FULLY AUTOMATED REAL-TIME TRAFFIC ANALYSIS FROM VIDEO

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Abstract: This paper describes briefly a fully automated system for traffic surveillance which is able to count passing cars, determine their direction and the lane which they are taking. The system works without any manual input whatsoever and it is able to automatically calibrate the camera by detection of vanishing points in the video sequence. The proposed system is able to work in real time and therefore it is ready for deployment in real traffic surveillance applications. The system uses motion detection and tracking with the Kalman filter. The lane detection is based on clustering of trajectories of vehicles.

Keywords: motion detection, tracking, vehicles, traffic surveillance camera, direction detection, lanes detection, real-time

1 INTRODUCTION

This paper presents a system for fully automated traffic analysis from a single uncalibrated camera. The camera is initially automatically calibrated and then statistics for the monitored traffic are generated. It is possible to use these statistics for many applications, for example simple monitoring of the traffic or more advanced predictions of the traffic flow. The system is currently able to count passing cars, determine their direction and lane which they are using. The classification of vehicles and speed measurement are going to be added in the near future.

2 PROPOSED METHODS FOR TRAFFIC ANALYSIS

This section describes the proposed methods for the traffic analysis which are used in order to achieve the goals which were presented above.

2.1 INITIALIZATION

Prior to running the algorithm for traffic analysis, it is necessary to initialize the system. The initialization focuses on the calibration of the camera by detecting vanishing points in the scene. It is assumed that the principal point is in the center of the image and the vehicles have approximately straight trajectories. Two vanishing points are detected and the third vanishing point and the focal length is computed during the initialization. The detection of the vanishing points is described in detail in paper written by Dubská et al. [1], which is currently submitted to IEEE Transactions on Intelligent Transportation Systems.

2.2 DETECTION AND TRACKING

The vehicle detection is based on motion detection in the video scene. Mixture of Gaussians background subtraction [4] is used for the motion detection. Also, shadow detection [2] is used for higher

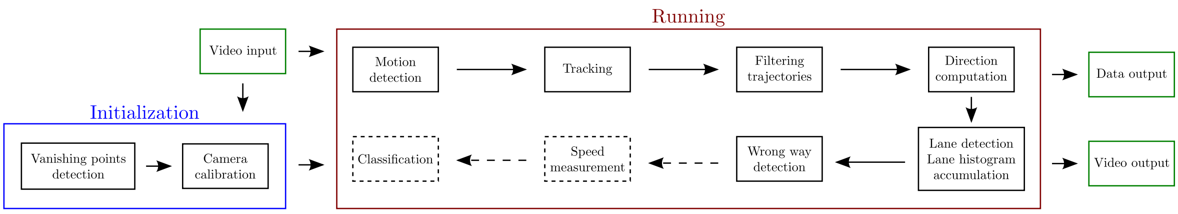

Figure 1: Overall pipeline of processing of the input video stream. The parts of pipeline which will be implemented in the future, namely Classification and Speed measurement, are shown in dashed boxes.

Figure 2: Process of motion detection. The leftmost image represents the original, the next one shows the detected motion with shadows which were removed in the third image. The result after the morphology opening and closing is shown in the last image.

accuracy of the motion detection. Noise in the detected motion is removed by morphological opening followed by morphological closing. Detected connected components are considered to be a potential vehicle. The Kalman filter [3] is used for prediction of the new position of the potential car and associating cars in consequent frames. The state variable of the Kalman filter $(x, y, v_x, v_y)^T$ contains the current position of the car and its velocity in image coordinates. Several conditions are evaluated for a tracked object and if the conditions are satisfied, the object is added to the statistics as a vehicle.

2.3 Direction Estimation and Lane Detection

The estimation of the direction of a vehicle is based on distance of the first and last point of the vehicle's trajectory. If the last point of the trajectory is closer to the first vanishing point, the vehicle is treated as it is going to the first vanishing point. On the other hand, if the first point is closer, the car is going from the vanishing point. The detection of lanes is based on accumulating the trajectories to one-dimensional histogram and searching for local maxima. The accumulation is based on the angle of the trajectories with the horizontal axis of the image. Statistics of the directions of vehicles are created for each lane and these statistics are used for the detection of vehicles which are travelling in the wrong way.

3 ACHIEVED RESULTS

The following section presents the achieved results. The processing speed is 57.97 FPS for a video in resolution 854×480 which contains traffic with high intensity. The processing speed is 28.59 FPS for a Full-HD video sequence and therefore, the system works in real time. The system was evaluated on a machine with Intel Dual-Core i5 1.8 GHz and 8GB DDR3 RAM.

3.1 Detection and Tracking

A manually annotated dataset was created for the evaluation of the accuracy of the detection and tracking of vehicles. For each vehicle in the video sequence, the dataset contains time and position of crossing the vehicle's trajectory with a virtual line. The time and position of the crossings are used for searching correspondences between the annotated vehicles and actually detected objects evaluated as vehicles. The accuracy computation of the detection and tracking is based on these correspondences.

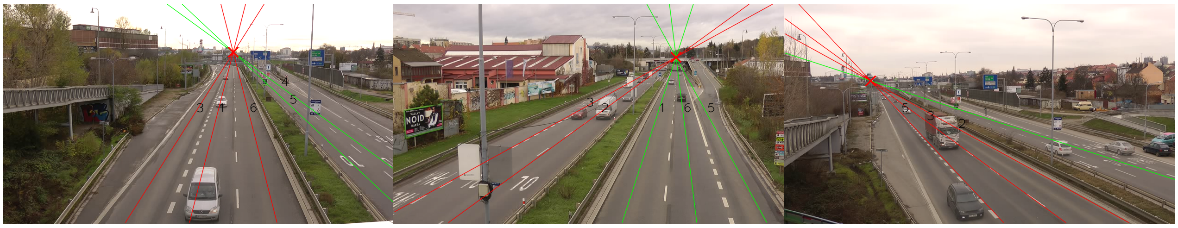

Figure 4: Detected lanes for long video sequences. Green color means that the majority of cars is heading towards the first vanishing point and red color denotes the opposite case. It should be noted that the centers of cars, which are used for lanes detection, are not in the middle of the lanes because of the angle of view.

Configuration providing the best results has F-Measure equal to 0.915 (Precision is 0.905 and Recall 0.925). The False Negative cases are caused mainly by vehicle occlusions. The occlusions are caused either by a shadow which connects vehicles into one connected component or by a situation when a vehicle partially covers some other vehicle. The False Positives are caused primarily by the motion detection incorrectly dividing a vehicle into two objects and both these objects are tracked and treated as vehicles.

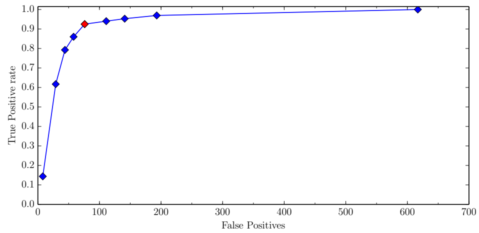

Figure 3: ROC curve of detection and tracking. Configuration with the best F-Measure is marked by red color.

3.2 Direction Estimation and Lane Detection

Several video sequences with a sufficient number of cars were obtained and stability of detected lanes was evaluated for these videos. The detected lanes in the video sequences are shown in Figure 4. The position of the lanes is almost totally stable and does not change with a higher amount of passed vehicles. Also the directions of the lanes were correctly estimated as shown in Figure 4.

4 CONCLUSION

This paper presents a system for fully automated traffic analysis from a single uncalibrated camera. The camera is automatically calibrated, vehicles are detected, tracked and their direction is computed. Also, the lanes are detected and therefore cars travelling in the wrong way can be detected. The system is ready for deployment and it is currently used for online traffic analysis. Future development will focus mainly on classification of the vehicles and speed measurement.

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