Estimation of vehicle speed based on video analysis

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Abstract: *The use of video cameras for automatic traffic management, as well as video surveillance cameras, has made it possible to visually observe traffic accidents, i.e. the manner and movement of the parties involved in the accident at the moment and immediately before it occurred. On the basis of a video of a vehicle passing through a section that can be photogrammetrically rectified and transformed into an orthogonal view, with knowledge of the dimensions of characteristic formations that are usually rectangular in shape, such as pedestrian crossings, etc., and with knowledge of the frequency of the video recordings, it is possible, using appropriate software, to determine the speed of the object under study. In this paper, the reliability of the speeds determined by rectification using the AnalyzerPro software has been compared with the target speeds of the vehicle defined by the speed limiter, measured by a handheld radar and a GPS device installed in the vehicle.*

Keywords*: speed, video recording, rectification, AnalyzerPro*

1. Introduction

Video cameras are increasingly present in private and public life, used for video surveillance, social media, monitoring, etc. In addition to cameras installed at crossroads to manage traffic or to detect offences and identify their perpetrators, the spread of CCTV (Closed Circuit Television) [1], i.e. video surveillance, has meant that more and more traffic accidents are being recorded on video.

In most cases, the video recording of a traffic accident is only analysed to determine how, i.e. in what way, the accident occurred. However, the video recording of the accident itself can be a very important source of information for determining the kinematic parameters relevant for a high-quality and reliable time-distance analysis of the traffic accident. One of the basic parameters for this part of the analysis is the speed of the accident participants [2].

For the videos themselves, there can be considerable variability in the quality and content of the recorded material. The parameters extracted from the videos to determine the speed of movement of the accident participants are time (s) and distance travelled (m).

Data on the time elapsed during the sequence analysed can be obtained by dividing the video into time slices (frames), using some of the professional or online video conversion tools from avi, mp4 or other codecs in jpg format, or from data recorded in the recording history. The video frequency is expressed in frames per second (fps). The most common video recording standard is 25 fps, which allows the human eye to see a clear and uninterrupted image in front of it. This means that the time interval between two successive images is approximately 0.04 s. In any case, the analysis of the time interval between two successive clips should be preceded by an analysis of whether they are repeated at identical successive intervals within one second, or whether they differ to some extent. The basic indicator of elapsed time between clips within a video, regardless of the frequency at which it is recorded, should be motion detection of the object between two sequacious frames.

Another parameter needed to calculate speed is the distance travelled. To determine this, the video must show the characteristic positions of the objects to be analysed in relation to stationary objects or markings in the plane of the road surface that can be subsequently identified, such as road markings, the position and dimensions of objects, road grids, etc. By means of plan photography and knowledge of the mutual distance between at least four characteristic points visible in the photograph or photographs taken during the inspection, which happen to include characteristic surface points whose mutual distance can be determined. With the aid of plan photography and the knowledge of the mutual distance between at least four characteristic points visible in the photograph or photographs taken during the inspection, which happen to include characteristic surface points whose mutual distance can be determined subsequently, it is possible to carry out rectification photography, i.e. its transformation into a plan view in one plane [3], [4], using specialised computer programmes based on photogrammetry. On the photographs transformed in this way, the object is observed from a so-called "bird's eye view", on which it is possible to determine the distances between certain characteristic surface points contained in the photograph.

Within the AnalyzerPro (ver. 24.0) software for simulation and reconstruction of traffic accidents, a video analysis module has been developed that can be used to recognise moving objects in videos and, under certain circumstances, determine their approximate speed. After directly downloading videos from a static camera in mp4. or avi. format and defining characteristic points visible on the video, whose mutual distance is known, using machine learning algorithms, the software detects movements in the video and identifies the objects whose speed is being tracked. In order to cover as large area as possible, most security cameras have wide-angle lenses, for which there is generally no close-up data available to calibrate them [5]. As a result, the rectification process distorts the images on the selected frames, which affects the accuracy of the mathematical calculation of the distance between each feature point, which is based on triangulation. The algorithm used by the AnalyzerPro program to obtain an orthogonal image relevant for analysis is based on the detection of groups of lines whose correspondences in reality are likely to be collinear, such as pedestrian crossings, road edges and other surface markings or other surface objects.

These groups of lines are corrected and then a new error function calculation is performed to estimate the remaining amount of distortion. The process is repeated iteratively until the optimal distortion parameters are found. However, due to the mostly unknown parameters of the cameras used for the recording, i.e. not knowing the frequency of the video recording, the low resolution of the recording and the dispersion during the rectification process, the speeds of the objects included in the recording can vary significantly from frame to frame. The AnalyzerPro programme partially solves this problem by fitting a polynomial curve which, at the usual video frequency of 25 fps, allows the speed and mode of movement of the object in the recording to be determined with reasonably satisfactory accuracy.

2. Video analysis module in the AnalyzerPro program

The video analysis module of the AnalyzerPro programme contains useful tools which, under certain conditions, can be used to determine the speed of movement of the vehicles in the video of the event being analysed.

After importing the video into the module (step 1), the top right corner of Figure 1 shows the basic video clip, while below is approximately the same clip, but from a slightly different perspective, with an orthogonal view of the section where the measured speed of the object will appears after rectification.

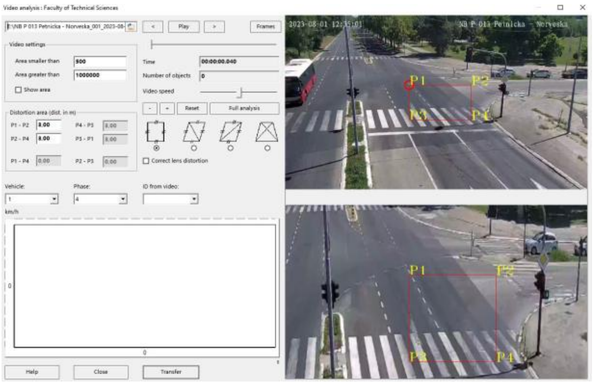


Fig. 1 *Analyzer Pro desktop after video import*

In the upper right figure appears the rectangle with the corners marked by points P1, P2, P3 and P4. By dragging these points to the corners of the quadrilaterals visible in the video, whose distances are known or can be determined later, in the lower right figure of the basic workspace, an approximate orthogonal representation of the section to be analysed is obtained.

In order to perform a video rectification, it is first necessary to define the way in which the known dimensions of the surface to be recorded are entered (step 2). These can be rectangular shapes, such as marked pedestrian crossings on the road for which it is sufficient to know the length of their sides, parallelograms, for which it is necessary to know the length of all four sides as well as the length of one diagonal, and irregular tetragons, for which it is necessary to know the length of all four sides as well as the length of both diagonals (step 3).

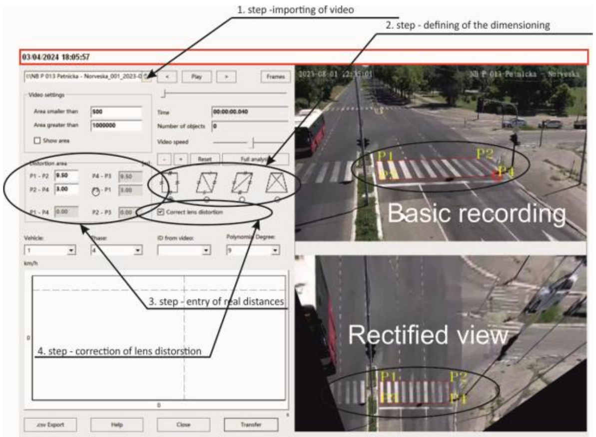


Fig. 2 *Video rectification process in the AnalyzerPro software*

After entering the parameters necessary for the rectification, depending on the position and characteristics of the video camera, whose parameters are mostly unknown, the optimisation of the orthogonal image is carried out using an algorithm based on the recognition of rectangular or collinear shapes, and in this way the image is calibrated in order to reduce as much as possible its distortion caused by the position of the camera and the ignorance of its parameters.

By activating the "play" command, the procedure for determining the speed of the vehicle on the basis of the rectified video is started and the monitor display shows the speeds of the vehicles included in the video, together with their identification by serial number (ID).

By selecting the identified vehicle from the video, a "fitted" curve can be obtained that represents the speed of its movement in time slices (frames) during the observation period of several seconds. The higher the frequency of the video recording, the lower the deviation of the current calculated values of the speed of the vehicles per frame from the curve showing their approximate average speed.

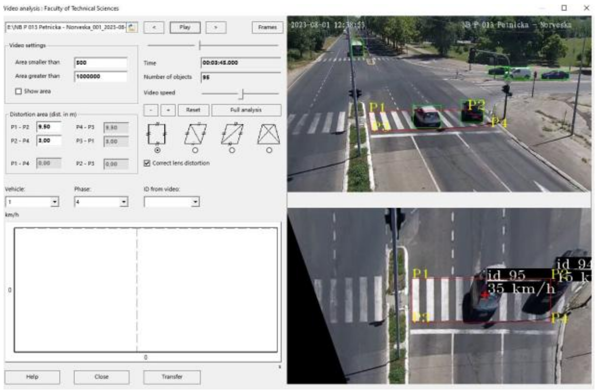


Fig.3 *Rectified view of the pedestrian crossing with identified vehicle speed*

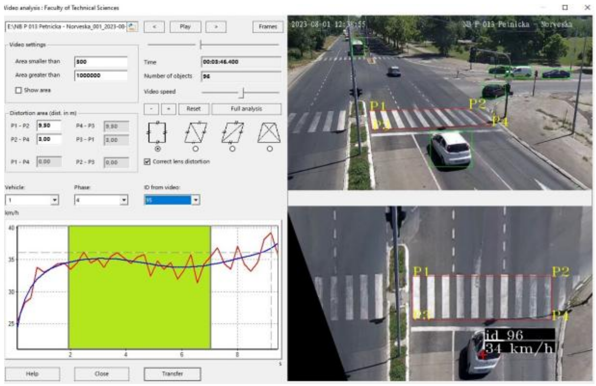


Fig.4 *Diagram of the speed of movement of the identified vehicle included in the video*

3. Reliability analysis of the speed of vehicle movement determined by video rectification

In order to determine the reliability of the speed of vehicle movement based on video analysis using the AnalyzerPro software, an experimental study was carried out in which the recorded speeds of the vehicle moving through the polygon created, obtained by rectification, were compared with its speeds measured in different ways. To do this, a speed limiter installed in the vehicle was used for each of the specified speeds, so that it could not exceed the speed defined by the threshold of the maximum set value. In addition, a hand-held Buschnel speed radar was used in the research.

The tests were carried out in city traffic at target speeds of 30, 35, 40, 45, 50, 55 and 60 km/h. It is important to note that even the target speeds set by the limiter and those measured by the handheld radar did not give absolutely identical results, so that at the target speeds mentioned there was a certain difference between the speeds set by the limiter in the car and those measured by the handheld radar.

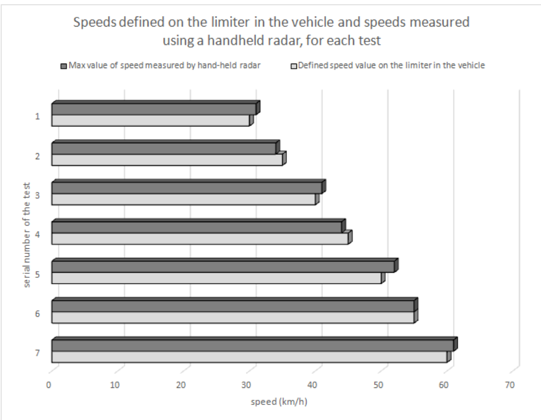


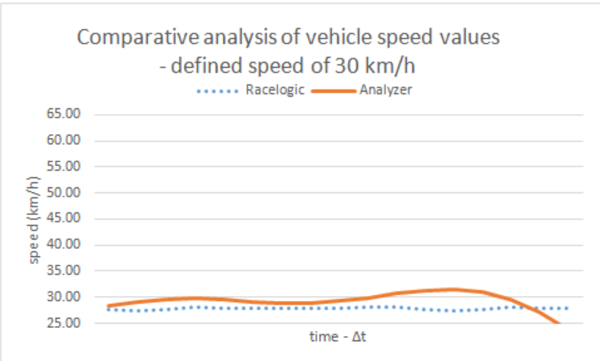
Fig. 5 *Relationship between the target speeds defined by the speed limiter in the vehicle and the speeds measured by the handheld radar*

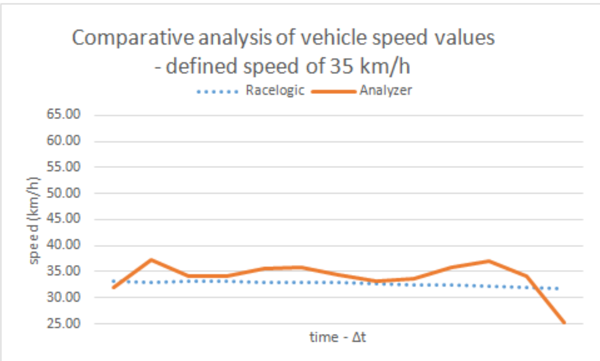
The movement of the vehicle through the training ground was recorded with a Canon G7x camera installed on a fixed mount. The Racelogic Performance Box Data Logger (V Box), installed in the vehicle, which functions on the principle of GPS technology and records current data at a frequency of 10 Hz, was used as the device responsible for accurately determining the speed, route and mode of movement of the vehicle.

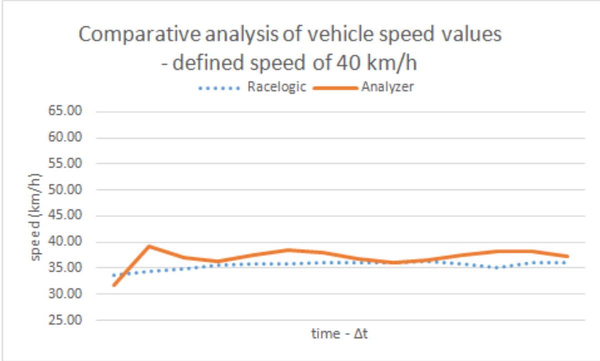
In order to achieve the best resolution of the video and the accuracy of the determined speed, the camera is placed at an angle of about 60o in relation to the road surface. After that, a polygon was formed on the road using four tiles marked with markers, and the distances between them, as well as the diagonals, were measured.

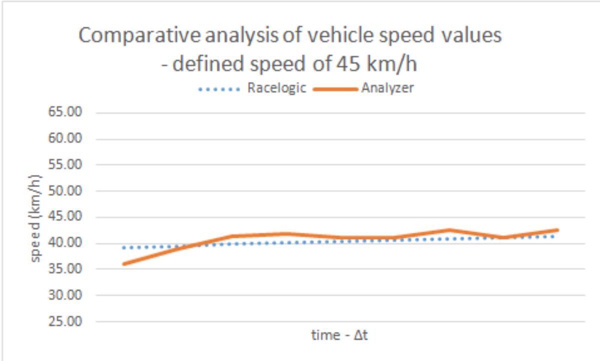
Fig. 6 *Layout of the training ground where the research was conducted*

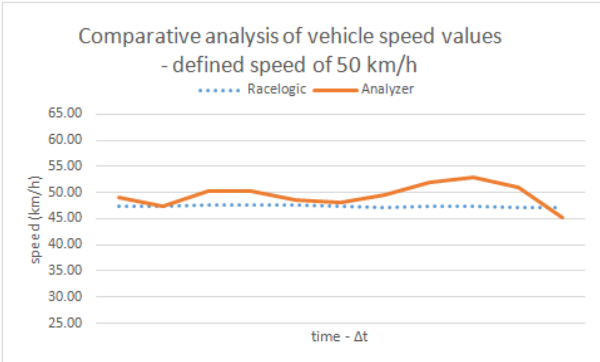
Vehicle movement speeds when passing through the training ground, determined using the AnalyzerPro program, were compared with the tentative target speeds defined by the research, as well as with the speeds determined using GPS technology. The analysis showed that the differences between the speeds determined by rectification and those measured by measuring devices installed in the vehicle are minimal. The comparative view between the targeted, measured and calculated vehicle speeds when passing through the virtual polygon is illustrated in the following diagrams.

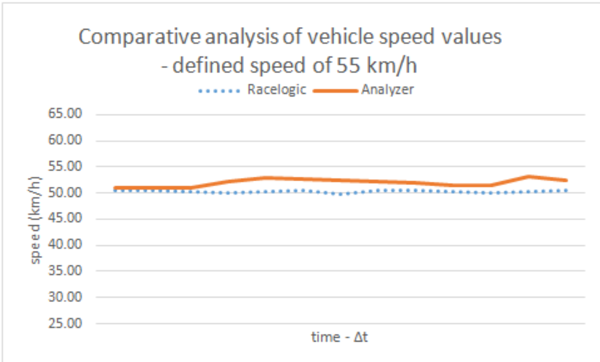












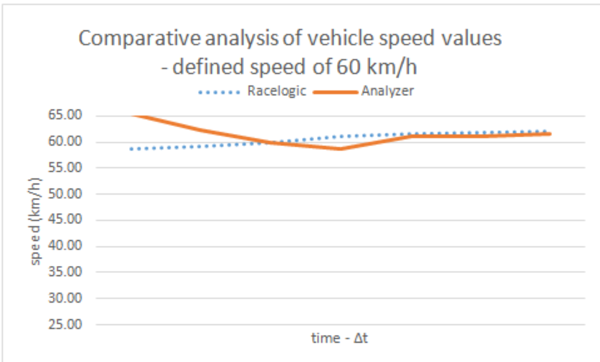


Fig. 7-13. *Comparison between the targeted, measured and calculated vehicle speeds when passing through the virtual training ground at speeds of 30-60 km/h*

4. Conclusion

The application of information technologies in the human environment has become an integral part of modern life. Video technology is mainly used in traffic for the purpose of traffic management, i.e. establishing the mode of movement of vehicles with light signaling in accordance with the traffic load. In addition, video recordings are also used for the purpose of detecting traffic violations and their perpetrators, and increasingly in the process of traffic accident reconstruction. Circumstances included in the video recording related to the occurrence of traffic accidents often represent one of the most important sources of information for their analysis. One of the basic factors in the analysis of traffic accidents is the speed of movement of the accident participants.

Within the AnalyzerPro software package, a module has been developed that provides the possibility to determine the speed of movement of participants in an accident under certain circumstances. Those circumstances imply knowing the distance between at least two characteristic points visible on the surface, if the object is captured by recording a square or rectangular shape, or knowing the distance between all points of the quadrangle, as well as the length of the diagonals.

After the research carried out, which included a comparative analysis between the speeds of the vehicles that participated in the experiment and those determined by rectification, the following can be concluded using the AnalyzerPro program:

- If the video recording includes an orthogonal surface, with known distances between characteristic points, the speed determined based on the analysis of the video can be considered quite reliable for the analysis of the event or traffic accident, which are the subject of the research.
- The error in the calculated speed, i.e. greater dispersion in relation to the "fit" speed curve, due to the constant value of the frequency of the video, increases with the increase in the speed of the vehicle that is the subject of the research.
- The smaller the angle between the position of the camera and the surface covered by the video, the greater the dispersion of the video and the error in the calculation of the speed of the object whose speed is the subject of research.
- Depending on the frequency of the video recording, a smaller dispersion of the actual speeds compared to the speeds determined by the video analysis can be expected at higher speeds of the objects (vehicles) that are the subject of the analysis.

6. References

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