Assessment of the bachelor thesis by Oleh Rybkin

Robust Focal Length Computation

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The goal of the thesis was to study a special case of camera self-calibration, the focal length computation, from fundamental matrices. This is an old problem that received great attention 30 years ago in works by Hartley, Sturm and Bougnoux. An elegant formula for solving the problem was presented by Bougnoux in 90's but it was believed that it was a ``not a good approach due to numerical instability". It was found that Bougnoux formula often gave imaginary focal lengths, which was considered a great flaw rendering the approach useless. Since then, the problem has been revisited by many researchers, e.g. Hartley, Kanatani, Torii, Sattler and their co-authors, again and again, for the last 20 years.

The thesis presents three main contributions.

First, it presents an experimental evidence that Bougnoux formula is not as ill-behaving as it was believed. Interestingly, the ratio of the absolute values of the squares of the focal lengths is quite stable. Also, it shows that degenerate situations are not always as harmful as it was believed since most degenerate cases of intersecting optical axes are resolved by measurement noise or by adding negligible perturbation to measured data.

Secondly, algebraic analysis of the constraints on up-to-focal-length calibrated cameras revealed that: (1) the algebraic constraints on the so calibrated fundamental matrices are identical to the algebraic constraints on completely uncalibrated fundamental matrices, (2) additional constraints are semi-algebraic, and (3) Bougnoux formulas are just one of the three possible sets of formulae. It allows to resolve certain degenerate cases. Although this was already derived by geometrical arguments, the thesis provides the first clear and fully algebraic derivation of this result.

Finally, the thesis presents an improved algorithm for focal lengths computation based on using the ratio of focal lengths in a Hartley-like optimization approach. Figure 5.3. shows a dramatic improvement in the quality of the focal lengths computation. The new method delivers 40% more correct results at 20% focal lengths computation error. Even better results are reported by using a variation of Chandraker's algorithm, which is based on a solver created by Z. Kukelova. It beats all other prior-based solvers by a large margin. This is an interesting and practical result that calls for publishing.

All three contributions of the thesis are going beyond standard BC theses by the result, by the methods used, as well as by the quality of the presentation.

Oleh Rybkin was a very motivated, capable, and hard-working student. He started our collaboration already during the first year of his studies by looking at a difficult work from algebraic geometry by D. Cifuentes and P. Parrilo. The work dealt with Groebner basis computation by chordal elimination in some special situations. He studied the basics of algebraic geometry from good books on his own and found a mistake in the implementation of the algorithms presented in that work. Later, he continued with working on the robust focal lengths computation problem. Oleh visited INRIA Paris in the summer of 2016, he will be visiting Tokyo Institute of Technology this summer and he will start studies towards PhD at the University of Pennsylvania in fall of 2017.

Oleh Rybkin presented a very professional research work and fulfilled all the goals set in the assignment. He mastered advanced techniques in the field and contributed by several new results.

I believe that this work is *excellent (A)*.

Prague, 12 June 2017

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