# Review of PhD Dissertation Thesis

**Title**: *Scalable Scheduling Algorithms for Embedded Systems with Real-Time Requirements*

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**Reviewer**: Dr.-Ing. Ramon Serna Oliver

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**Review:**

The efficient allocation and planning of resources in complex embedded systems, like those designed to fulfill the requirements of modern automotive services and industrial automation needs, are currently trending topics in industry. The time-triggered paradigm is often pictured as an enabler to provide strict guarantees for the allocation and scheduling of core resources, like CPU and network bandwidth. However, system configuration enforcing these guarantees are not easy to compute as time-triggered scheduling is known to be an NP-hard problem, which entails an exponentially scaling complexity.

The scientific community has studied the adoption of the time-triggered paradigm in the context of safety and mix-criticality systems since many years, partly motivated by the increasing complexity of industrial embedded system designs. As surveyed in this dissertation, multitude of reference architectures and scheduling algorithms have been developed and analyzed in existing literature. Nevertheless, the problem of scalability for large industrial use-cases, addressed by the author, remains as one of the main barriers to generalize the adoption of the time-triggered paradigm in safety-critical real-time embedded systems.

This work documented in this dissertation extends the current state-of-the-art with the contribution of several heuristic-based time-triggered scheduling algorithms exploring domain-specific knowledge. In building them, the author considers a reasoned number of trade-offs balancing the optimality of the solutions with respect to the capability to scale up to realistically-sized domain problems. In fact, having a focus on the automotive domain enables the author to customize the proposed algorithms and metrics to efficiently solve the target problem. Further, the evaluation of these algorithms is performed by contrasting them against exact methods derived from abstract system models as well as the underlying technological constrains. This analysis renders an objective comparison framework exposing the gains in performance as well as the lose in optimality. Moreover, by mostly using a domain representative set of benchmarks, provided by one of the lead industrial players in the automotive sector, the authors ensure to be working within realistic use-case assumptions adding credibility to the evaluation and conclusions of this work.

I personally find the organization and structure of this document well suited for its purpose. Three different problem statements with increasing complexity are presented and explored with

a deep analysis of the current approaches in the state-of-the-art. For each problem, a system model is built and a set of exact methods, based on satisfiability modulo theories (SMT), integer linear programming (ILP) and/or constraint programming (CP), are constructed. The proposed heuristic algorithm is then contrasted against the exact methods via a set of benchmarks resulting in an extensive evaluation of the results.

Besides the heuristic algorithms this thesis exposes interesting findings, which I consider valuable for future developments in the field. I find particularly interesting the analysis on the suitability of ILP vs SMT methods in finding solutions depending on the problem complexity, which can serve as a guidance to engineer incremental and compositional methods. I also appreciate the variety of methods employed to contrast the proposed heuristics (SMT, ILP, CP), which enriches the evaluation and lowers the level of inherent bias in the comparison.

Overall, the presentation of this dissertation has been carefully addressed. It is well written and thoroughly documented, including significant references to the state-of-the-art and an extensive survey of related work. The models and algorithms documented in this work are valuable contributions to the scientific community and fully satisfy the proposed objectives in this dissertation following a correct and well-structured methodology.

On the basis of the above considerations I gladly conclude the following:

**The author of the thesis proved to have an ability to perform research and to achieve scientific results. I do recommend the thesis for presentation with the aim of receiving a Ph.D. degree.**

Sincerely,

SERNA OLIVER, RAMON (FIRMA)

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