analysis using basic numerical database characteristics. The following values are established: minimum, maximum, standard deviation, etc. The program used for a statistical analysis of traffic images is shown on Fig. 10,11. The step of the calculations is to add the number of vehicles classified as disrupted (for each place identified as a disruption point). To do so it is necessary to determine the numeric values of characteristics of a database spread out spatially along and across the measurement section. This method is currently relatively slow and extends time required to process traffic characteristics (from the perspective of planned integration of camcorder with FPGA box). Characteristic locations of the spatial layout shown on Fig 10,11 directly correspond with traffic disruptions used in micro-simulation programming for the analyzed road network [5]. This corresponds with comparing the layout of the number of disruptions along the measurement section (filmed) with the section of the network calculated by the micro-simulation model. Both sections (model and actual network) are then divided into parts in which the number of disruptions is calculated:

$$\Delta_j = |L_{ZM} - L_{ZV}|$$  \hspace{1cm} (1)

where:

- $\Delta_j$ – difference in the number of disruption, the j-th section of the measurement section, between the microsimulation model and the real world network,
- $L_{ZM}$ – number of vehicles disturbed at the j-th section of the test section in the micro-simulation network model,
- $L_{ZV}$ – number of vehicles disturbed at the j-th section of the real world measurement section (video registration process).

The difference in the number of disruptions between the micro-simulation model and the real network, is then expressed as relative values by the following equation:

$$\Delta^*_j = \left(\frac{\Delta_j}{L_{ZM} + L_{ZV}}\right)$$  \hspace{1cm} (2)

The indicator expressed by equation (2) takes one a value from the range of <0.1>; values close to 0 indicate a good correspondence of the results of the micro-simulation program with the traffic conditions along the actual road network within the given section; values greater than 0 indicate an error in the calculation of disruptions in the analyzed network, as indicated by the simulation program. It must be emphasized that this is solely an estimate of the number of disruptions – due to the complex nature of traffic [5,7,4].

3. Conclusion

The method suggested for determining traffic flow characteristics on road networks undoubtedly requires further research. The method makes it possible to parameterize traffic flow in near-real-time conditions; this is the method’s significant advantage. As part of further research, it would be possible to conduct calibrating measurements using a different motion detector as well as a camcorder [9]. This traffic research method additionally creates far greater-reaching implementations than simply classic, basic detection: detection of the presence of a vehicle or determining its speed. In the case of classic motion detection devices, the production technique and operating technology impose the manner in which measurements are made. In the case of the suggested method, the manner in which measurements are made is mainly the result of image processing logic (manner). It can be used, e.g., as a specialized system of modeling and controlling transportation flow [10]. This would require an integrated processing module and statistical analysis of traffic flow in FPGA integrated circuit. A diagram of such a system is presented on Fig. 13.

Fig.13. Diagram of special. CCTV/FPGA system
This specialized system, in combination with the functionality of a camcorder, may serve as a universal traffic flow detector. It can be used to measure traffic characteristic, depending on the various statistical analysis algorithms implemented in FPGA to analyze registered traffic flow images. The possibility of measuring traffic characteristics would be limited solely by used processing procedures and image statistical analysis procedures. Functionally, such modules – for the needs of determining various traffic characteristics – can be implemented in the memory of the FPGA system. It would thus be possible to attempt to construct detectors for collecting data such as: license plate numbers, vehicle speed, but also to determine data not currently collected: number of passengers inside vehicles, use of traffic lanes, as well as numerous other data.

Shown in Fig. 13 box called analysis (set of methods) represents variant types of algorithms: statistical analysis (this article case), artificial neural networks, genetic algorithm etc. Finally output data are designed for modeling transportation networks [11][12].

Bibliography


[8] vision-traffic.ptvgroup.com (Date of acces: 2014-12-03)


