References

[1]Kasdin, N. J., "New, Guaranteed Positive Time Update for the Two-Step Optimal Estimator," *Journal of Guidance, Control, and Dynamics*, Vol. 23, No. 2, 2000, pp. 215–221.

[2]Garrison, J. L., Axelrad, P., and Kasdin, N. J., "Ill-Conditioned Covariance Matrices in the First-Order Two-Step Estimator," *Journal of Guidance, Control, and Dynamics*, Vol. 21, No. 5, 1998, pp. 754–760.

[3]Kasdin, N. J., and Haupt, G. T., "Second-Order Correction and Numerical Considerations for the Two-Step Optimal Estimator," *Journal of Guidance, Control, and Dynamics*, Vol. 20, No. 2, 1997, pp. 362–369.

Reply by the Author to M. Lisano

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THE comment by Michael Lisano examines the comparisons made between the two-step optimal estimator (TSOE) in previous papers of mine and the extended Kalman filter (EKF). It is stated in his comment, and substantiated with a short simulation, that the EKF only shows the large biases relative to the TSOE when large deviations from truth are introduced in the initial conditions. For initial conditions with very small error, the EKF is shown to work quite well with very low biases.

This is certainly true. In the various papers on the TSOE, I try to show that the primary disadvantage of the EKF relative to the TSOE is in its linearization about the previous state estimate in the cost function. If the a priori error is large, then the linear approximation is a poor one, and the EKF can grossly underestimate the true covariance, resulting in potentially large biases Certainly, the better the a priori estimate, the more accurate the linearizing approximation becomes, and thus the more likely the EKF is to perform well. The EKF has been used successfully on many systems where this is the case.

Unfortunately, this situation cannot always be arranged in practice. There are certainly many situations where there is little or no a priori knowledge, and thus it is impossible to guarantee initial conditions with small error. The TSOE was developed in an effort to find a more robust estimation scheme that would perform with little or no initial knowledge. When dealing with nonlinear systems, it is rarely possible to develop a scheme that works in all situations. Rather, we develop an arsenal of techniques that can be applied. I certainly agree that for situations where the initial conditions are such that the EKF is an effective approximation it can be used without concern. It may also save on some computational burden over the TSOE. However, the TSOE provides a tool for those nonlinear estimation problems where the EKF fails. I also claim that, independent of any differences in computational complexity, the TSOE will always perform at least as well as the EKF for problems with small initial error (and increasingly outperform it for problems with large initial error).

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