Grand Challenges Conference Application

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Topic 1: Context Aware Computing

The effects of Moore's Law are apparent everywhere: chip density, processor speed, memory cost, disk capacity and network bandwidth are improving relentlessly. With all the exponential growth in capacity, computing systems still remain oblivious to their environment. They distract and disrupt their users in any and every surrounding including announcing the arrival of electronic mail with an audio tone in the middle of a meeting or the ringing of a cell phone during a restaurant meal. As pointed out by Herb Simon more than 40 years ago, a resource that we have ignored until now - *human attention* - has become the scarcest resource in computing systems. By "human attention" we mean the ability of a user to focus on his primary task, oblivious to system-generated distractions such as failures and poor performance. By trading off plentiful computing resources for the scarcest resource, human attention, the digital systems of the future will have a considerably higher effectiveness than that of typical systems today.

Context-aware computing describes the situation where a mobile computer is aware of its user's state and surroundings, and modifies its behavior based on this information. A user's context can be quite rich, consisting of attributes such as physical location, physiological state (such as body temperature and heart rate), emotional state (such as angry, distraught, or calm), personal history, daily behavioral patterns, and so on. If a human assistant were given such context, he or she would make decisions in a proactive fashion, anticipating user needs. In making these decisions, the assistant would typically not disturb the user at inopportune moments except in an emergency. For example, as I am driving a car and talking to a passenger, I often notice road signs too late to read them completely. An assistant would have observed the situation, carefully observed the sign, and tell me the content of the sign when I requested. Another example would be an assistant observing my e-mail and tell me to stop as I walked by the main office to pick up a FAX.

The goal of this challenge is to enable mobile computers to play an analogous role, exploiting context information to significantly reduce demands on human attention. Combined with inferences about users' intentions, context-aware computing would allow improvement in user-perceived network and application performance and reliability through actions such as staging or prefetching of data, suggesting corrective actions that may alleviate resource limitations, or changing a client's behavior to the characteristics of the task, the computing platform, and the computing environment.

How will mobile computers obtain the information they need to function in a context-aware manner? In some cases, activity context may already be maintained by an application such as schedules, personal calendars, address books, contact lists, and to-do lists. More physical information has to be sensed in real time from the user's environment. Examples of physical context information include position, orientation, the identities of nearby persons, locally observable objects and actions, and emotional and physiological state.

In addition to the challenges of interruption, there are also challenges of privacy. The information routinely emitted by wireless devices to stay in contact with the network, is open to abuse. Some social objectives related to collection and use of personal information may be in conflict. We must determine what information is requested of users, what information is collected through monitoring, how long such information is stored, how it is protected from unauthorized access, who is authorized to examine information associated with an individual, and who is authorized to examine aggregate information on groups of users individual users.

One outcome of this research will be novel mechanisms that reconcile competing objectives. Meeting the needs of users requires revealing personal information in some cases, and protecting it in others. One way to meet diverse needs is to allow individuals to state their own preferences to the system. This requires a protocol with which individuals can precisely express their preferences. The challenge will be to create a protocol that is complex enough to address the diverse privacy issues, while embedding it in a user interface that is simple enough for the layman to use.

An alternative to rule-based approaches, in which users specify who can have what information for what purposes, are more dynamic market mechanisms. In economic theory, markets are social institutions designed to promote efficient allocation of scarce resources. The scarce resource is human attention, and its value varies dynamically between senders of information (e.g., the person needing help) and recipients (the potential helper). The social problem is that in the age of the Internet the marginal cost of sending a communication is close to zero. As a consequence, many companies send unsolicited electronic mail to advertise goods and services, including pornography, get-rich-quick schemes, travel offers and computer products. The intuition from economics is that if communication were more costly than it is now and if senders had even a little knowledge of the value that a recipient would place on a message, then the imposition of "professional hourly fee" on communication would benefit both senders and recipients of messages.

The goal is to employ theory from social science, cognitive science, and economics. Social science models of collaborative behavior can be used as a basis for determining the nature of the social setting. Theories and observations of which clues humans use to interrupt a social situation and gain attention can form the basis for sensor data processing and software decisions in context-aware devices. By mapping observable parameters into cognitive states, the computing system can estimate the form of interaction that minimizes user distraction and the risk of cognitive overload.

Topic 2: Improving Human Cognition

The challenge is to develop a method of teaching adults to “optimize their brain utilization” by directly monitoring thought processes and providing guidance on improving them. Currently brain-imaging technology of functional Magnetic Resonance Imaging (fMRI) can determine location and amount of brain activity as a function of task. Augmented by theories that link detectable brain activation to modifiable cognitive functions it should be possible to map brain activity to critical states that either impede performance (e.g., cognitive overload) or enhance it (e.g. strategic reflection). By controlling cognitive load, coordination of inter-cortical activity, and the invocation of strategic/executive processes, it should be possible to facilitate learning and the attainment of high performance in complex tasks. In addition, it should be possible to correlate external physiological and behavioral clues to the critical states of brain activity.

By bringing together the theory linking brain activation with cognition, a brain-activity-guided instructional system could be produced that enhances thinking skills. It should be possible to develop a method of teaching users how to perform a task at an extremely high level of proficiency by guiding their own thought processes to improve the quality and speed of their thinking. Such guidance can be provided by: 1) controlling the total processing load (so as to prevent overload and more importantly, to leave resources available for system-self-improvement), 2) facilitating coordination and communication among specialized subsystems or individual agents, and 3) invoking higher level executive processes at points of impasse or when an opportunity for an improved algorithm/strategy arises.

The systems monitoring cognitive workload using physiological and behavioral data is an example of context-aware computing.

BIO:

Daniel P. Siewiorek, Buhl University Professor of Computer Science and Electrical and Computer Engineering at Carnegie Mellon University, is currently Director of the Human Computer Interaction Institute. He leads an interdisciplinary team that has designed and constructed 24 generations of mobile/wearable computing systems and also helped to initiate and guide the Cm* project that culminated in an operational 50-processor multiprocessor system. He has designed or been involved with the design of nine multiprocessor systems and has been a key contributor to the dependability design of over two dozen commercial computing systems. In addition, Siewiorek has written eight textbooks and over 400 papers in his research areas. Siewiorek received the BS in electrical engineering from the University of Michigan and the MS and PhD, both in electrical engineering, from Stanford University. He was elected an IEEE Fellow in 1981 for contributions to the design of modular computer systems; in 1988 received the Eckert-Mauchly Award for his contributions to computer architecture; was elected as a member of the 1994 Inaugural Class of ACM Fellows; and elected to the2000 class of the National Academy of Engineering. He is also founding Chairman of the IEEE Technical Committee on Wearable Information Systems. He is a member of the IEEE Computer Society, ACM, Tau Beta Pi, Eta Kappa Nu, Sigma Xi, and the IEEE Computer Society.