Assessment of the master thesis by Petr Hrubý

Efficient Homotopy Continuation for Multi-View Geometry

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The goal of the thesis was to investigate whether and how homotopy continuation can solve difficult minimal problems in computer vision in a time that is practical for real applications.

Existing symbolic-numeric solvers provide efficient and stable solutions to simple minimal problems. However, they fail to deliver practical solutions for hard problems. There are two reasons for that. First, symbolic elimination suffers from the exponential complexity of Groebner basis construction. Secondly, hard problems often lead to polynomial systems with many spurious solutions, which appear due to algebraic formulation and do not correspond to geometrically meaningful configurations. Previous attempts at solving hard problems by homotopy continuation removed symbolic manipulations but still failed to deliver a practical method due to solving for all spurious solutions.

The thesis of Petr Hrubý develops a method that combines optimized homotopy continuation with machine learning to remove solving for all spurious solutions. The method has been developed for the well-known five-point problem for computing two-view calibrated camera geometry and applied to the problem of four points in three views. The four-point problem has 271 spurious solutions and is very difficult. Despite all the effort in the last 15 years, no efficient solver has been found for this problem. The best homotopy continuation solvers for similarly difficult problems run for about 500 milliseconds. In 2004, the runtime in order of milliseconds had been reported for a very carefully designed approximation of the four-point problem. However, no implementation of that technique is available.

Petr's thesis trains a model that predicts where to start a single path homotopy continuation to find the right solution. He implemented a complete solver efficiently in C++ and evaluated it on the state-of-the-art data in computer vision. His method can, in 80 microseconds, successfully solve about 25% of inputs. Hence, when used in RANSAC, four samples suffice on average to obtain a valid candidate of camera geometry in 320 microseconds. He thus achieves about 1000 times speedup w.r.t. the best general methods available. Most importantly, his approach can be generalized to other hard minimal problems in multi-view geometry and thus opens a way to solving many problems that seemed impractical until now. I believe that this is a breakthrough in solving minimal problems.

Petr is an excellent independent student. He brings his new ideas and implements them to make them work. He can grasp advanced mathematical concepts and combined them with high-quality engineering. Petr presented very professional research work far exceeding the master thesis level. He fulfilled all the goals set in the assignment and presented a new approach to solving challenging problems in the geometry of computer vision.

His work is exceptional. I grade it as excellent (A).

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