The 2008 Kyoto Prize Workshop in Advanced Technology

Symposium

"Computational Approach to Science: Our Dream and Your Dream"

Laureate: Dr. Richard Manning Karp

[University Professor, University of California, Berkeley
Research Scientist, International Computer Science Institute]

13:00 - 17:30, November 12, 2008 (Wed.)
Kyoto International Conference Center

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Program

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(Professor, Graduate School of Information Science and Engineering, Tokyo Institute of Technology)

13:00 **Opening Address**
Yasuyoshi Inagaki

Introduction to Laureate
Osamu Watanabe

Laureate Lecture
Richard Manning Karp (the Laureate in Advanced Technology)
"Understanding Science through the Lens of Computation"

Intermission

Lecture
Satoru Miyano (Professor, Institute of Medical Science, The University of Tokyo)
"Biology as Computational Science"

Lecture
Mitsunori Ogihara (Professor, Department of Computer Science, University of Miami)
"Algorithmic Analysis of Network Traffic"

Lecture
Osamu Watanabe
"Algorithmic Understanding of Some Stochastic Methods"

Intermission

Panel Discussion
Moderator Osamu Watanabe
Panelists Richard Manning Karp
Satoru Miyano
Mitsunori Ogihara

17:30 **Closing**

Abstract of the Laureate Lecture

Dr. Richard Manning Karp
University Professor, University of California, Berkeley
Research Scientist, International Computer Science Institute

Understanding Science through the Lens of Computation

There is a growing awareness that information processing lies at the heart of the processes studied in fields as diverse as quantum mechanics, statistical physics, nanotechnology, neuroscience, linguistics, economics and sociology. In short, our message is that “Nature computes.” Increasingly, mathematical models in scientific fields are expressed in algorithmic languages and describe algorithmic processes. Examples of information processing tasks solved by natural systems are molecular self-assembly; learning in neural networks; the regulation of protein production, metabolism and embryonic development; the self-organization of bee and ant colonies; flocking behavior of birds; the phase transitions of thermodynamic systems; the strategic behavior of economic agents; the flow of vehicle traffic; and the evolution of Web-based social networks.

We will illustrate the role of information processing concepts in understanding natural computation through examples from several areas: quantum computing, statistical physics, economics, sociology and molecular biology.

Computation at the atomic or subatomic level must be understood in terms of quantum mechanics. The challenge of quantum computing is to exploit the richness of quantum information. Quantum computing is as much about testing the foundations of quantum physics as it is about building powerful computers.

Statistical Physics and Computer Science both study how macroscopic properties of large systems arise from local interactions. Phase transitions such as the freezing of water or the magnetization of materials have close parallels with the study of constraint satisfaction problems in Computer Science.

The Internet and the Web are simultaneously computational, social and economic. They must be studied as emergent natural systems. A new challenge for social science is to understand networks of Web-based interactions linking organizations and communities. Economics is challenged to design mechanisms to induce economic agents with private data and selfish interests to respond in socially productive ways.

The view of living cells as complex information processing systems has become a dominant paradigm in molecular biology. A fundamental challenge is to understand how genes, proteins and other molecules act in concert to control cellular processes.

As the algorithmic worldview pervades the sciences Computer Science is placing itself at the center of scientific discourse and the exchange of ideas.

Abstracts

Satoru Miyano

Professor, Institute of Medical Science, The University of Tokyo

Biology as Computational Science

In the last decades of 20th Century, the Human Genome Project was called the largest international project in the history of biology. We, however, will soon get into the era when individual genomes are determined with 1000 dollars. Further, cutting-edge techniques using computers and robotics enable scientists to challenge analyzing what molecules, including gene products encoded on genomes, are expressed when, where, and how in cells. The information on the functions of parts building biological systems in organisms is explosively increasing by simultaneously generating large amounts of heterogeneous data with noises and missing information. Thus, biology is rapidly changing into a science of managing such biological information. In this talk, we present a computational strategy for analyzing and understanding biological systems. The first topic is on mathematical modeling of biological systems and its simulation software. The second topic is on computational method for inferring gene networks and its application to drug target gene discovery, which uses several hundreds of gene knockdowns and their gene expression analysis with DNA chips.

Mitsunori Ogihara

Professor, Department of Computer Science, University of Miami

Algorithmic Analysis of Network Traffic

The Internet has shown an explosive growth over the past decade. It now has become an essential infrastructure in industrial societies. An important issue in providing safe and efficient communications in very large computer networks is to find anomaly and counteract to it promptly. Since delay in detection increases the impact of anomaly, algorithms are needed that monitor network data dynamically and discover signs of anomaly at as an early stage as possible, and development of such algorithms is an important task for computer scientists. Two main characteristics of the network data are that they flow very fast and that the routers have limited computational power. These characteristics are very well represented in the data streaming model, in which the goal is to compute some property of the input data series using only one scan and with limited storage. This talk presents some problems in data streaming where the goal is to compute properties of the numbers appearing the input data series.

Abstracts

Osamu Watanabe
Professor, Graduate School of Information Science and Engineering, Tokyo Institute of Technology

Algorithmic Understanding of Some Stochastic Methods

Many advanced applications of computation are related to some probabilistic or stochastic events. Computer simulation often targets some stochastic phenomenon. We also use randomized computation for solving some problem efficiently, in which case, the computation itself is some probabilistic event. In such cases various statistical analyses are quite important for understanding the nature of those probabilistic events. It should be also noted that computational view reveals yet some important aspects of such probabilistic and computational events. Here we show one such example - computational analysis of belief propagation.

Belief propagation is an algorithm or computational method for analyzing a stochastic system expressed as a Bayesian network; more precisely, it is a method of computing the marginal probability of a given state in a given Bayesian network. It has been originally proposed by Pearl, but similar methods have been proposed and studied in several areas, in particular, in statistical physics. It has been still open when and why this method works. Here we consider one application of this method to some simple clustering problem and show that its computational analysis reveals an interesting aspect of the belief propagation.