Recursive Hybrid Filter for Systems with Mixed Observations

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The presented work deals with online state estimation for dynamic hybrid systems with mixed continuous and discrete observable and non-observable variables. Dynamic systems that show both continuous-time and discrete-valued behavior are met in many fields (target tracking, image processing, speech recognition, traffic control, etc.) Modeling and especially adaptive control of such hybrid systems is a difficult task. Fast online state estimators for hybrid systems are desired in some of these areas.

Many algorithms exist for state estimation of such systems. The well-known approach is the interactive multiple model (IMM) algorithm [1], which performs Kalman filter [2] for each model and then computes a weighted combination of updated state estimates produced by all the filters. The IMM filter is close to that proposed in this paper. A difference is that the presented method takes the state-space model in a general form for both the normal and discrete states along with mixed observations and control inputs.

The proposed solution is based on a decomposed version of the state-space model and Bayesian filtering [3]. The general solution is universal in the sense of exploited distributions. The provided specialization shows usage of the approach with normal and multinomial models. The proposed algorithm performs a joint estimation via Kalman filter and multinomial state estimation.

A part of the proposed work concerned with the estimation of discrete multinomial state is also close to hidden Markov models (HMM) theory [4]. However, the algorithms mentioned run mostly offline and are supported by Monte Carlo computations. The presented paper aims at online state estimation and analytical solution as far as possible. It means that it applies numerical procedures only in that parts, which cannot be computed analytically. The paper exploits a decomposition of state estimate, which enables to consider state as a product of various (here specialized) distributions that is convenient for computations with exponents. An online filter for discrete multinomial state based on fully analytical solution is proposed. The state-space model is taken as the probability (density) function in more general (not reduced) form, including control variables for corresponding distributions.

The presented approach was tested on traffic data with real intensities measured at one of the controlled microregions in Prague. A queue length of awaiting cars was estimated as the normally distributed state jointly with the discrete multinomial level of service (LoS) of the microregion. LoS reflects a degree of traffic saturation in the sense how easy the cars can pass through the microregion with 4 possible values from 1 (the best) to 4 (the worst). The fast online estimation of these states can influence the adaptive control of the intersection via the green light time.

References

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