Event-Based State Estimation in Networked Control Systems

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Abstract:
The problem of state estimation in a networked control system with multiple sensor-actuator agents is considered. The agents are spatially distributed along a dynamic system, and they can share their sensor data over a communication bus. The objective is to maintain an estimate of the full system state on each agent while, at the same time, reducing the exchange of sensory data over the network. This work is inspired by the Balancing Cube, a cube that can balance autonomously on any of its corners through the action of six rotating arms, which constitute the agents of the control network (www.cube.ethz.ch).

An event-based approach is used to address the state estimation problem. The common bus allows each agent to run a copy of a so-called common estimator which operates only on the sensory data that has been broadcast over the network. Hence, its estimate represents the common information in the network. Each agent compares its local measurement against the common estimate of that measurement, and it transmits the measurement only if it is required to meet a certain estimation performance. The estimators themselves are implemented as time varying Kalman filters handling the varying set of available measurements.

Different rules for making the transmit decision are conceivable. One such rule is to transmit a measurement if its associated prediction variance grows too large. For this scenario, the variance of the event-based Kalman filter evolves according to a new type of Riccati iteration with switching based on the available set of measurements. Based on simulation results, the variance sequence typically converges to a periodic solution of the switching Riccati equation. For the scalar, single sensor case, we prove conditions that guarantee the global convergence to a periodic solution.

Experimental results of applying the event-based state estimation technique for feedback control on the Balancing Cube are discussed.