Model-based Development of Cyber Physical Systems

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Why Model-based Development (MBD)?

Effective systems engineering is fundamental to achieving the national goal of "smart design, smart manufacturing and smart operations," seen widely as crucial to the nation's global competitiveness. As in past generations, end-users want functional, easy-to-use, reliable, secure and safe systems. Today, rapid advances in electronics, control, communications, computing, robotics, software, algorithms, deep learning and readily available modeling tools facilitate myriad architectural possibilities for systems. Integrating these technologies – along with customer requirements and real-time data supplied by embedded and external sensors – while enabling the design of modular, scalable, highly-reliable and secure architectures, requires a multidisciplinary systems approach.

MBD is a rigorous and consistent application of multi-domain modeling tools and techniques integrating deep physics-based models with the control, communication, and computing models for the rapid creation of alternative system design concepts and the evaluation of design trade-offs that are salient for the selection and implementation of optimized designs (considering performance, cost, reliability, safety, security, etc.). A primary element of MBD is a coherent model of the system that supports formal specification and analysis of end-user requirements, design of modular and extensible architectures, and frequent and iterative model-in-the-loop/software-in-the-loop/hardware-in-the-loop verification and validation. Since MBD facilitates testing at the requirements phase, defects are caught and removed earlier, thereby reducing development risks (cost and schedule) through improved design productivity, quality and traceability. These benefits are complemented by enhanced communication and coordination among stakeholders, and by reusability of models across system's life-cycle to reduce operational costs.

MBD Technical Challenges

- Modeling abstractions that evolve with the design of complex, dynamic, multi-mode systems that span the life cycle from concept → preliminary design → detailed design → verification & validation → manufacturing → operations → disposal
- Knowledge integration from data, models and experience-based rules for nominal and off-nominal ("failure") system behavior
- Multi-criteria simulation-based optimization methods for robust design under uncertainty
- Real-time model predictive and adaptive control and decision making
- Integrated design and health management of cyber-physical systems
- Co-simulation, optimization and design of physical, cyber and human elements of a system
- System verification methodologies for performance, reliability, security and maintainability
- Human-system integration and decision support systems

MBD Educational Issues

- How to teach top-down thinking needed for a successful system design engineer using case/project-based learning?
- Multi-domain Modeling
- Formal Methods for Requirements, Verification & Validation
- MBD-based Design Flows for Coordinated, Standardized and Measurable Design Process