Ain Shams University

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Model Predictive Control (MPC) On Chip

A Thesis

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All praise be to Allah the High, “who teacheth by the pen, teacheth man that which he knew not.”, Quran[96:4, 96:5]. I say what Prophet Solomon said: “· · · O my Lord! so order me that I may be grateful for Thy favours, which thou hast bestowed on me and on my parents, and that I may work the righteousness that will please Thee: And admit me, by Thy Grace, to the ranks of Thy righteous Servants.”, Quran[27:19]

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Abstract

Applying a computationally intensive control algorithm inside an embedded time-safety-critical application represents a Cyber-Physical challenge. This thesis applies Generalized Predictive Control on automotive active suspension system. The main objective of any automotive active suspension system is to achieve an acceptable behavior, i.e., ride comfort, over a range of working frequencies while minimizing the exerted energy. Thesis objective is to proof the ability of using time-consuming advanced control algorithms on time-safety-critical embedded applications while satisfying tight real-time constraints.

Digital model identification is carried out for an automotive active suspension system, which is then used for numerical simulation of the process and the design of digital controller filters. Frequency and time response of the process are studied in order to emphasize on the challenges of the closed loop control over a networked and embedded control system. An experimental environment based on an automotive CAN channel is used to apply identification and real-time closed loop experiments.

Experimental results show the efficiency of the proposed controller tuning while giving a considerable minimization of the exerted energy. These results are obtained using an embedded software controller implementation, which is tuned offline and verified against a linearized model of the process. In order to tackle the nonlinearities presented in the process, controller filter should be computed online each sampling period. Software results show real-time challenges in the implementation of the online controller. These real-time implementation challenges are highlighted by profiling the software implementation.

Matrix operations consume a large portion of the overall execution time of the online computation of the controller. A hardware co-processor based on a set of systolic arrays is proposed to meet real-time constraints. The proposed computing system is then integrated inside an ARM-based embedded platform using the state-of-the-art CAP9 technology. The proposed computation system is verified to meet real-time constraints over wide range of tuning parameters.

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