Poster Abstract: Closing the Loop: Towards Control-aware Design of Adaptive Real-Time Systems

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I. Motivation

Current trends, such as mixed-criticality real-time systems, boost performance by leveraging system dynamics and adaptivity, but also amplify challenges for control engineering and real-time-system design. Applications behave more adaptively and more applications will be consolidated on the same real-time system competing for the same resources, turning timing properties of single applications more and more unpredictable.

A presumption of such adaptive systems is that scheduling timing-sensitive applications with better response times will hopefully provide better but in any case not worse quality on the application level. The experiment depicted in Figure 1 disproves this simple assumption: A simulated switch of schedule e. g., when raising criticality, towards better response times for the application induces a short but massive degradation of Quality of Control, as can be deduced from an increase in cost.

This demonstrates that the timing sensitivity of control applications is far more complex than anticipated by most real-time engineers and calls for a close collaboration with control researchers. It needs to be analyzed how scheduling and other decisions in the design process of real-time systems relate the Quality of Control. Based on this, the results of this analysis should be made available in the design process to directly optimize systems with respect to the control application.

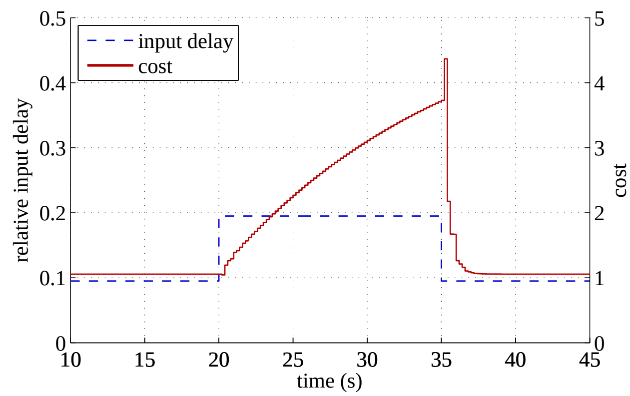

Figure 1. Performance of an inverse pendulum controller with discrete timing properties as anticipated for mixed-criticality scheduling. During low-criticality operation ($20 \leq t < 35$) the input delay was doubled, leading to a slow degradation of control performance. When switching back to the original delay ($t = 35$), the cost first unexpectedly overshot, then slowly decreased.

II. Approach

To address these issues, we propose a continuous toolchain from the original control system model to the resulting schedules. As a first step towards control-aware yet adaptive system design, we focused on a global, context-sensitive analysis of control and data flow across control-application layers and threads of execution. This step is of vital importance as these dependencies manifest differently on the various levels of abstraction. Consequently, we extract semantics and internal dependencies directly from control-system models by an extended version of the Real-Time Systems Compiler (RTSC) [1], which is capable of analyzing and transforming real-time applications on the source code level. Here, an RTOS agnostic intermediate representation is used to retain relevant information so that all real-time activities can be traced back to the control system's building blocks. This allows for end-to-end assessment of execution conditions to determine the actual influence that RTOS decisions have on control systems. Up to this point, a control-aware analysis and synthesis of given real-time control systems is possible. This includes scheduling, I/O-timing and latency. In the future the extracted information will be passed to RTOSes providing such mechanisms to allow for dynamic and flexible scheduling based on the dependencies originally specified by the control engineer. The envisioned traceability also facilitates current research in adaptive control systems as proposed in [2].

References

[1] F. Scheler and W. Schröder-Preikschat, ‘The real-time systems compiler: Migrating event-triggered systems to time-triggered systems’, *Softw. Pract. Exper.*, vol. 41, no. 12, pp. 1491–1515, 2011.

[2] Y. Xu, K.-E. Årzén, A. Cervin *et al.*, ‘Exploiting job response-time information in the co-design of real-time control systems’, in *21st IEEE Int. Conf. on Embedded and Real-Time Comp. Systems and Applications*, 2015.