Beyond Traditional Sampling Strategies for Enhanced Performance and Cost-Effectiveness

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Abstract
In classical motion control applications a single-rate, equidistant sampling scheme is used. This imposes a hard trade-off between cost-effectiveness and performance. The aim of this research is to relax this trade-off through several approaches, including non-equidistant sampling.

Non-equidistant sampling
In order to reduce cost, multiple applications are often executed on a single embedded platform, e.g., in case of visual servoing, where the resource allocation is taken care of by a scheduling policy. Due to the scheduling, the applications are sampled in a non-equidistant sampling sequence, as illustrated in Fig.1. Realizing equidistant sampling on such platforms is inflexible, expensive in terms of resource, and conservative in terms of performance since control points are discarded. This can be observed in Fig. 1 where the non-equidistant sampling sequence (red) has a control point at time Δ^0, whereas equidistant sampling sequence (yellow) does not. Our aim is to relax the equidistant sampling requirement, where a key challenge lies in the fact that typical motion control design approaches are not directly applicable in this situation.

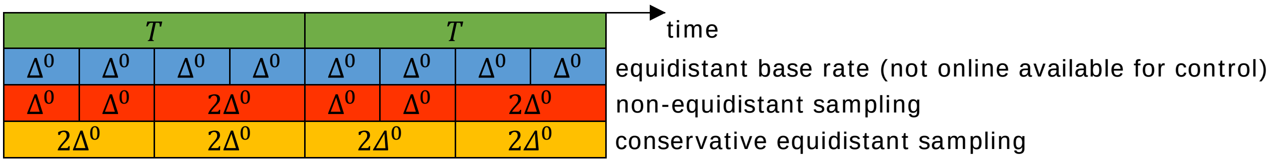

Fig.1 Example timeline of different processes executed on a single processor. Due to platform limitations, the equidistant base rate (blue) is not available for online control. The non-equidistant sampling (red) is available for control and provides an additional control point in each period (green) compared to conservative equidistant sampling (yellow).

Relaxing this requirement is possible due to recent developments in embedded platforms such as the Composable and Predictable System on Chip (CompSOC) platform [2]. The platform composability allows for independent development of multiple applications, while predictability provides precise temporal behavior of the platform. The combination results in a set of known, precise, and periodically varying sampling periods, see Fig.1.

Currently, we are developing a control design framework that exploits the non-equidistant sampling and can potentially break the traditional performance/cost trade-off. Our approach is based on a finite-time lifted representation of the system. The framework enables optimal (feedforward) controller design incorporating non-equidistant sampling. A preliminary motion control case study demonstrates the benefit of exploiting non-equidistant sampling, see Fig.2.

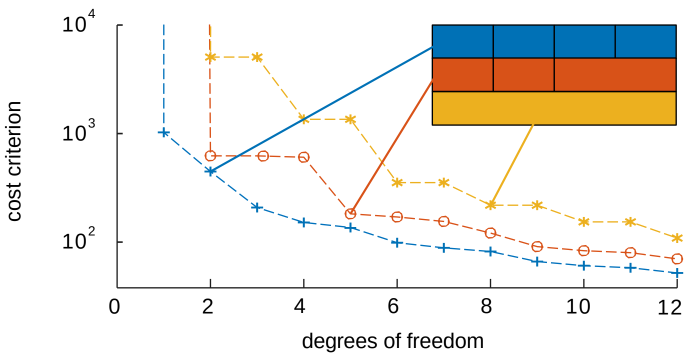

Fig.2 Performance criterion V^0 (lower is better performance) as function of the number of feedforward filter parameters for the three different sampling sequences of Fig.1. Due to the additional control point, the non-equidistant sampling sequence (red) yields better performance than the conservative equidistant sampling sequence (orange).

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References
[1] Zundert J. van, Oomen T., Goswami D., Heemels W.P.M.H., On the Potential of Lifted Domain Feedforward Controllers with a Periodic Sampling Sequence. In Proceedings of the 2016 American Control Conference, Boston, MA, 2016.

[2] Goossens K., Azevedo A., Chandrasekar K., Gomony M.D., Goossens S., Koedam M., Li Y., Mirzoyan D., Molnos A., Beyranvand Nejad A., Nelson A., and Sinha S., Virtual Execution Platforms for Mixed-Time-Criticality Systems: The CompSOC Architecture and Design Flow. ACM SIGBED Review, 10(3):23–34, October 2013.