Review of Dissertation Thesis

Title: Vehicle Speed Measurement Using Stereo Camera Pair

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I was asked to review the above stated Ph.D. thesis dated from August 2020. The thesis has 61 numbered pages and consists of eight chapters (1. Introduction, 2. Image acquisition and feature detection, 3. Vehicle speed measurement, 4. Stereoscopic measurement and calibration methods, 5. Proposed method for vehicle speed measurement, 6. Experimental results of the proposed method, 7. Possible applications and future work, 8. Conclusion). I was given the thesis in electronic form, including the papers of the applicant.

In the thesis, a method is proposed for measuring the speed of vehicles in traffic; stereo camera pair is used for this purpose. Special attention is given to the precision and reliability of speed measurement with the goal that the method, software, and device can be used by the corresponding authorities for enforcing the speed limits. For this scenario, certain legislative requirements must be met, e.g. the parameters like measurement range, precision, and accuracy must be better than certain required values. The requirements are quite severe if the device is to be used for the mentioned purpose. I believe that it is quite difficult to achieve the parameters that are required by the system that is based on a usual stereo camera pair.

My overall opinion about the method that is proposed by the author is the following one: The method is based on detecting the license plates, on tracking the plates in time, on finding the correspondences between the images from both cameras, on selecting several points in each license plate whose positions are detected and that are used for tracking and finding the correspondence, and on the use of Kalman filtering for tracking. From the point trajectories, the speed and acceleration are computed. Although the principle of all the particular steps must certainly be regarded as known, the details of how they are exactly used and organised in the whole system is also important, which I regard as the main contribution of the thesis. Without sophisticated and effective organisation of the whole system, it would not be possible to achieve the parameters that are needed for the given purpose and that have been really achieved as the author shows in the thesis. Moreover, the author proposes a method for calibrating the camera pair (extrinsic parameters). Again, it seems to me that the method is built on the thoughtful use of the known basic principles that are put together in the way that gives rise to a calibration method that is suitable in the environment for which it is intended.

In Chapters 1-4, the needed background is presented, which is done in an appropriate way. The presentation in these chapters is brief, but sufficient to provide the reader with what is needed in the chapters that are focused on the new method itself.

The method of measuring the speed and the method for calibrating the stereo camera pair are described in Chapters 5.1 and 5.2, respectively. In essence, I understand the principle of both the methods. However, It seems to me that it was possible to provide the reader with more relevant details, which especially holds for the method of camera calibration; Chapter 5.2 should contain more details according to my opinion. I cannot imagine, for example, how the “calibration vehicle” is exactly realised if its exact speed and acceleration should be known. The usual in-car tools would not probably be precise enough, measuring from the outside of the car would probably be

impractical. I am aware of the further notes regarding calibration that are done in Chapter 6. However, it seems to me that it would be appropriate to present the method of calibration as a whole consistently in one place, i.e. in Chapter 5.2 in this case. Moreover, I do not understand quite clearly the logic behind choosing the weight in Formulas (5.7), (5.8). Altogether, it seems to me that more information should be presented in Chapter 5.2 as well as in Chapter 5.1 since they are the core of the thesis. Chapter 6 is divided into the four subchapters (6.1 Prototype hardware, 6.2 Dataset and reference data, 6.3 Implementation, 6.4 Results). In this chapter, the author present the results showing that his method is better than the methods that were used for comparison, which I appreciate. I also appreciate that the needed hardware was constructed, and that the method and hardware were tested in the conditions of real traffic. On the other hand, I am still in doubts whether I understand correctly the way how the calibration was exactly done, e.g. what and how was exactly measured to obtain the values of $d_{i,i+1}$. What should be exactly shown by the distribution in Fig. 6.4? Is it safe to relay on the timestamps that are generated not in the camera, but in computer after receiving UDP packets?

In the Scopus database, I have found three papers of the author. One of them is focused on the topic of the thesis, which may be regarded as a not very high number. On the other hand, it is a paper in a respectable journal (IEEE Transactions on Intelligent Transportation Systems), which I appreciate.

On the whole, it seems to me that the thesis is relatively short. This is in contrast to the fact that, according to my opinion, the solution proposed by the author could be described with more details in several places. As an illustration only, I note that the most important chapter describing the speed measurement (Chapter 5.1) corresponds one to one to what is presented in the paper mentioned above. According to my opinion, the thesis usually provides a broader background for papers and usually contains more details since the papers are often restricted in size.

Summary: The author has solved the problem that is technically demanding. The results reported by the author are better than the results of the other state-of-the-art methods that were used for comparison. The method presented in the thesis was accepted to a respectable journal. On the basis of all this, *I recommend the thesis for the defense*.

Ostrava, May 7, 2021

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