PhD Thesis Abstract

Thesis Title: Multi-rate Strategies for Power and Bandwidth Optimization in Embedded Control
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The design of embedded real-time control systems requires careful balancing of control performance and computational bandwidth needs. With the widespread adoption of embedded software based control under the overarching umbrella of *cyber-physical systems*, it has become necessary to share embedded processors among multiple control loops, sometimes belonging to features having widely different sampling rates and control task sizes. It is also not uncommon to have features that are *live* only in some states of the embedded system and *sleeping* in other states. For example, the rear parking sensing feature of an automobile is *live* only when it is in reverse gear.

The dynamic nature of the computational needs of a modern embedded control system, both in response to engaging/disengaging of features and in response to varying control/power performance requirements has highlighted the necessity for re-examining some of the classical practices of control design. The use of multi-rate control as a mechanism for optimizing power, performance and computational resources is one such paradigm of interest to the embedded control community. This thesis presents a bouquet of new methodologies for these tasks.

The primary goal of this research is to study the trade-off between control performance and resource requirements by regulating the rates of sampling the plant and scheduling the control tasks. In our study, we consider various types of resources, including computing resources, power consumption, etc. This thesis demonstrates the benefits of regulating the sampling rates adaptively and to find the methods for doing such adaptive regulation during the execution of the controller. Towards these objectives, the current investigations have led to several problems and their solutions, which are outlined below.

Multi-rate Control for Performance Driven Resource Utilization:

This thesis studies the benefit of partitioning the operating space of a control system and then using controllers with suitable sampling rates in each zone. An algorithmic basis for choosing the sampling rates in various operating zones is provided, without compromising the control performance.

Disturbance Driven Control Optimization using Multi-rate Sampling:

This thesis studies dynamic switching between sampling rates in response to varying levels of input disturbances. A methodology is provided, that uses a pre-synthesized set of sampling modes for different disturbance levels, and develops a set of controllers for these modes.

Multi-rate Sampling for Power-Performance Trade-off:

This thesis develops a methodology for improving the power efficiency of a low power embedded control system without compromising the control performance by using multi-rate control.

Multi-rate Sampling and Stability:

This thesis addresses the stability issues of the multi-rate controllers associated with linear time-invariant control systems and formalizes the basis of selecting the sampling rates for the different sampling modes, such that the overall system stability under arbitrary switching can be guaranteed.