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Kalman filter control of a model of spatiotemporal cortical dynamics

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Introduction

In 1809, Carl Frederic Gauss [1] dealt in depth with problem of estimation of planetary and comet orbit parameters when the terrestrial observational data was sparse and imprecise. Gauss's problem bears strong resemblance to the problem we face in the estimation of neuronal state through electrical or optical measurements. Recent advances in Kalman filtering to estimate system state and parameters in nonlinear systems has offered the potential to apply such approaches to spatiotemporal neuronal systems. We here adapt the nonlinear method of unscented Kalman filtering (UKF) to observe the state and estimate parameters in a computational spatiotemporal excitable system that serves as a model of cerebral cortex.

Methods

We employ the modifications to the Wilson-Cowan equations as suggested by Pinto and Ermentrout [2], to model an experimental system in which we measure the wave dynamics of mammalian middle cortical layers using voltage sensitive dye. Employing a strategy of UKF suitable for neuronal models [3], we adapt covariance inflation from meteorological modeling to compensate for higher order errors known to occur in UKF [4].

Results

We demonstrate the ability of an observer UKF (Figure 1A) to track spiral wave dynamics (Figure 1B), and to calculate control signals delivered through applied electrical

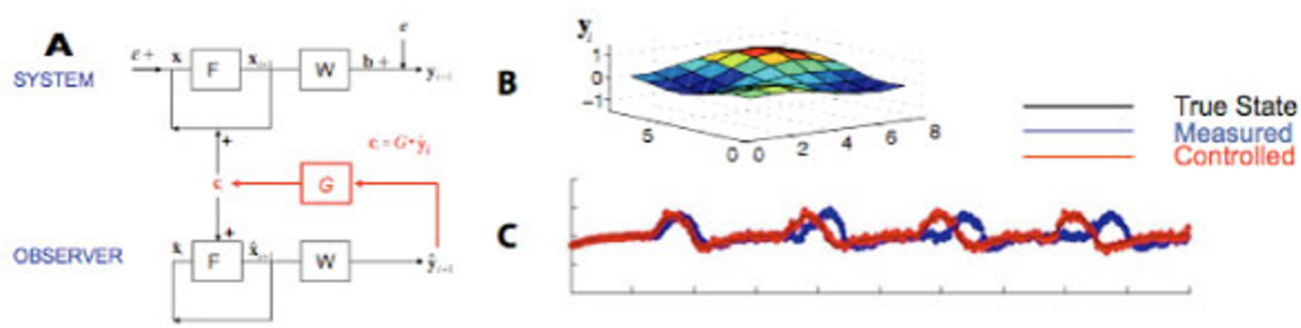

Figure 1
A: UKF schematic, B: activity variable in 8 × 8 grid, and C: time trace of activity from one grid cell.

fields in a manner that can be implemented experimentally. We demonstrate how this strategy can control the frequency of such a system, or quench the wave patterns, while minimizing the energy required for such results (Figure 1C).

Discussion

We have, to our knowledge, demonstrated the first computational framework to apply nonlinear Kalman filtering to track and control spatiotemporal cortical neuronal activity. The use of a Kalman observer permits state variable reconstruction and parameter estimation under conditions where direct proportional control calculated from measured variables would fail. In experimental applications, employing an observer UKF to generate the control signal can substantially reduce the control energy required to increase or decrease the frequency of oscillations, or to quench wave activity. We are adapting these findings to models of Parkinson's disease dynamics, and to experimental applications in control of cortical waves, control of hippocampal rhythms in navigating animals, and the extraction of features from EEG in brain machine interface paradigms. These results are in press in [5].

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References

1. Gauss CF: **Theory Of The Motion Of The Heavenly Bodies Moving About The Sun In Conic Sections.** In *C F Davis translator Boston: Little, Brown and Company*; 1857.
2. Pinto DJ, Ermentrout GB: **Spatially Structured Activity In Synaptically Coupled Neuronal Networks: I. Traveling Fronts And Pulses.** *SIAM J Appl Math* 2001, **62:**206-225.
3. Voss H, Timmer J, Kurths J: **Nonlinear dynamical system identification from uncertain and indirect measurements.** *Int J Bif Chaos* 2004, **14:**1905-1933.
4. Hunt B, Kostelich EJ, Szunyogh I: **Efficient data assimilation for spatiotemporal chaos: A local ensemble transform Kalman filter.** *Physica D* 2007, **230:**112-126.
5. Schiff SJ, Sauer T: **Kalman Filter Control of a Model of Spatiotemporal Cortical Dynamics.** *Journal of Neural Engineering* 2008 in press.