

Model-Based Software Tool Suite for the Design of Networked Embedded Control Systems ^{*}

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1 Position Paper

Networked embedded control systems are a key enabling technology for the recent vast increase in functionality of many critical engineering applications such as automotive systems, manufacturing systems, electrical energy systems, medical devices and transportation networks. The recent explosion in the number of processors for delivering greater functionality automation and efficiency provided have set the stage for a new set of advances in the design of networked embedded control systems. The design of network embedded control systems is challenging owing to the hybrid dynamics of the systems, concurrency and the need for establishing real time guarantees for communication protocols, and probabilistic issues arising from the networking protocols and the wireless medium. However, the design of software tools for enabling sophisticated model-based control design becomes an important design challenge.

Model-based design frameworks such as Model-Integrated Computing (MIC) [1], Model Driven Architecture (MDA) [2] and Model Driven Design (MDD) [3], have been advocated to raise the level of abstraction in software tool design by placing stronger emphasis on the use of models in the software tool design process. In some of these frameworks, domain-specific modeling languages (DSMLs) can be defined by the users to ease the complicated task of software tool design by having the DSMLs designed to capture the concepts, relationships, integrity constraints, and semantics of the application domains and by allowing users to program declaratively through model construction. As the application of the model-based approach extends further into safety critical embedded systems, formal specification of the operational semantics of DSMLs is becoming a more crucial issue since any semantic mismatch between DSMLs may result in may produce conflicting results across different tools or cause ambiguity in safety analysis.

Practical and effective development of formal specifications for DSML semantics within model-based tools is challenging, but could positively impact adoption and reuse of these tools. The semantic anchoring methodology [4] is developed to address this design challenge by formally tying DSMLs to some “semantic units.” Each semantic unit is a formal specification that captures the operational semantics of a specific model of computation. These semantic units can also be composed together via a set of well defined operational rules to capture heterogeneous behaviors of systems. The infrastructure for semantic anchoring facilitates the transformational specification of DSML semantics. For example, the semantics of a DSML can be anchored to a well-defined semantic unit, which captures the operational semantics of a model of computation, via model transformation. We believe semantic anchoring can provide a theoretically solid yet practical solution. We have developed semantic units for finite state machines [4], timed automata [5] and hybrid automata [6]. By properly

^{*} National Workshop on Beyond SCADA: Networked Embedded Control for Cyber Physical Systems (HCSS-NEC4CPS), Pittsburgh, PA, 2006.

composing semantic units together, the operational semantics of networked embedded systems can be formally captured. In the future, the semantic anchoring methodology should be extended to enable the construction of sophisticated and meaningful model-based software tool suite for the design of high-confidence networked embedded control systems.

2 Biography

T. John Koo is the Research Director of the Ministry of Education National Key Laboratory on Embedded Systems and the Chair Professor of the Departments of Electronics Engineering and Computer Science at Shantou University in China. He received the Ph.D. degree in Electrical Engineering from the University of California at Berkeley in 2000, and the M.Phil. degree in Information Engineering and the B.Eng. degree in Electronic Engineering from the Chinese University of Hong Kong in 1994 and 1992, respectively.

Prof. Koo is an Associated Faculty of the National Science Foundation ITR Center for Hybrid and Embedded Software Systems (CHESS). He was on the faculty of Vanderbilt University as Assistant Professor in the Department of Electrical Engineering and Computer Science (EECS) and the Institute for Software Integrated Systems (ISIS) during 2003-2006. He was a Visiting Faculty in the Department of Electrical Engineering and Computer Sciences of the University of California at Berkeley in 2002. In 2001, he held a Research Specialist position in the Electronics Research Laboratory of the University of California at Berkeley. He was a Postdoctoral Fellow in the Department of Electrical Engineering of the University of Pennsylvania in 2000. In 1998, he held a Consultant position at the Stanford Research Institute International, Menlo Park, CA. From 1995 to 2002, he was the founder and project leader of the Berkeley Aerial Robot project. In 1994, he was a Graduate Research Fellow in the Signal and Image Processing Institute of the University of Southern California. His research interests include embedded software, model-integrated computing, hybrid systems, nonlinear control, robotics, sensor networks and scientific computing.

Prof. Koo received the Nation Science Foundation Faculty Early Career Development (CAREER) Award in 2005 and the Distinguished M.Phil. Thesis Award of the Faculty of Engineering, the Chinese University of Hong Kong, in 1994. Prof. Koo has coauthored over 50 technical papers and book chapters. He was the Chair-US and Speaker of the Workshop on Hybrid and Embedded Systems: Technologies and Applications, Hong Kong Science and Technology Parks Corporation and Department of Automation and Computer-Aided Engineering, the Chinese University of Hong Kong in 2006. He is the Guest Editor of the Special Issue on "Networked Embedded Hybrid Control Systems," *Asian Journal of Control*. He is a senior member of IEEE and a member of Sigma Xi.

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