Toward a Science of Cyber-Physical System Integration

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Abstract

System integration is the elephant in the china store of large-scale Cyber-Physical System (CPS) design. It would be hard to find any other technology that is more undervalued scientifically and at the same time has bigger impact on the presence and future of engineered systems. The unique challenges in CPS integration emerge from the heterogeneity of components and interactions. This heterogeneity drives the need for modeling and analyzing cross-domain interactions among physical and computational/networking domains and demands deep understanding the effects of heterogeneous abstraction layers in the design flow. To address the challenges of CPS integration, significant progress needs to be made toward a new science and technology foundation that is model-based, precise, and predictable. This work describes a theory of composition for heterogeneous systems focusing on stability. Specifically, we present a passivity-based design approach that decouples stability from timing uncertainties caused by networking and computation. In addition, we present cross-domain abstractions that provide effective solution for model-based fully automated software synthesis and high-fidelity performance analysis. The design objectives demonstrated using the techniques presented in the paper are group coordination for networked UAVs and high-confidence embedded control software design for a quadrotor UAV.