

Hot Topics in Computer Science and Engineering

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INTRODUCTION

This paper is a result of recent discussions at MIT (Massachusetts Institute of Technology) during which selected professors and/or their assistants presented their views (pearls of wisdom), in front of a group of scientists from all over the world interested in multi, inter, and trans-disciplinary research. Topics in this paper appear in the order in which they were presented.

The paper consists of ten sections on ten important computer science and engineering (CSE) topics. We do not know what the final research results will be; we only believe that we have learned which avenues might lead to results, and we present them, in expectation of the response from the readership.

Each section of this paper includes the following elements: (a) Brief topic description and its social relevance; (b) Pointer to a state-of-the-art research at MIT; (c) Technical challenge on the way to a more effective future solution; (d) Important note or something to keep in mind while studying the subject.

The major purpose of this paper is education of graduate students in the topics of mission and vision of further advances in computing and communications.

I. GLOBALIZED EDUCATION

Globalized world can be achieved only if global education is performed in all relevant languages of the world, as underlined in the research of Tom Greene. A tool that enables automatic translation of courseware among different languages can be treated as an important accelerator of the globalization process. Each individual on earth can start thinking crea-

tively only if properly educated, with a stress on creative thinking.

An important state-of-the-art solution in the field is the Open Courseware of MIT, with about 1400 different free courses, as well as the related translation efforts (no intellectual property issues involved), as an important step in the process.

The mayor technological challenges for future research are translation and motivation efforts based on NLU (natural language understanding) and system integration and optimization efforts based on PSN (psycho social neurology).

Information about everything is doubling every two years and it now takes 10 years to develop experts. To be truly expert, they must also learn how to learn to find the answers for what they do not know by learning and using the best, most current information.

II. QUICK REUSE OF EXISTING DESIGNS

Effective tools are needed for fast design of Application-Specific Integrated Circuits (ASICs). The variety of chips must increase, so we can have a variety of applications at the ASIC power consumption of typically 1W, rather than the PC power consumption of typically 100W. Such a power dissipation reduction enables the penetration of sophisticated applications into the current cell-phone environment or the future wearable computing environments.

The MIT Term Rewriting Systems (TRS) based synthesis technology, which is in the foundation of BlueSpec Electronic Design Automation (EDA) toolset, enables quick and reliable design of new chips as well as quick reuse of existing designs.

The mayor challenge is building a library of micro-architectural Intellectual Property (IP) blocks and how IP blocks should be written to

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be easily modifiable and reusable, as in the research efforts led by Arvind.

The major issues are power, size, programmability, and time to market in less than 6 months. After 12 months there is no profit and after 18 months some new technology comes that brings new applications.

III. HARDWARE HELPING SOFTWARE

Single processor computers are reaching their limit. Computers with multiple processors will rule in the future. However, programming for multiple processors is still a disaster area due to unwanted asynchronous hazards. An appropriate hardware architecture is needed that makes the software less likely to be incorrect (there is no software failure – software can only be incorrect).

State-of-the-art is that industry knows how to put very many CPUs on a single chip, but nobody knows how to program them. Different languages for programming multiple processors, as for example, Sisal from Lawrence Livermore National Laboratory, and different research efforts, as for example, Monsoon data flow multiprocessor lead by Arvind, address this problem.

One of the avenues leading to possible solution is to make computer architecture that employ simultaneous multithread processors, employ a global shared name space, and support modular program construction through functional programming, as in the research of Fresh Breeze multi-core architecture led by Jack Dennis.

It makes no sense to design computers without taking into account the principles of software methodology and program language design.

IV. PROGRAMMING SENSOR NETWORKS

Appropriate languages are needed for effective programming of systems with millions of processors, in general, and in particular in sensor networks. In many sensor network applications, the network is deployed to approximate a physical space. For example, millions of sensors can be thrown from a plane to a field to measure humidity. They must communicate with each other and with the man processor.

Although many of them can be damaged, the network as a whole must still perform its job.

A state-of-the-art solution to the problem is Proto, a high-level language for programming sensor networks developed by Bachrach and his group. The spatial nature of sensor network is abstracted as amorphous medium. This separates sensor network problems into two largely independent domains. Above the abstraction barrier we are concerned with description of applications, while below the barrier we are concerned with fast, efficient, and robust communication between neighboring devices. Existing applications, such as target tracking and threat avoidance, can be expressed in only a few lines of Proto code.

The main challenge is programming of self-organizing systems. The study of self-organizing systems has now reached the tool-building phase, in which a new discipline of self-managing systems engineering can begin to emerge. The next step is to refine the principles of self-organization into a system of parts suitable for engineering – as the principles of electromagnetism are captured for electronic engineering in components like capacitors, transistors and resistors.

The ability to control emergent phenomena depends on decomposing them into aspects susceptible to independent engineering. For spatial self-managing systems, the amorphous-medium abstraction lets you separate the system specification from its implementation.

V. PLACING INTELLIGENCE INTO A SYSTEM OF DEVICES

Intelligence has to be placed into a system of devices; not into a single device. Ad hoc networks formed from consumer electronic devices, as cell phones, PDAs, notebooks, cameras, etc., which can perform certain tasks which could not be accomplished with a single device.

An example of such ad hoc network developed in MIT Media Laboratory led by Bove is a network formed by personal devices of people present at a meeting, which can form a microphone array. The devices use an active audio self-localization algorithm which is effective in distributed sensor networks even if only coarse temporal synchronization can be established.

Another distributed algorithm is then used to recognize the active speaker and electronically “turn” the microphone to his direction.

Often the amount of local data produced by these devices, and their sheer number, makes centralized data processing infeasible. Many distributed algorithms exist that work locally to produce results from a collection of nodes, but as this number grows the algorithm's performance is quickly crippled by the resulting exponential increase in communication overhead. One possible solution of this problem is local organization of nodes by a protocol that provides a method for nodes to create a bottom-up organization based purely on local conditions. Another is in programming model based on mobile code fragments which self assemble into larger structures.

By connecting personal resources with those of the people nearby, tasks can be achieved, through distributed placement and statistical improvement that a single device could not do alone.

VI. PLACING INTELLIGENCE INTO ROBOTS

In robotics a point was reached where it will be possible to build robots that will act as partners and not only industrial assemblers or children toys. They will act as teachers, domestic assistants, healthcare assistants, and so on. A great emphasis will be given to Human-Robot Interface (HRI).

State-of-the art robot is Leonardo. He has 61 degrees of freedom – 32 of those are in the face alone. As a result, Leonardo is capable of near-human facial expression.

Robotic Life Group at MIT led by Cynthia Breazeal takes inspiration and guidance from the science of animal and human behavior to build cooperative robots that can work and learn in partnership with people. The main challenge is to teach a robot as you teach a child, through guidance with rewards and punishments.

The research of human-like robots is multi-disciplinary in nature. It can not only help to build robots with human-like behavior but can also give scientific insight into the mechanisms that underlie human competence and deeper understanding of human abilities.

VII. PLACING INTELLIGENCE INTO HOMES

Computational sensing and Artificial Intelligence (AI) techniques – integrated with architectural principles and effective interface design – can be used to create new types of living environments which would greatly improve Quality of Life (QoL).

The PlaceLab – an apartment-scale shared research facility of MIT Architecture research group led by Stephen S. Intille – is a state-of-the-art tool for exploring how new technologies, materials, and design concepts can make possible dynamic, evolving places that respond to the complexities of life. Hundreds of sensing components are installed in nearly every part of the department. The facility is managed as a multi-disciplinary shared scientific tool in the tradition of other scientific facilities developed to study unique environments.

A special focus is now given to new algorithms that use ubiquitous sensing to recognize activities of daily living in order to determine when and how to provide preventive healthcare education in the home. Main challenges are: How can ubiquitous computing technologies be created and evaluated that work for extended periods of time? How can persuasive interfaces designed to motivate behavior change in the home be studied in context?

Measuring behavior can change behavior when a person is aware that he/she is monitored. She/he starts to behave differently, to avoid socially unaccepted behaviors, etc. Like in quantum mechanics, certain things simply cannot be measured.

VIII. PLACING INTELLIGENCE EVERYWHERE

Once the home infrastructure has become intelligent, the next step is to inject intelligence into all kinds of everything at homes beyond homes. People have developed sophisticated skills for sensing and manipulating our physical environments. However, most of these skills are not employed by traditional Human Computer Interface (HCI).

State-of-the-art examples from the MIT Media Lab Tangible Media Group include lukastro suits (textile, iron, cotton, nylon) that detect touches (for applications like home and workplace abuse detection), an electrically

charged coat that could prevent women from being attacked, domestic applications with funny interfaces (e.g., Blendie, an interactive, sensitive, intelligent, voice controlled blender with a mind of its own), monitoring of the environment and changing of personal trajectories for risk reduction (e.g. changing of song tunes for joggers in heavy traffic), or intelligent Lego cubes (to enhance creativity in children).

The Computing Culture group lead by Chris Csikszentmihályi creates unique media technologies for cultural applications. Projects will result in specific works of art, but will also help further an understanding of the relationships between new media and cultural production. Some of the strategies they utilize include interventions in contemporary consumer electronics, creating special events for public situations, and applying technical research and development to cultural agendas that wouldn't normally receive them.

Future efforts must involve artists to help reconfigure technology, to address the full range of human experience. Of special importance are the issues related to creativity enhancement in children.

IX. WEB OF TRUSTED RESOURCES AND WEB FOR EVERYONE

By the words of the director of W3C and inventor of the World Wide Web Sir Tim Berners-Lee: "The social value of the Web is that it enables human communication, commerce, and opportunities to share knowledge. One of W3C's primary goals is to make these benefits available to all people, whatever their hardware, software, network infrastructure, native language, culture, geographical location, or physical or mental ability." However, for Web to be a useful, people must be able to trust the resources. While technology cannot guarantee trust, it should enable secure transactions with trusted parties. The W3C has already developed its agenda for future developments.

World Wide Web has already reached 16.6% global user penetration explained Steve Bratt, the Chief Executive Officer of W3C. The Web has transformed the way we communicate with each other. People now "meet on the Web" and carry out commercial and personal relation-

ships, in some cases without ever meeting in person.

One of W3C's goals is to design technology that will work independent of a particular hardware platform, including mobile telephones, kiosks in airports, kitchen appliances, and automobiles. Access from these devices should be as simple, easy and convenient as Web access from a home computer.

While foundation of today's Web is in HTML, CSS, XML, and Architecture, foundation for tomorrow's Web is in Web 2.0, Web services, Semantic Web, Mobile Web, ubiquity, universality, internationalization, security and privacy.

X. GETTING AN EXTREMELY FAST COMPUTING INFRASTRUCTURE

The ultimate goal in concept modeling (which is the key issue for a number of important applications of the future) is how to get closer to the brain model. This implies an extremely strong computing infrastructure. The driving forces towards a much stronger computing power are not only the needs of ubiquitous computing and web of trusted resources, but also the needs of fundamental research in particles physics.

State-of-the-art needs one billion collisions in an event per second, and about 200 to 300 particles per event. Today, this is achievable only off-line.

This to be achievable on-line believes Nobel Laureate Jerome I. Friedman. That implies zillions of CPUs talking to each other. Once this computing/communications goal is achieved, we are very close to the brain model. Computer communications is like cheering and drinking. If two persons like to cheer and drink, they can do so many times in one evening, which means that they can drink many glasses of wine during that evening. Zillions persons, if they all like to cheer with each other, will not drink a single glass of wine in their entire lifetime.

Note that often technological advances in one specific field may trigger application advances in another field, less or more remote. On the other hand, scientists start making errors when conditions change – subconsciously each person likes to protect the time he/she spent on learning something. The major ad-

vances are usually made by researchers which novel to the field, who do not know that it cannot be done. Many Nobel Laureates were told, by their senior colleagues, that what they are doing is a waste of time.

Conclusion

From the above presentations we conclude that lot of effort is given to improve quality of life, proper education accessible to every one in his own language, being one of the most important prerequisite to obtain this goal. Only after this goal is achieved, different advances in technology can make life easier and more pleasant for everyone on this Earth.

From technological point of view, in computer science, standalone single computer systems became to complex and to power consumptive. The only alternative are systems with many, possible millions, of units than can communicate among each other and perform complex tasks which would be unthinkable of stand alone computers. The idea resembles the way the nature “thinks”, using many very simple and very similar units (e.g., cells), to “produce” very complex systems (e.g., human beings).

We also noticed that the research in computer science is becoming more and more multi, inter, and trans disciplinary, as scientists from almost all fields must be included in development of modern, computer added systems at one hand and the researches in all fields need some form of computers as a tools in their research at the other hand. Thus, people with creative mind and wide horizons which are capable of horizontal thinking will be the pillows of further progress in the field.

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