

Invited Talks

IT**2: Information Technology Initiative for the Twenty-First Century

Ruzena Bajcsy, Assistant Director of CISE, National Science Foundation

This presentation has two parts: The first part explains what this Initiative is all about. We will describe the history, how it evolved, what are the supporting arguments and what are its goals. The second part presents the NSF specific plan for this Initiative. We shall elaborate on the scientific content of this

program, pose some open questions and outline the path of how we plan to achieve the goals. We shall discuss the identity of Computer Science as a scientific discipline and the consequences for funding. Finally, we shall speculate about the future of our discipline and the challenges stemming from it.

Game Playing: The Next Moves

Susan L. Epstein, Hunter College and The Graduate School of The City University of New York
(An extended abstract of this talk is included at the end of this Proceedings.)

As people do it, game playing addresses critical AI issues: learning, planning, resource allocation, and the integration of multiple streams of knowledge. Epstein highlights recent develop-

ments in game playing, describes some cognitively-oriented work, and poses three new challenge problems for the AI community.

Thinking on our Feet: Wearable Computing and Artificial Intelligence

Steven K. Feiner, Columbia University

As computers decrease in size and increase in power, they are beginning to move off our desks and onto our bodies to become wearable. Wearability implies a host of important properties that distinguish wearable computing from desktop and laptop computing (S. Mann, Smart Clothing: The Wearable Computer and Wearcam, *Personal Technologies*, 1(1), March 1997, 21-27; B. Rhodes, The Wearable Remembrance Agent: A System for Augmented Memory, *Personal Technologies*, 1(4), December 1997, 218-224; T. Starner, Wearable Computing and Contextual Awareness, Ph.D dissertation, Program in Media Arts and Sciences, Massachusetts Institute of Technology, Cambridge, Mass., June 1999). These include mobility, which ideally allows the wearer to use the system both indoors and outdoors; intimacy, which makes it possible to sense the wearer's body and present information privately; context sensitivity, which takes into account the continually changing environment experienced as the wearer moves about; and constancy, which encourages the permeation of the user interface into much of the wearer's activities, even when she is not actively "computing."

I will describe research in developing wearable user interfaces that mix different displays and interaction devices, and will discuss some of the ways that these user interfaces can exploit AI techniques. Our approach to wearability is based on

augmented reality, in which a synthesized virtual world is overlaid on and registered with the surrounding real world. Our audiovisual augmented reality is presented using a see-through head-worn display and earphones whose position and orientation are tracked. In our outdoor augmented reality testbed (S. Feiner, B. MacIntyre, T. Hoellerer, and A. Webster, A Touring Machine: Prototyping 3D Mobile Augmented Reality Systems for Exploring the Urban Environment, *Personal Technologies*, 1(4), December 1997, 208-217), we use real-time kinematic differential GPS for position tracking, and inertial and magnetometer trackers for orientation tracking. A handheld display with stylus input complements the head-worn display. Opportunities for applying AI techniques in such systems include hybrid tracking, fusing vision with other sensors; user and context modeling, perceptual user interfaces, and location-aware user interfaces, to adapt the system to the wearer and context; multimodal input and output, coordinating the use of speech, graphics, sound, gesture, and haptics; and knowledge representation and reasoning strategies that address the rich set of available sensory data. The goal is to create user interfaces that meet the changing needs of the wearer, without continually requiring the undivided attention and low-level interaction demanded by conventional desktop applications.

How Common Sense Might Work

Kenneth D. Forbus, Northwestern University

This talk describes how a combination of analogical and first-principles reasoning, relying heavily on qualitative representations, might provide a computational model of common sense reasoning. Forbus discusses the psychological and computa-

tional support for this approach, and illustrates how it can be used in building new kinds of multimodal interfaces and educational software.

AI and Space Exploration: Where No Machine Has Gone Before

Kenneth M. Ford, Institute for Human and Machine Cognition, University of West Florida, and NASA Ames Research Center

Humans are quintessentially explorers and makers of things. These traits, which identify us as a species and account for our survival, are reflected with particular clarity in the mission and methods of space exploration. The romance associated with the Apollo project is being replaced with a different vision, one where we make tools to do our exploring for us. We are building computational machines that will carry our curiosity and intelligence with them as they extend the human exploration of the universe.

In order to succeed in places where humans could not possibly survive, these “remote agents” must take something of us with them. They must be self-reliant, smart, adaptable and curious. Our mechanical explorers cannot be merely passive observers or puppets dancing on tenuous radio tethers from earth. They simply will not have time to ask us what to do: the twin constraints of distance and light-speed would render them helpless while waiting for our instructions, even if we knew what to tell them. AI plays a central role in space explo-

ration because there is, literally, no other way to make it work. Our bodies cannot fly in the tenuous Martian atmosphere, endure Jupiter's gravity or the electromagnetic turbulence of Saturn's rings; but our machines can, and we can send them there. Once at distant worlds, however, they must deal with the details themselves. The only thing we can do is to make them smart enough to cope with the tactics of survival.

How clever will these agents of human exploration need to be? Certainly, cleverer than we can currently make them. It will not be enough to be situated and autonomous: they will need to be intelligent and inquisitive and thoughtful and quick. NASA is committed to integrating intelligent systems into the very center of our long-range strategy to explore the universe.

In this talk, I will describe the current and future research directions of NASA's expanding information technology effort with a particular emphasis on intelligent systems.

Real-time Applications of Computer Vision: Computer Assisted Neurosurgery and Visual Monitoring of Activities

W. Eric L. Grimson, Artificial Intelligence Laboratory, Massachusetts Institute of Technology

Recent advances in computational power, coupled with constraints enforced by real-world applications, have led to two real-time vision systems: an image-guided neurosurgical sys-

tem, now in daily use; and a monitoring system that learns common activity patterns by visual observation over extended periods, and automatically detects unusual events.

Decrypting the Human Genome

Jill P. Mesirov, Whitehead Institute / MIT Center for Genome Research

There has been a recent explosion in the need for computational support in molecular biology. This has been driven by new laboratory technologies which generate biological data at a more rapid pace than ever before. The exploitation of this large amount of data by biologists and medical scientists requires contributions from many areas of computer science. Mesirov will present a few key examples where computing has

made a major impact in today's genomic research, and also point out some interesting opportunities for the future. The examples will be drawn both from structural genomics (determining the actual sequence of the genome) as well as functional genomics (decoding the sequence to understand gene function).

AI Rising

Nils J. Nilsson, Robotics Laboratory, Stanford University

Serious work toward artificial intelligence (AI) began about fifty years ago. In this talk I review what I think are the major milestones of our first half-century and make some guesses about what might lie ahead. In the spirit of millennial ap-

praisals, I will survey what I think are the most important things we have learned about AI in the last fifty years. Are these lessons sufficient to produce human-level artificial intelligence within the next fifty?

Quantum Computation and AI

Lee Spector, Howard Barnum, Herbert J. Bernstein, and Nikhil Swamy, Hampshire College

Computational complexity theory underpins current discussions across the cognitive sciences in general and artificial intelligence in particular. But classical computational complexity theory does not hold for the best computational devices allowed by modern physics. According to current quantum theory, computers that are designed to exploit atomic-scale dynamics—so-called quantum computers—can compute significantly more efficiently than one would expect from classical computational complexity theory. A few examples of dramatic quantum speedups are already known.

Two of the questions driving a wave of new work in this area are, “How much more efficiently can quantum computers compute?” and “Can we really build quantum computers?”

This talk will briefly survey current thinking on these questions and then move on to a longer discussion about the relations between quantum computing and AI.

The questions on which we will focus are, “How can AI technologies advance the study of quantum computation?” and “How can quantum computers, if built, advance AI?” On the first of these there are already concrete results, and we will look in detail at one example, the use of genetic programming to find new better-than-classical quantum algorithms. Our answers to the second question are more speculative, but the possibilities—for example a quantum logic machine that could answer Prolog queries in better-than-classical time—are enticing.

Why I Am Optimistic

Patrick Henry Winston, Artificial Intelligence Laboratory, Massachusetts Institute of Technology

From the engineering perspective, artificial intelligence is a grand success. Today, most big systems are built with elements that are readily traced to research done by the field's practitioners. From the scientific perspective, however, achievements have been small, and the goal of understanding human intelligence, from a computational point of view, remains elusive.

Nevertheless, to an optimist, the current state of artificial intelligence seems analogous to that of biology in 1950: on the engineering side, antibiotics had been discovered, developed, and applauded; on the science side, many prominent biologists said the field was dead, and little more of value could be done. But then, along came Watson and Crick, and their discovery of DNA's structure launched a fifty-year period of fantastic progress.

Is artificial intelligence ready for its own analog to the discovery of DNA? Have we been looking under the wrong lamp posts? Is there a new paradigm that will revitalize the

field? Or must we resign ourselves to 300 years of slow progress?

It is time to rekindle the original enthusiasm that actuated the pioneers. We should squarely, bravely, and optimistically confront the problems that block our understanding of human intelligence and prevent our construction of programs with human-level intelligence and beyond.

This time, however, we must exploit an abundance of neglected clues accumulating not only in artificial intelligence, but also in allied fields, such as systems neuroscience and developmental psychology. These clues will help us to unlock the secrets of intelligence, and likely lead to the conclusion that our sophisticated vision and language faculties are not mere I/O channels. Instead, our vision and language faculties embody powerful computational and engineering ideas that account for much of our intelligence.