Guaranteed State Estimation of Biotechnological Systems with Discrete-Time Measurements

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The on-line estimation of component concentration in biological processes is very useful for monitoring and control purposes. However, the availability of hardware sensors is often restricted by cost and operational constraints. When available, these sensors provide measurements at a relatively low sampling rate (e.g. a few hours or even days, depending on the application). Hence, software sensors [1] based on a process model and a few hardware sensors have been developed to reconstruct on-line non-measured variables (as well as variables measured at large sampling periods; see, e.g., [3] for a few applications).

However, most of the state estimation techniques (with the notable exception of the asymptotic observers, which do not depend on the reaction kinetics) require knowledge about the main biological phenomena (reaction scheme, including stoichiometry and kinetics). However, initial conditions, inputs, model parameters and measurements are only known to a certain level (of certainty and accuracy). In order to take consistently into account all these uncertainties, state estimation techniques based on interval algebra have been developed ([4], [2], [5]). Based on intervals bounding the initial conditions, inputs and measurements, this family of observers computes, continuously in time, intervals in which the state variables are guaranteed.

The contribution of this work is to extend selected interval algorithms to handle discrete-time measurements. In this context, measurements are predicted between two sampling instants using the model equations. Three interval methods are analyzed :

- **A plain interval observer**. In this algorithm, the full biological model allows the computation of upper and lower bounds for the actual state vector.
- **An asymptotic interval observer**. A classical linear state transformation [1] is used to eliminate the reaction kinetics from the mass balance equations. The method then relies on guaranteed intervals for the initial conditions, the inputs, the measurements and pseudo-stoichiometric coefficients.
- **A hybrid interval observer**. This latter algorithm combines the plain and asymptotic approaches, taking advantage of the convergence properties of the plain observer (assuming a correct model) and the robustness properties of the asymptotic observer (assuming a nonzero dilution rate).

These observers are tested in simulation, considering CHO (Chinese Hamster Ovaries) cultures.

References

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