Statement of Research Purpose

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Embedded computer systems are ubiquitous and pervasive in our modern society with a wide application domain, such as automobiles, medical devices, communication systems, mobile electronics, and so on. Embedded technology has been the most pervasive technology ever with deeper penetration than electricity and safe drinking water [1].

There are two trends for modern embedded systems in recent years. First, various types of components are integrated into one system, including sensors, analog-to-digital converters, general-purpose CPUs, digital-signal processors (DSPs), dedicated hardware accelerators implemented as application-specific integrated circuits (ASICs), application-specific instruction-set processors (ASIPs), and customized memory components [2]. The *heterogeneity* of the system imposes both theoretical and engineering challenges on system modeling, validation, debugging, synthesis, and design space exploration. Second, the interaction with the physical world with strict real time requirements, massive amount of data processing and communication, and mixed signal interfaces brings traditional embedded systems into a new era, *cyber-physical systems* (CPS). In CPS, embedded computer systems are connected as a network working synergistically with physical processes. The cyber and the physical system are tightly coupled and affect each other via feedback loops. To handle such dynamics in CPS, research must address the areas of system abstraction, modeling, analysis, and design [3][6].

My research so far has been focusing on efficient embedded system modeling and validation. I have studied topics in the area of system-level description languages, models of computation, parallel simulation, and transaction level modeling. My work has utilized compiler technology, scheduling theory, and novel modeling approaches to improve embedded system design.

Dissertation Work

My dissertation research has been focusing on parallel simulation approaches for system-level description languages (SLDLs) in which most embedded system models are described. My work extends the simulation kernel of the SpecC SLDL for parallel discrete event simulation (PDES) so as to exploit the underlying parallel computational capability in today's multi-core simulation hosts. I've also proposed an advanced simulation approach called out-of-order PDES, which significantly improves model simulation speed by breaking the global simulation cycle barriers with the help of a corresponding conflict analyzer in the compiler.

Besides my dissertation work, I have also been working on different research projects in the area of embedded system design and building computer aided development tools. My experience includes designing the software architecture of a language front-end tool for the *SystemC* SLDL by using the *LLVM+Clang* compiler infrastructure; providing the compiler analysis support for an embedded system recoding tool; proposing new model of computation for system-level design; building industrial-sized embedded system-level applications; developing a symbolic analog circuit simulator based on a graph reduction algorithm; optimizing algorithms on special-purposed hardware platforms; and building a heterogeneous multiprocessor instruction set simulator.

Research Plan

In the future, I strive to conduct research work in the broader areas of system design. I intend to apply my knowledge on simulation, modeling, and compilers to develop next generation embedded systems, and propose new programming paradigms for new architecture platforms.

Design and model the next generation embedded system - Cyber-Physical Systems

Cyber-physical systems (CPS) are getting tremendous attention in recent years due to their broad potential application domains, such as healthcare monitoring, traffic control, search and rescue, and energy efficient facility infrastructures. CPS has tightly coupled computational and physical processes as a whole system [3]. While there are many well-defined models for computations, new abstractions and design methodologies are needed for cyber-physical systems due to the qualitative differences between the physical and the computational world. For instance, the physical world is naturally continuous while the computation theories are fundamentally discrete. Physical processes are concurrent while concurrency is very hard to comprehend and describe in computer programs due to the underlying computer architecture and the intrinsic sequential semantics for most programming languages. In addition, computer systems are usually very predictive and reactive but unpredicted situations often happen in the physical world. Thus, safety and reliability are imperative for computer systems to interact with the physical world.

I am interested in research work on modeling approaches for cyber-physical systems. I would try to apply the philosophy behind the transaction-level modeling (TLM) for electronic system-level (ESL) design onto Cyber-physical systems to figure out what are the different abstraction levels for CPS, how to formalize the physical features in the context of CPS, how to define the interaction between the cyber and physical parts, and how to take essential system features such as security, reliability and timeliness into consideration while modeling the system.

Along with the central mission of the TerraSwarm project which aims to enable sophisticated sense-control-actuate applications on massive swarm-base platforms through a universal systems architecture, I wish to make research contributions by proposing new definitions of abstract levels for swarm systems, exploring the algorithms and tools on synthesis the model into real implementations with critical system features, and enhancing development tools which facilitate automatic system deployment.

Also, I am very interested in building real-world CPS applications, which are promising to make our future life more convenient and smarter. I am looking forward to collaborate with researchers in different disciplines, such as biological science, chemistry, medicine, and mechanics to transfer the theoretic research result into the application domain.

Research in computer science education

During my graduate study in UC Irvine, I am very fortunate to be selected as the Pedagogical Fellow by the Teaching, Learning and Technology Center (TLTC). I have received an extensive training on pedagogy skills and developed an avid interest in innovative practices for computer science education.

I believe that our students, who will be the future computer engineers and scientists, should be trained to take the new features of the future systems into consideration at the very first stage of their development work. Otherwise, it will be very challenging to adjust legacy designs to new systems. For example, the fundamental reason why it is difficult to exploit the parallelism in the existing software applications is because that most of the software engineers are trained to think sequentially by using the traditional structural programming languages. The disparity between the traditional programming philosophy and new hardware architecture is the very source of the performance barriers for software development. Since cyber-physical system will very likely be pervasive and dominate in the future society, our students need to be educated to not only be aware of the essential features of CPS and but also proficient in the designing paradigms which are suitable for the upcoming systems. I wish to contribute on designing new course curriculum, building new educational tools, and introducing new technologies into the classroom so as to promote the pedagogies to educate the future designers.

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