HYPERACCURATE LEAST SQUARES AND ITS APPLICATIONS

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Fitting an algebraic equation to geometric measurements is one of the first steps of many image processing and computer vision applications. For example, we often fit lines and curves to noisy points in 2-D and planes and surfaces in 3-D. Computing geometric characteristics such as fundamental matrices and homographies of multiple images can also be viewed as fitting an algebraic equation in a high-dimensional space.

A naive method for solving this problem is *least squares*, also known as *algebraic distance minimization*, minimizing the sum of squares of terms that should be zero in the absence of noise; the solution is obtained by solving eigenvalue problems without any iterations. However, this is known to be of low accuracy. Today, it is well known that high-accuracy estimation requires methods based on maximum likelihood (ML) that incorporate statistical characteristics of noise.

The main difficulty of all ML-based methods is that they are highly nonlinear optimization, requiring iterations, which may not converge in the presence of large noise. Also, an appropriate initial guess is necessary to start the iterations. Thus, accurate algebraic procedure that yields high accuracy solution, even though it is not exactly optimal, is very much desired.

We propose a new approach to improve the algebraic fitting based on least squares to the utmost accuracy, which we call *hyperaccuracy*. Assuming Gaussian noise, we analyze the error of a general parameterized algebraic fitting scheme up to high order noise terms and adjust the parameters so that the resulting solution has the highest accuracy. We apply our analysis to circle/ellipse fitting [1, 3] and homography computation [2]. By simulation, we demonstrate that our approach indeed produces an accurate solution even in highly noisy situations where ML-based iterations fail to converge.

References

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