



Center for Hybrid and Embedded Software Systems (CHESS)



*College of Engineering
University of California, Berkeley*

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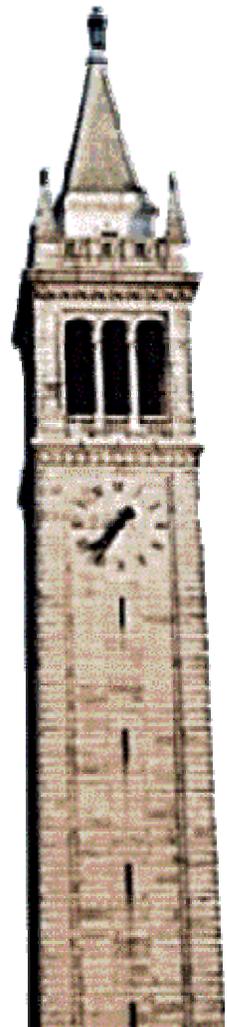
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Charter

Mission

"A cyber-physical system (CPS) integrates computing and communication capabilities with monitoring and / or control of entities in the physical world dependably, safely, securely, efficiently and in real-time." - S. Shankar Sastry

The mission of the Center for Hybrid and Embedded Software Systems (CHESS) is to provide an environment for graduate research in cyber-physical systems by developing model-based and tool-supported design methodologies for real-time, fault tolerant software on heterogeneous distributed platforms that interact with the physical world. CHESS provides industry with innovative software methods, design methodology and tools while helping industry solve real-world problems. CHESS is defining new areas of curricula in engineering and computer science which will result in solving societal issues surrounding aerospace, automotive, consumer electronics and medical devices.

Research Rationale

Embedded computers and networks monitor and control physical processes in feedback loops where physical processes affect computations and vice versa. For the last 30 years or so, computers have been increasingly embedded in stand-alone, self-contained products. We are poised, however, for a revolutionary transformation as these embedded computers become networked. We refer to such systems, which blend sensing, actuation, computation, networking, and physical processes as *action webs*. The transformation is analogous to the enormous increment in the utility of personal computers with the advent of the web. Just as personal computers changed from word processors to global communications devices and information portals, embedded computers will change from small self-contained boxes to cyber-physical systems, sensing, monitoring and controlling our intrinsically distributed human environment.

The Center maintains a close interaction between academic research and industrial experience, in order to facilitate the creation and transfer of modern, "new economy" software technology methods and tools to "old economy" market sectors in which embedded software plays a central role, such as aerospace, automotive, consumer electronics and medical devices.

The deliverables that emerge from this project could have enormous societal and economic consequences. Applications of CPS include solving real-world problems in high confidence medical devices and systems, traffic control and safety, advanced automotive systems, process control, energy conservation, environmental control, avionics, instrumentation,

critical infrastructure control (electric power, water resources, and communications systems for example), distributed robotics (telepresence, telemedicine), defense systems, manufacturing, and smart structures.

The intellectual products of CHESSE will also have an enormous effect on engineering and computer science education. Curricula in these fields evolve remarkably slowly, given the rapidity of technological change, and it may be that a concerted effort to blend computation with engineering disciplines that are more deeply rooted in the physical world is required.

As embedded systems increasingly permeate our daily lives on all levels, from microscopic devices to international networks, the cost-efficient development of reliable embedded software is one of the grand challenges in computer science today.

The Center for Hybrid and Embedded Software Systems is founded on the following premises:

1. Current software engineering methodologies are inadequate for handling the complexities of embedded software. Embedded programming has never transitioned from a resource driven (platform-centric) to a requirements driven (application-centric) paradigm. The results are costly, overengineered, brittle systems.
2. The generous attitude of desktop software vendors towards system reliability is not acceptable for embedded systems. Failures are unacceptable for safety-critical systems, such as transportation systems. Overengineering is unacceptable for systems that require expensive or limited physical resources.
3. Embedded software is software that interacts with physical processes. This interaction of discrete and continuous processes makes embedded software intrinsically hybrid. Traditional computation and communication paradigms are discrete and speed-independent, and therefore inadequate for embedded software design.

We believe that in order to address these issues, a new systems theory is necessary as a mathematical foundation for embedded software design. While traditional systems theory focuses on behavioral attributes of small, homogeneous, unconstrained systems (e.g., linearity), a modern systems theory must be based upon the following attributes of complex systems:

1. **Concurrency.** The main source of design complexity is the concurrent activity of parallel, possibly distributed components. Model composition and model decomposition must therefore lie at the very center of modern systems theory. In particular, such a theory must be compositional in the sense that the tasks it supports (e.g., design, verification) can be decomposed into subtasks about individual system components.
2. **Hierarchy.** The main vehicle for controlling design complexity is a layered approach that permits multiple abstract views of a design, at multiple levels of detail. The central issue, then, is the consistency between different views of a design, and between different layers of abstraction.
3. **Heterogeneity.** An obvious source of heterogeneity is the hybrid (i.e., mixed discrete-continuous) nature of embedded systems. Additional sources of heterogeneity arise from approaching different system aspects (e.g., functionality, timing) or different abstraction layers using different

modeling techniques, and from having multiple forms of interactions between the components of a system (e.g., different synchronization mechanisms).

4. **Resource constraints.** The main characteristic that distinguishes embedded software from other kinds of software is that embedded software operates under physical constraints (e.g., time, space), some of which can be chosen, and some of which cannot. Resource constraints render traditional models of computer science, from Turing Machines to Communicating Sequential Processes, which explicitly abstract away physical attributes of computation and communication, inadequate for critical aspects of embedded software design.

The transitioning from systems theory to design technology will be based on two convictions that have a long and successful tradition at Berkeley:

1. **Model-based design.** We believe that mathematical models offer the vehicle for integrating in a systematic and coherent fashion a variety of diverse efforts in system specification, design, synthesis (code generation), analysis (validation), execution (run-time support), and maintenance (design evolution). Mathematical models offer a precise common language that permits multiple approaches with complementary strengths to be directed towards a single design.
2. **Tool support.** We believe that an effective methodology must at all stages involve automatic and semi-automatic support by software tools. We have a long history of disseminating pioneering tools (e.g., Espresso, Giotto, HyTech, Metropolis, Ptolemy, Polis, VisualSense, Viptos). The feedback from tool users directs further the research towards the issues of practical importance.

Center Organization

The Center is a research unit operating in conjunction with the Department of Electrical Engineering and Computer Science and the Department of Mechanical Engineering at the University of California, Berkeley. The Center organization consists of a board of directors and an industrial advisory board. The board of directors and the participating faculty direct all research activities. The website for the Center may be found at <http://chess.eecs.berkeley.edu/>.

Membership

CHESS follows a model of university-industry-government partnership that many academic, industry, and government leaders believe is necessary if the U.S. is to maintain world leadership in advanced technologies. This model involves forging deep relationships between academic research and industry so that university researchers can benefit from industrial experience, and industry can more rapidly transfer new technologies. Center membership provides access to faculty and graduate students involved in a large interdisciplinary research effort investigating issues relevant to future generations of embedded software systems with a relatively modest investment.

The Center further provides a state-of-the-art design environment, supported by some of the latest developments in design methodology and tools, as made available by the University of California, Berkeley, and the member companies. The critical-mass combination of UC

Berkeley researchers and leading companies has the potential of making truly significant advances possible.

All member companies participate in research reviews and member day conferences. Industry Members are required to sign the *CHESS Industry Membership Agreement*, which is available from the any of the CHESS directors or staff. Membership consists of a limited number of Affiliate Members, Small or Minority-Owned Businesses, Partners and Premium Partners as described below.

Type of Member	Annual Fee	Benefits
Affiliate	No less than \$75,000	<p>Invitation to periodic reviews of CHESS.</p> <p>Access to selected internal CHESS websites.</p> <p>Access to publications, reports and presentations by CHESS researchers.</p> <p>Access to students and faculty in CHESS.</p> <p>An annual research report of the activities of CHESS.</p> <p>Advance notice of intellectual property created by CHESS.</p> <p>Intellectual property access as defined in the CHESS Industry Membership Agreement.</p>
Small or Minority-Owned Business	No less than \$10,000	All of the benefits of an Affiliate.

Partner	No less than \$150,000	<p>All of the benefits of an Affiliate, plus the following:</p> <p>Opportunity to nominate a member of the Industrial Advisory Board of CHESS on an annual basis.</p> <p>Opportunity to place visitors, as Visiting Industrial Fellows (VIF), at the University using the process identified in section H of the CHESS Industry Membership Agreement. VIF appointments are subject to standard University of California policies, which are more described in section H of the CHESS Industry Membership Agreement.</p> <p>Company may request VIF status for additional people, and the Directors will review and provide approval conditions.</p> <p>Selected early access to software developed by CHESS. When possible, and for software projects within CHESS that use networked version control systems (such as CVS) for collaborative software development, early access to pre-release development versions of the software is available.</p> <p>Intellectual property access as defined in the CHESS Industry Membership Agreement.</p>
Premium Partner	No less than \$300,000	<p>All of the benefits of a Partner, plus the following:</p> <p>Intellectual property access as defined in the CHESS Industry Membership Agreement.</p> <p>No more frequently than once per year, if requested by the company a private research review meeting at the University or at a mutually agreeable site. Travel and related expenses for the participants, if any, will be covered by the individual Premium Partner.</p>

Research Reviews and Member Day

The Center conducts research reviews twice per year. Research results, progress, and future directions are presented by faculty, students, visiting researchers, and invited guests. These meetings are open only to CHES Member companies. There is no limit to the number of representatives that member companies can send to the research reviews.

Member day is a one-day meeting, held once a year typically in conjunction with one of the research reviews, in which each Partner and Premium Partner Member Company is briefed by the Center's directors and research group leaders on research results and directions. Member Company representatives have the opportunity to present their perspectives on the research and are encouraged to provide input to influence the research agenda. Each Partner and Premium Partner Member Company can send a maximum of two representatives to these meetings.

Research Dissemination and Intellectual Property

The Center publicly disseminates all research results as rapidly as possible. The CHES website (<http://chess.eecs.berkeley.edu>), journals, conferences, and workshops are used for dissemination. Software is made available in open-source form, usually with the BSD license.

Center patents are expected to be rare. However, when they do occur, they are handled in a manner consistent with University of California policy. All members of the Center research staff, including VIFs, are subject to this policy. Patents resulting from inventions by one or more Center research staff members or VIFs, and one or more employees of a Member Company who are not VIFs, are jointly owned by the University of California and the Member Company.