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Reliability of data obtained from video systems of traffic surveillance

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ABSTRACT
The paper presents a way for estimating the reliability of data obtained with video systems of traffic surveillance. It describes the elements of factors determining the reliability of this indicator and presents a method for determining it using a computer simulation. This indicator can be used for assessing the quality of services.

KEYWORDS: telematics, information reliability, traffic surveillance

1. Introduction

In transport telematics, the information reliability has a considerable impact on the traffic safety. In particular, this applies to the case of traffic surveillance systems based on video images in real time. The present paper will discuss measurement errors affecting the reliability of vehicles' flow parameters. It is assumed that such parameters are measured using motion masks. That is, using the method of difference detection of changes in the image.

1.1. Motion mask

A matrix of image differences (Fig. 1) is the matrix defined as a difference between the functions of brightness of each i(x,y) pixel in two successive frames of a scene's sequence:

$$\Delta i_{(x,y,t)} = i_{(x,y,t)} - i_{(x,y,t-1)} \qquad (1)$$

(for all the pixels in the image: x=1,2,3,...,w; y = 1,2,3,...,h, where 'w' and 'h' values are image resolutions, while 't' and 't+1' are two successive moments of taking the frames into consideration).

A motion mask is defined as a processed matrix of image differences. Considering an image to be a matrix of values indicating pixels brightness, it can be assumed that a movement between images takes place only when a difference of brightness of frames from two different moments t and t+1 is other than zero. Mathematically, the difference between images may be defined as a change in pixel brightness over time. Therefore, it is the value of the partial derivative

$$\frac{di_{(x,y,t)}}{dt}$$

(function i(x,y,t) is a brightness assigned to a pixel of coordinates (x,y) at a time t). Since in the case of computer image analysis, we are faced with a discrete case, both in the case of the domain and the function, the subtraction of values corresponds to the calculation of a partial derivative in relation to time: i(x,y,k+1) – i(x,y,k), where 'k' is an index assigned to successive images in a sequence.

An object motion mask is a fragment of the motion mask obtained as a result of the movement of the given object. One of the types of object motion masks is a vehicle motion mask.

We can isolate several types of motion masks that can be used for obtaining various pieces of information from an image. In the case of the methodology presented here, we applied a vehicle motion mask depending on four conditions.

1.2. Measurement Assumptions

As the mask method supposes a measurement based on the analysis of a motion mask, we need at least two images from a video sequence in order to effectuate a measurement. That is, it is possible to state that a measurement can be performed only after the acquisition of the full number of images necessary for this measurement. This propriety will be further called the first assumption.

The next (second) assumption will be the necessity to identify the vehicles. A measurement is possible only when we process the image of the same object (vehicle). That is, when we have properly identified it. It is particularly important while measuring the speed using visual methods when it is necessary to acquire information on a vehicle position in two different moments.

1.3. Measurement errors

Measurement errors affect the reliability of such measurement. A measurement often needs to be done within the limits of a certain error, for instance, a measurement of distance between vehicles.

- Errors resulting from the discrete nature of image.
- Errors resulting from the discrete nature of image changes over time.
- Errors resulting from a camera position in relation to moving vehicles.
- Errors resulting from inappropriate parameters of detection.

2. Causes of errors occurrence

In the previous section, we enumerated the errors occurring while measuring using the method based on motion masks. In this section, such errors will be described in detail.

It has been assumed that the following algorithm for the motion mask segmentation and speed measurement will be analyzed as to error occurrence. The following algorithm shows the whole analysis of the image of several vehicles motion with the measurement of their speed. The analysis is carried out in two stages:

- First, we calculate two successive motion masks using the formula:

$$m_{(x,y,\tau)} = \begin{cases} 1 \ when & \left| i_{(x,y,t+1)} - i_{(x,y,t)} \right| > P_{(|\Delta|)} \\ 0 otherwise & \end{cases} \quad (2)$$

where:
$i_{(x,y,t)}$, $i_{(x,y,t+1)}$ – elements of images, x = 1(1)w, y = 1(1)h;
w i h – respectively, width and height of an image;
$P(|\Delta I|)$ – differences of brightness threshold;
$m(x,y,\tau)$ – element of matrix of a motion mask.

- then we search for fronts of objects' motion masks in the calculated motion masks on the road.

As a result of the algorithm application, we obtain:

- the number of objects, images of which are correct for the analysis,
- coordinates of the fronts of two successive, but different motion masks of objects (or of their ends, as a function of the measurement mode).

We calculate two motion masks for three successive frames of the input sequence M_t and M_{t+1}.

Algorithm's data:
M_t and M_{t+1} – motion masks matrixes;
G – trial window with dimensions lw x lh;
l_w, l_h – width and height of the trial window G, respectively;
w, h – width and height of an image, respectively;
w_p – width of a traffic lane on the image;
S_g – surface threshold (number of 1's) in the window G;
S_d – threshold of deviation from zero for a change of the number of points with the value of 1.

We calculate the coordinates of the ends of two successive motion masks of each object and we write them down in the vectors $x_{s(n1)}$ and $y_{s(n1)}$, $x_{s(n2)}$ and $y_{s(n2)}$, where n is an index of a mobile object, n = 0,1,..L; L is a number of vehicles' motion masks on the image.

As a result we obtain four coordinates $x_{s1(n)}$ and $y_{s1(n)}$, $x_{s2(n)}$ and $y_{s2(n)}$ of the fronts of vehicles' motion masks. The variables n_1 and n_2 contain indexes, the value of which equals the number of detected fronts of vehicles' motion masks. $n_1 = n_2$ means that the algorithm has detected the same number of motion masks in two matrixes of masks.

The pairs of coordinates $x_{s1(n)}$ and $y_{s1(n)}$, $x_{s2(n)}$ and $y_{s2(n)}$ with the same indexes n, indicate the beginning and the end of a vehicle speed vector, respectively.

2.1. Measurement errors resulting from the discrete nature of image and its changes over time

The nature of video sequences is discrete in space and in time. It follows from it that while locating a vehicle on a scene's image, an error occurs as to the dimension magnitude of a pixel. The same applies to the time between successive images of a sequence. This error can be represented in the way shown in Fig. 2.

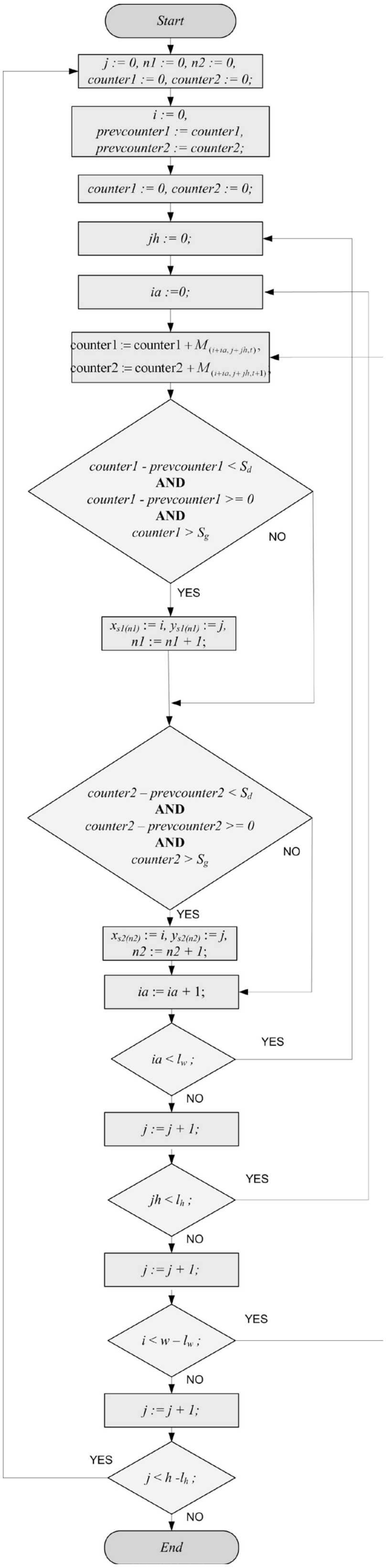


Fig. 1. Algorithm of mask segmentation and speed measurement
Source: [own work]

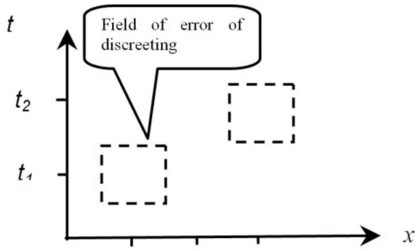


Fig. 2. Error field of vehicles localization
Source: [own work]

2.2. Measurement errors resulting from a camera position in relation to moving vehicles

Fig. 3 shows one of the problems resulting from the geometry of the scene as it is viewed by the camera. The camera is placed above the vehicle. In the drawing we see that a vehicle length measurement changes as a function of a vehicle position. The length measurement, as well the localization of the front and end of the vehicle may be effectuated with an error resulting from the scene's geometry. The drawing shows that the vehicle length, as viewed by the camera l_p', is different from the l_p'''. This error results from the fact that it is impossible to assume the constant height of the vehicles passing by.

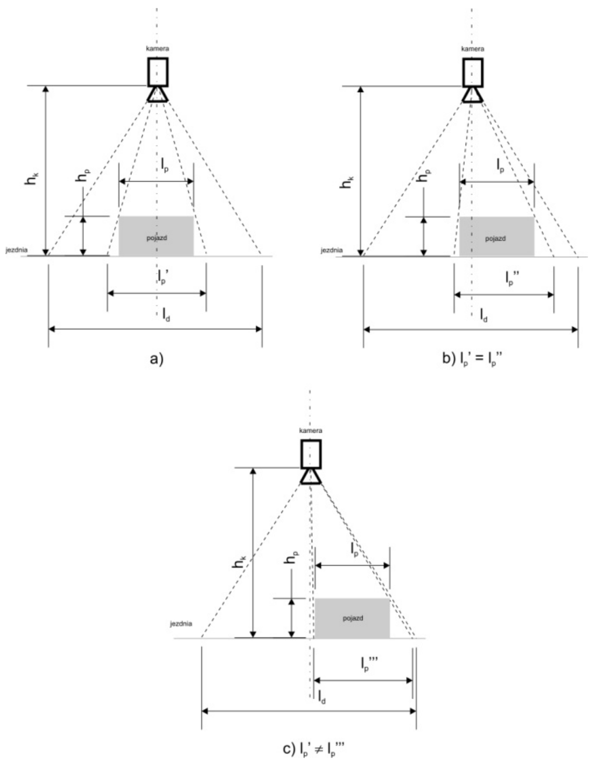


Fig. 3. Localization of the front and end of a moving vehicle. Different positions of vehicle in relation to camera
Source: [own work]

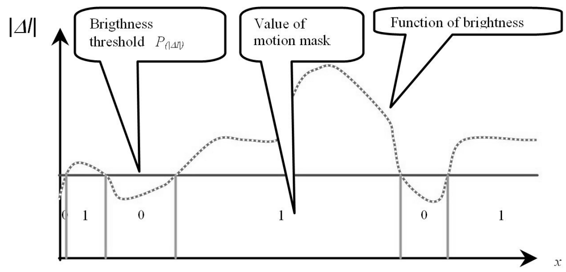
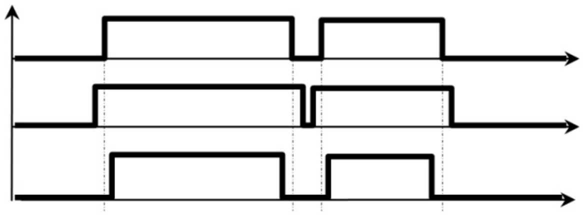


Fig. 4. Brightness threshold in motion mask calculation
Source: [own work]



$$S_g = \frac{1}{2} \cdot l_w \cdot l_h \qquad S_g < \frac{1}{2} \cdot l_w \cdot l_h \qquad S_g > \frac{1}{2} \cdot l_w \cdot l_h$$

Fig. 5. Surface threshold in motion detection
Source: [own work]

2.3. Measurement errors resulting from incorrect parameters of motion masks processing

In order to remove noises inducing images differences, a threshold of differences detection for successive frames of video sequences is applied. Fig. 4 shows how such threshold affects the motion detection. Any threshold decrease will induce an increase in motion detection sensitiveness, while its decrease will induce the contrary effect. The application of such threshold will affect the precision while indicating the motion mask position, because any change of its value affects the magnitude and the location of motion zones positions.

In order to eliminate undesirable detections, we applied the second threshold, i.e. a non-zero threshold of motion masks elements. It induces the elimination of little motion zones created by disturbances or by movements of objects smaller than vehicles. The application of this threshold will induce a decrease in detection zone sensitiveness to motion masks changes. Consequently, it will induce the errors occurrence on the border of the motion zone. This problem was represented in Fig. 5 showing the detection of a motion zone as a function of three different values of the threshold of non-zero elements of the S_g mask.

The correct localization of the position of a vehicle motion mask also depends on the width of changes detection zone in this mask. The larger a zone, the less precise the detection is. Fig. 6 shows two diagrams. One diagram for the detection window of the width of 1 pixel, the second one for the window of the width of 5 pixels.

On the other hand, a larger zone improves the certainty of the border detection by elimination of partially erroneous elements of a vehicle motion mask. That is, those having a value bigger than 0 for the pixels which do not belong to the vehicle image.

3. Measurement reliability indicator

After the analysis presented in the previous section, it is possible to try to determine the measurement reliability indicator. It can be determined on the basis of the impact of each error on the measurement. Fig. 7 shows the process of measurement reliability indicator calculation.

The measurement reliability indicator can be expressed by the following general formula:

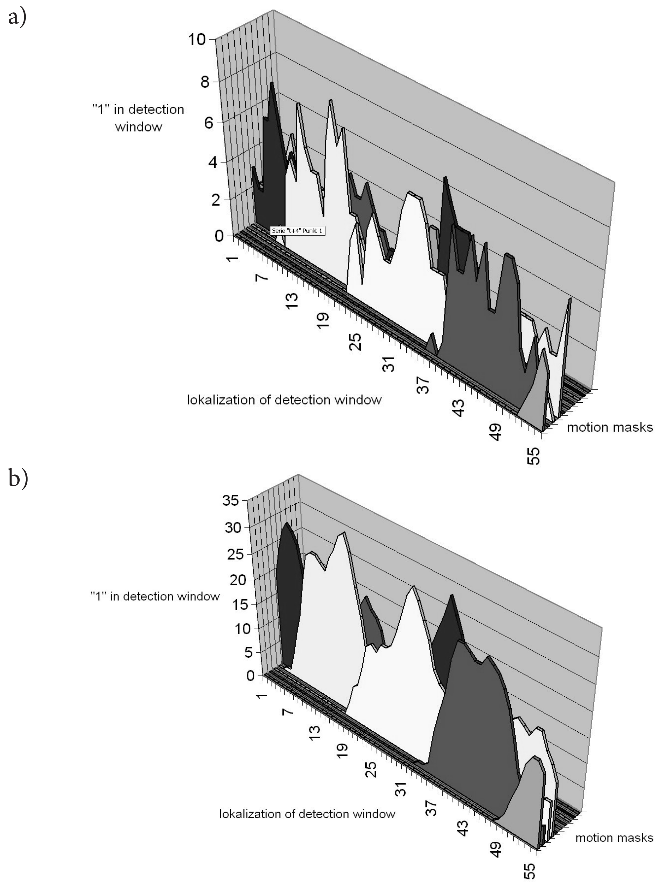


Fig. 6. Motion masks of object detection by a moving window:
a) detection window is 1 pixel in width;
b) detection window is 5 pixels in width
Source: [own work]

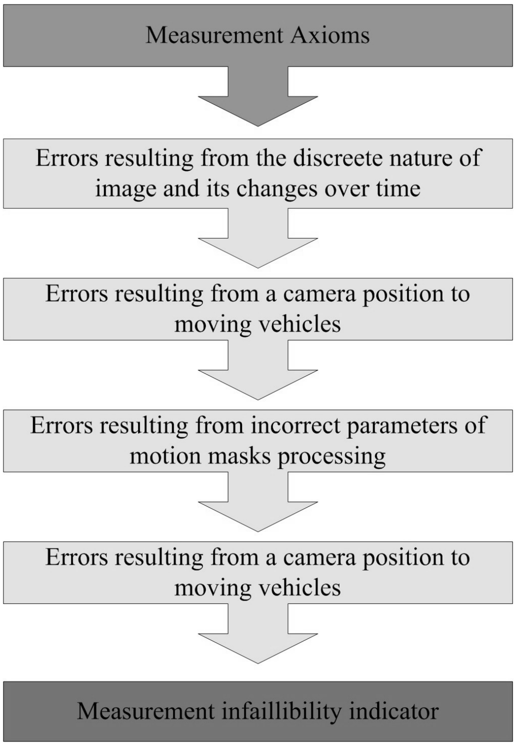


Fig. 7. Elements for determining the measurement reliability indicator
Source: [own work]

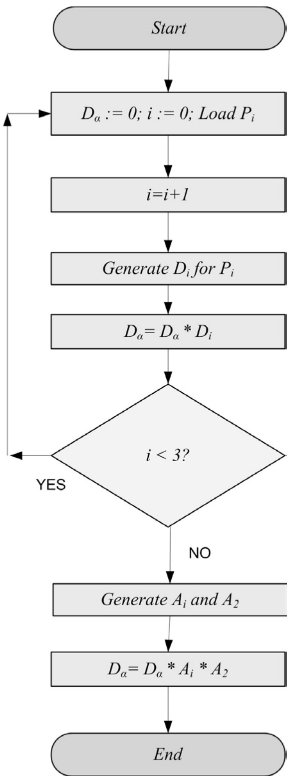


Fig. 8. Algorithm of reliability data indicator calculation
Source: [own work]

$$D_\alpha = \prod_{i=1}^{n} D_i \tag{3}$$

where: D_i is the next factor affecting the reliability and n is a number of such factors.

Two assumptions should also be attached to the reliability. They could be represented as zeroing coefficients. In this way the indicator formula would be as follows:

$$D_\alpha = A_1 \cdot A_2 \cdot \prod_{i=1}^{n} D_i \tag{4}$$

where: A_1 is an indicator for the first assumption and can have the value 0 or 1; A_2 is an indicator for the second assumption and can have the value 0 or 1.

The strength of the impact of various errors is different and it would be worth preparing a special set of coefficients for each error. If we develop the previous formula with the next coefficients, we will obtain:

$$D_\alpha = A_1 \cdot A_2 \cdot \prod_{i=1}^{n} k_i D_i \tag{5}$$

where: k_i is a coefficient for each factor affecting the measurement reliability.

4. Determination of the measurement reliability indicator using computer simulation

An indicator simulation can be carried out using the actual data in the form of known probability distributions of erroneous measurement occurrence outside the tolerance limits. In this case, the simulation algorithm for estimating the reliability indicator would be as shown in Fig. 8.

It can be rather difficult to obtain the above-said distributions; therefore, we propose the algorithm presented below, which will register incorrect measurement events while segmenting the motion mask and indicating the vehicles' position. To this end, the algorithm in Fig. 1 has been modified and presented in Fig. 9.

Front outside and no front outside is the information from a different system of vehicles localization detection. Ei is a table for registration of differences (precisely, the xor function) between the detection due to this system and the detection due to the outside one.

Using the registration of detection or non-detection of vehicles fronts by the outside system of detection, it is

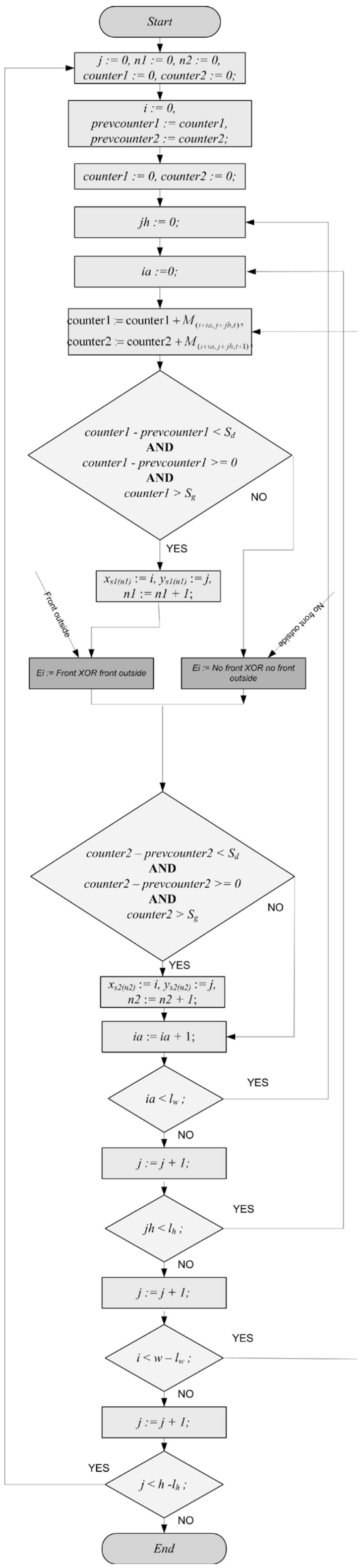


Fig. 9. Algorithm for mask segmentation and speed measurement with elements for registration of front detection, different from these of the outside system
Source: [own work]

possible to build a 0-1 table indicating whether the outside system has detected a vehicle front in the same place. Locating several such recorders in the analyzed system, all the incorrect detections can be registered. When the differences are written down as the road function, it is possible to assess subsequently how big is an error due to the analyzed system in proportion to the standard one. Such error can be used for indicating the Di factor of the measurement reliability indicator.

5. Conclusions

The present paper shows an attempt at estimating the reliability of traffic parameters measurement using visual systems. As the result of the analysis of the selected system detecting the position of vehicles and measuring their speed, we have defined two assumptions for such measurements and four sorts of errors occurring while using the above-said system of motion parameters measurement. We have defined the indicator allowing determining the measurement quality (service quality).

Further steps include the implementation of the presented algorithms and analysis of the results obtained from actual measurements.

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Road user protection via intelligent camera surveillance

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ABSTRACT

Because of increasing traffic volume and complexity, road safety is now more than ever a hot topic on the government agenda. Traffic managers at all levels are organizing today debates with the following central topic: how can we better protect the road user?

One of the solutions to improve pedestrian safety is via Video Image Processing technology. This video detection technology detects faster than any other detection technology. By analyzing the video images in real time, you immediately receive a clear image of potentially dangerous situations. Result: the danger of the incident is substantially reduced and secondary impacts are prevented.

Is video detection a cure-all? Just like any other ITS technology, this detection technology must be used correctly. Different applications require different cameras and different camera positions. One must not start implementing video detection technology without a complete understanding of the costs and benefits associated with these systems. If the correct guidelines and parameters are taken into account and implemented correctly, video detection has proven to be very reliable and can offer great solutions to the end user

KEYWORDS:

1. Introduction

Every year, more than 1.2 million people die on the world's roadways, and as many as 50 million others are injured. Nearly half of those killed each year are pedestrians, motorcyclists and passengers on public transport. As well as the devastating loss of life, pedestrian accidents cost countries financially – the level of injuries affects global GDP by up to 3%. In low- and middle-income countries, road traffic accidents can cost US$64.5 billion per year.

2. Road User Protection in Urban Environments

The number of fatalities is highest in urban areas, which is logical, as urban areas are where the numbers of pedestrians are higher and more concentrated. And although many pedestrian deaths occur at locations where vehicle speeds tend to be fairly high (for instance, freeways) and drivers are not expecting to stop, there are a significant amount of crashes at intersections.

Studies in the USA have shown that 36% of older pedestrian deaths occur at intersections (compared to 21% of deaths involving pedestrians under 70). Factors contributing to this include older pedestrians taking longer to negotiate intersections, as well as the increased possibility of diminished hearing, vision and reaction time.

Younger pedestrians are also at risk on the roads, with the almost clichéd example of a child running out between parked vehicles being a factor in many vehicle-pedestrian collisions. Around 500 children die in traffic accidents every day, many of whom are pedestrians. Of course, it is not only deaths that we should be concerned about. Hundreds of thousands of people suffer debilitating injuries