Optimal Control with Low-sensitivity to Sampling Period Uncertainty

Anusha Krishna-Murthy
Faculty: John Watkins, Ed Sawan
Department of Electrical Engineering and Computer Science, College of Engineering

In a sampled-data system, a computer is used to control a continuous-time system. Analog-to-digital converters (ADC) are used to convert analog sensor signals to digital signal that can be read by a computer. ADCs use a sample and hold process where the sampling period is prespecified. Although it is set in advance, the sampling period may be subject to small variations during the operation. Such uncertainty may be more likely to occur in large-scale systems. Complex systems whose mathematical equations are difficult to handle due to their higher orders are classified as large-scale systems.

In this paper, we consider the optimal control design of a large-scale sampled-data system. To reduce the impact of potential uncertainty in the sampling period, a sensitivity function is defined to represent the effect of uncertainty on the system performance. A quadratic performance index is considered for the optimal control design and it is to be minimized. Such a performance index is augmented to include the sensitivity function. Minimization of the augmented performance index ensures a reduction of performance sensitivity along with the cost.

When the augmented performance index is formed, it contains an additional term that corresponds to the sensitivity function. Since the system considered is already a large-scale system, the inclusion of the sensitivity parameter only accentuates the difficulty that the resulting mathematical equations pose. It is, therefore, often desirable to reduce the order of the system.
The design procedure is based on a reduced-order model of the original system, which is to be obtained using aggregation techniques. The resulting controller is then adjusted for implementation on the original full-order system.

The sampling period is represented as an embedded parameter of the sampled-data model of a given continuous-time system represented in state space. This is accomplished using the state transition matrix over a single sample. An appropriate aggregation matrix is used to obtain a reduced-order model that sustains the impact of the dominant states. The augmented performance index is minimized using the Pontryagin Minimum Principle. Two controller structures are considered, state feedback and output feedback.

The research focuses on minimizing the cost function while reducing sensitivity to sampling period changes. The cost function is augmented to include a sensitivity variable that represents the impact of such uncertainty on the performance. Minimizing the augmented cost function will achieve both objectives.