Grand Challenges Conference Application

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January 30, 2002

My recent thinking about the future of computer science has focused on four themes:

- **Computation**: Computational modeling of the world and of its constituent entities and processes; along with newly emerging models of computation based on the world and its constituent entities and processes (for example, quantum mechanics, nanotechnology, or biological molecules).

- **Immersion**: Unifying computation and nature—by embedding each pervasively within the other—and naturally embedding people within this new synthesis, with the ultimate goal of providing effortless and effective combinations of people, computation, and the world.

- **Autonomy**: Systems—whether they be agents, robots, computers, networks, or any other type of active engineered entity—capable of standing robustly on their own through embodiment of capabilities for self-reliance and self-defense.

- **Interaction**: Mutual/reciprocal action or influence—among people, robots, agents, computers, sensors, and/or other active entities—that supports effective group/ grouped activity.

Multiple grand research challenges can be imagined within each of these four themes, plus additional challenges that cut across them. However, the focus here will be on two such challenges about which I have thought the most. The first challenge sits primarily within the interaction area (although with some clear overlaps with the other themes), and arises out of one of the most pressing concerns facing our nation today; that of responding to unexpected disasters, whether natural or man-made.

One of the most difficult aspects of events such as 9/11 is that they have major components that are entirely unplanned for. It is not simply their precise nature or timing that surprises; such events fall completely outside the range of the planned capabilities of the organizations tasked to deal with them. A society of limited resources cannot afford to have a prepared response for every conceivable disaster; however, it should be possible to create general infrastructure and capabilities that are adaptable instantly to respond to any threat.

A big chunk of the needed instant-response infrastructure and capabilities can be based on a three level hierarchy of interaction technologies. At the bottom is the network level, where the focus is on providing a means for all of the involved entities to communicate with each other. This includes the deployment (ahead of time and/or immediately after the disaster) of pervasive, robust communication among the relevant people (members of responding agencies, government decision makers, the public, etc.), information stores, robots and sensors.

On top of the network level is the grid level, where the focus is on the development of middleware that aggregates networks, and the entities that they connect (such as data, storage, computation, codes, visualization, sensors, robots, and people), into pools of resources that can be uniformly accessed in a secure manner across a large-scale distributed environment. This goes far beyond the simple pooling of files or cycles that is provided by the current generation of peer-to-peer technology—such as Napster and SETI@home—to include all aspects of the networked environment.

On top of the grid level is the organization level, where the focus is on marshaling pools of resources into robust and effective virtual organizations. Entities from all of the relevant resource pools become active, collaborative partners in achieving the goals of the organization through an infrastructure that facilitates such necessities as organization creation, member recruitment, role assignment, responsibility tracking, collaborative interaction, and as-needed reorganization. Suitably active and intelligent entities may directly participate in such virtual organizations, while less capable ones may team with proxies that make up for their organizational deficiencies.

The grand research challenge is to develop this hierarchy of interaction technologies to the point that it can provide general infrastructure and capabilities to dynamically create a robust virtual organization consisting of the people and resources necessary to flexibly respond to unexpected disasters. Presently, the network level is the best understood of the three levels, although there are still significant research problems remaining to be solved in reaching the full capabilities implicated in this challenge. The grid level is a newer development, but one that has already shown its promise in the high-performance-computing and peer-to-peer environments. The research challenges at the grid level cover such areas as distributed data storage and access, distributed computation, security, scheduling, compilation, and visualization. The organization level has just recently begun to emerge as a distinct concept on top of the grid level. The research challenges at the organization level include coordination in heterogeneous groups, group creation and preparation, and group awareness and communication.

The second challenge sits primarily within the overlap between computation and autonomy, and arises out of the need to model people for biological and biomedical uses and to replace and/or supplement people across a wide variety of service activities, such as education, training, personal care, retail, defense, human-computer interaction, and entertainment. This is the challenge of creating functioning model humans—or humanoids—in both hardware (humanoid robots) and software (virtual humans). Even just focusing on the software side provides a very large-scale, interdisciplinary research challenge covering the structure and function of the human body and mind at multiple levels (such as the organism, organ, cell, and molecule).

A complete and integrated model across all of these levels is clearly beyond what either computer science or the life sciences could support any time in the near future. However, a range of approximate, component models—such as a molecular model of a cell, a cellular model of an organ, or a functional model of an organism—would provide useful and worthy challenges, while at the same time keeping an eye on the ultimate challenge. The research challenges for computer science in particular would be in areas such as numeric and symbolic algorithms; large-scale computation and simulation; graphics and visualization; artificial intelligence, neurocomputing, and robotics; and computational biology and bioinformatics.

Short Biography of Paul S. Rosenbloom

Paul S. Rosenbloom is a Professor of Computer Science at the University of Southern California (USC), the Director of New Directions at the USC Information Sciences Institute (USC/ISI), and the Deputy Director of the Intelligent Systems Division at USC/ISI. Prior to coming to USC in 1987, he was an Assistant Professor of Computer Science and Psychology at Stanford University and a Research Computer Scientist at Carnegie Mellon University. He received a B.S. degree from Stanford University in mathematical sciences in 1976 (with distinction) and M.S. and Ph.D. degrees in computer science from Carnegie Mellon University in 1978 and 1983, respectively. He is a Fellow of the American Association of Artificial Intelligence (AAAI) and has been Chair of the Association for Computing Machinery (ACM) Special Interest Group on Artificial Intelligence (SIGART).

Broad syntheses have been at the core of Prof. Rosenbloom's professional career. During much of his career this has meant investigating diverse components of intelligent behavior and integrating them together into a novel cognitive architecture (called Soar) supporting a range of applications; while in the process also spinning off contributions in such areas as memory, learning, planning, hybrid models, cognitive models, match algorithms, computer games, cognitive architectures, intelligent agents, multi-agent systems, virtual humans, and synthetic forces. Near the end of this period, he spent several years leading a project concerned with the creation of human-like agents for virtual environments (in this case, synthetic battlespaces).

More recently, as Director of New Directions at USC/ISI, the development of broad syntheses has meant roles in conceptualizing, instigating and coordinating interdisciplinary efforts across computer science and its interactions with other disciplines and society. This has included a significant role in the creation of the Institute for Creative Technologies, an Army funded University Affiliated Research Center whose mandate is "to enlist the resources and talents of the entertainment and game development industries and work collaboratively with computer scientists to advance the state of immersive training simulation." It has also included contributions to the development of new Centers for "High Performance Computation and Communication" and "Technology and the Arts" (the latter of which was unfortunately short lived), and a role in guiding the revitalization of the USC School of Engineering Distance Education Network. Additional efforts included facilitating collaborations between computer scientists across a range of sub-disciplines with researchers in other disciplines, such as biomedical engineering, electrical engineering, earthquake engineering, geosciences, biomedical imaging, and marine biology.

One of Prof. Rosenbloom's major current interests concerns dynamically created organizations/societies composed of mixtures of robots, agents, and people. In this context he has just chaired a DARPA ISAT study on "Robot, Agent, Person (RAP) Teams for Emerging Threats" and is co-organizing a workshop for the National Science foundation (sponsored jointly by its CISE, SBE, and ENG directorates) on “Responding to the Unexpected.”