Model-Based Cross-Design for Wireless Networked Control Systems with Limited Resources

Modellgestütztes Cross-Design für funkbasierte Regelungssysteme mit beschränkten Ressourcen

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Abstract

English- This work shall provide a foundation for the *cross-design* of wireless networked control systems with limited resources. A *cross-design* methodology is devised, which includes principles for the modeling, analysis, design, and realization of low cost but high performance and intelligent wireless networked control systems. To this end, a framework is developed in which control algorithms and communication protocols are jointly designed, implemented, and optimized taking into consideration the limited communication, computing, memory, and energy resources of the low performance, low power, and low cost wireless nodes used. A special focus of the proposed methodology is on the prediction and minimization of the total energy consumption of the wireless network (i.e. maximization of the lifetime of wireless nodes) under control performance constraints (e.g. stability and robustness) in dynamic environments with uncertainty in resource availability, through the joint (offline/online) adaptation of communication protocol parameters and control algorithm parameters according to the traffic and channel conditions. Appropriate optimization approaches that exploit the structure of the optimization problems to be solved (e.g. linearity, affinity, convexity) and which are based on Linear Matrix Inequalities (LMIs), Dynamic Programming (DP), and Genetic Algorithms (GAs) are investigated. The proposed *cross-design* approach is evaluated on a testbed consisting of a real lab plant equipped with wireless nodes. Obtained results show the advantages of the proposed *cross-design* approach compared to standard approaches which are less flexible.

German- *Diese Arbeit soll die Grundlage für das Cross-Design von funkbasierten Regelungssystemen mit beschränkten Ressourcen legen. Es wird eine Cross-Design Methodik entwickelt, welche gleichzeitig die Ebenen Control (Regelalgorithmus), Communication (Protokolle) und Computing (Energie, Speicherkapazität und Rechenleistung) betrachtet. Ziel dieser Methodik ist der gemeinsame Entwurf von Regelungsalgorithmen und Kommunikationsprotokollen, die aufeinander abgestimmt werden, unter Berücksichtigung von beschränkten Ressourcen, wie Rechenleistung, Energievorrat und Speicherkapazität, der eingesetzten Funkknoten. Eines der Hauptziele ist die Vorhersagbarkeit und Optimierung der Lebensdauer der Funkknoten bei gleichzeitiger Einhaltung einer Mindestregelgüte in dynamischen Umgebungen mit Unsicherheiten bei der Verfügbarkeit von Ressourcen, durch eine gemeinsame (offline/online) Anpassung der Reglerparameter und Protokollparameter an Kanal- und Traffic-Zustände. Methodisch gesehen werden unterschiedliche Formen der Optimierung unter Einhaltung von Nebenbedingungen und Betrachtung der Eigenschaften (z.B. Linearität, Affinität, Konvexität) untersucht, sowohl auf Basis der Linearen Matrixungleichungen (LMIs), Dynamische Programmierung (DP), als auch der Genetischen Algorithmen (GAs). Die Garantie einer Mindestlebensdauer der Funkknoten bzw. deren Optimierung ist dabei das Hauptziel. Die vorgeschlagene Cross-Design Methodik wird an einem Testbed, bestehend aus einer realen Regelstrecke und ausgewählten Funkknoten, evaluiert. Ergebnisse zeigen die Vorteile des Cross-Design-Ansatzes gegenüber Standardansätzen, die weniger flexibel sind.*

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Kaiserslautern, May 2013

Alain Chamaken

In memory of my father KAMDE NGANDJUI Claude Laurent
R.I.P.

To Ulrich Adrien, Fayola Chanecia, Lise Gäelle and Line Chloe

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