News Release

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NEC C&C Foundation Awards 2018 C&C Prize

- Recognition of outstanding contributions to the fundamental mechanism for quantum annealing machines and the development of thin-film organic light-emitting devices -

Tokyo, October 10, 2010 - The NEC C&C Foundation today announced that the 2018 C&C Prize will be awarded to two groups for their contributions to quantum annealing and to research into random spin systems which underlie the fundamental mechanism enabling the development of quantum annealing machines, and to discovery and pioneering development of thin-film organic light-emitting devices. Prof. Hidetoshi Nishimori will represent Group A and Prof. Ching W. Tang will represent Group B. Each recipient will be recognized with a certificate of merit and a plaque. Each group will also receive a cash award of ten million yen.

The C&C Prize was established in 1985 and is awarded to distinguished persons in recognition of outstanding contributions to R&D activities and pioneering work related to the integration of computers and communications technologies and the social impact of developments in these fields. This year's two recipient groups are outlined below.

The prize ceremony and acceptance speeches will be held on Wednesday, November 28 from 15:00 at the ANA InterContinental Tokyo.

Prof. Hidetoshi Nishimori

Prof. Ching W. Tang

1) **2018 C&C Prize Recipients**

<u>Group A</u>

Professor Hidetoshi Nishimori
Professor, Tokyo Institute of Technology
Professor, Tohoku University

Citation
For contributions to quantum annealing and to research into random spin systems which underlie the fundamental mechanism enabling the development of quantum annealing machines

Achievement
Quantum computing is computing that exploits the quantum-mechanical phenomena such as superposition and entanglement. Two quantum-computing approaches are commonly known. One approach replaces classical logic gates with quantum gates that perform computations with quantum algorithms. The other approach, called quantum annealing (QA), solves the optimization problem by means of an Ising model or other statistical physics model. It is believed that superimposed quantum bits (qubits) can be used in quantum computing to perform massively parallel computations and high-speed processing of data. This ground-breaking computing capability is expected to enhance materials development and combinatorial optimization and, moreover, has potential for future artificial intelligence applications.

Prof. Nishimori's quantum annealing, as a technique of quantum computing, has greatly enhanced the possibility of quick resolutions for complex combinatorial optimization problems that were difficult to solve with traditional methods. His innovative achievements, particularly, his fresh ideas from a field of theoretical research in random spin systems that is away from the information science field, are worthy of special mention. In recent years, Prof. Nishimori has participated in an IEEE Standards Association group to promote standardization of a quantum computer language. He is also involved in the Quantum Enhanced Optimization program, which was launched by the U.S. Government's Intelligence Advanced Research Projects Activity (IARPA) to develop high-performance quantum annealers. Through his involvement in these projects, Prof. Nishimori continues to actively contribute to the development, expansion, and dissemination of quantum computing technology.

Quantum annealers are interesting not only for their high-speed performance, but also for their ability of low power consumption to utilize superconducting qubits. In light of the high expectations set on quantum computing in promoting sustainability and solving the increasingly complex issues facing our information society, Prof. Nishimori's remarkable achievements make him an excellent recipient of the C&C Prize.

Group B

Professor Ching W. Tang

Professor Emeritus, University of Rochester
Professor, The Hong Kong University of Science and Technology

Citation

For discovery and pioneering development of thin-film organic light-emitting devices leading to the progress of organic electronics industry

Achievement

Interface technologies are the backbone of today's information and communication society. Flat panel displays (FPDs) in particular play a vital role as general interfaces as well as in compact information devices like smartphones that support everyone within the reach of the mobile internet. While liquid crystal displays (LCDs) have long dominated the FPD market, organic light-emitting diode (OLED) displays, which work on the principle of organic electroluminescence (EL), are becoming more and more popular. OLEDs are characterized by their thin, shape-free, flexible, and surface-emitting design, and their low-voltage characteristics that are ideal for portable devices. They outperform LCDs in providing high-contrast images, high-speed response, and wide viewing angles. OLEDs have already acquired a substantial share of the compact information device market and have begun to be used in TVs and other large devices. Their myriad features may lead to revolutionary new device interfaces that will enrich the lives of people in the information society.

Prof. Tang's extensive research on organic electronics, especially OLEDs, culminated in his discovery of a highly luminous and efficient layered thin-film structure with separated functions, has remained one of the most important technological contributions in today's display industry. Since their commercialization in the late 1990s, OLEDs have surpassed LCDs to become the mainstream mobile displays. Furthermore, OLED TVs have been on the market since the late 2000s, and their sales are expected to grow in the future. Besides outstanding image quality and design, OLEDs feature low power consumption, enabling compact devices that connect people and have minimal impact on the environment. These and other aspects have made OLEDs crucial elements in various information devices and display devices; they will help to ensure the sustainability of Computers & Communications (C&C) and the information and communication society. In recognition of the enormous impact his pioneering work on OLEDs has had on the world, we believe that Prof. Tang would be an excellent recipient of the C&C Prize.

See the attachments for profiles and detailed achievements of the recipients:

Attachment 1: Profile and Detailed Achievements of the Group A Recipient of the 2018 C&C Prize

Attachment 2: Profile and Detailed Achievements of the Group B Recipient of the 2018 C&C Prize

For additional information, please visit The NEC C&C Foundation website at: http://www.candc.or.jp/en/index.html

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About The NEC C&C Foundation

The NEC C&C Foundation is a non-profit organization established in March 1985 to foster further growth in the electronics industry by encouraging and supporting research and development activities and pioneering work related to the integration of computers and communications technologies, that is, C&C, and ultimately to contribute to the world economy and the enrichment of human life. The Foundation is funded by NEC Corporation.

The Foundation currently has two main activities. It presents the annual C&C Prizes to recognize outstanding contributions to R&D activities and pioneering work in the area of C&C. Candidates are recommended from all over the world. Each prize winner receives a certificate, a plaque, and a cash award (ten million yen per group). As of 2017, 110 prominent persons had received the prize. In addition, an Outstanding Paper Award for Young C&C Researchers is awarded annually to outstanding paper(s) presented at an international conference overseas with the support of a grant from the Foundation. Each recipient is given a cash award of 200,000 yen.

The Foundation also gives the following two grants: (1) grant to enable researchers in Japan to attend international conferences overseas to make presentations in the field of C&C and (2) grant to non-Japanese researchers in Japan.

For additional information, please visit The NEC C&C Foundation website at: http://www.candc.or.jp/en/index.html

About NEC Corporation

NEC Corporation is a leader in the integration of IT and network technologies that benefit businesses and people around the world. The NEC Group globally provides "Solutions for Society" that promote the safety, security efficiency and fairness of society. Under the company's corporate message of "Orchestrating a brighter world," NEC aims to help solve a wide range of challenging issues and to create new social value for the changing world of tomorrow. For more information, visit NEC at http://www.nec.com.

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ATTACHMENT 1: Profile and Detailed Achievements of the Group A Recipient of the 2018 C&C Prize

Prof. Hidetoshi Nishimori

Current positions:
Professor, Tokyo Institute of Technology
Professor, Tohoku University

Personal History (born in 1954):

1977 BS, The University of Tokyo
1981 Researcher, Carnegie Mellon University
1982 PhD, The University of Tokyo
1982 Researcher, Rutgers University
1984 Research Associate, Department of Physics, School of Science, Tokyo Institute of Technology
1990 Associate Professor, Department of Physics, School of Science, Tokyo Institute of Technology
1996 Professor, Department of Physics, School of Science, Tokyo Institute of Technology
2011 Dean, Graduate School of Science and Engineering, Graduate School of Science and School of Science, Tokyo Institute of Technology
2016 Professor, School of Science, Tokyo Institute of Technology
2018 Professor, the Institute of Innovative Research, Tokyo Institute of Technology
2018 Professor, Graduate School of Information Sciences, Tohoku University (cross appointment)

Major Awards:

1990 The 4th IBM Japan Science Prize
2001 Fellow, The Institute of Physics
2006 The 52nd Nishina Memorial Prize
2014 Special Award of Japan Innovators Award
2016 Tokyo Institute of Technology Best Teacher Award (top honoree)
2018 Special Award of Tokyo Institute of Technology Suematsu Digital Technology Award

Achievements

Quantum computing is computing that exploits the quantum-mechanical phenomena such as superposition and entanglement. Two quantum-computing approaches are commonly known. One approach replaces classical logic gates with quantum gates that perform computations with quantum algorithms. The other approach, called quantum annealing (QA), solves the optimization problem by means of an Ising model or other statistical physics model. It is believed that superimposed quantum bits (qubits) can be used in quantum computing to perform massively parallel computations and high-speed processing of data. This ground-breaking computing capability is expected to enhance materials development and combinatorial optimization and, moreover, has potential for future artificial intelligence applications.

Prof. Hidetoshi Nishimori was the first to propose the quantum annealing computation model that operates under the natural laws of physics to enable high-speed resolution of hard and complex problems, such as combinatorial optimization. The basic theory of quantum annealing was developed in the field of statistical mechanics. The professor spent many years conducting research on the phenomena of random spin systems, which is a typical spatially non-uniform system that is regarded as a central problem in statistical mechanics. Through this research, he showed that there is a special area in a phase diagram, called the "Nishimori line", where an exact solution can be obtained. This discovery has been of monumental importance to statistical mechanics, and the professor’s remarkable contribution has been paramount to outcomes such as error correction code in information theory which leverages the properties of random spin systems and the Nishimori line. His findings also gave rise to a quantum annealing model that he jointly proposed with his student, Tadashi Kadowaki, in 1998. Through his research on mathematical models of magnetic bodies, in which he studied random interactions of particles with surrounding particles that had only two allowed orientations (up or down), he discovered that optimization problems consisting of systems that search for the lowest energy configuration is a standard format of combinatorial optimization.

Combinatorial optimization problems are parts of central to the field of information science, and since the 1980s, the statistical mechanical approach of simulated annealing (SA) has been regarded as a general purpose technique for solving them. SA uses thermal fluctuations to overcome high “energy” barriers to gradually lead the system to a low energy state that can be considered to be a solution to lowest-energy configuration problems. In QA proposed by Prof. Nishimori, rather than thermal fluctuations, quantum fluctuations are used to create a tunnel effect for faster convergence to the low energy state. This feature qualitatively indicates that QA offers a higher probability of finding the lowest-energy configuration; in other words, it finds an optimal solution faster than SA. Furthermore, on the basis of his knowledge of the ground state search problem of spin glasses, which is a typical problem encountered in research on random spin systems, the professor saw the potential in its application to the optimization problem. This prompted him to begin research on developing a solution based on quantum mechanics transitions, in other words, controlling quantum fluctuations. By gradually “annealing out” the effect of large quantum fluctuations on a frustrated system, the system converges to a stable statistical mechanics model that means the lowest-energy configuration. The resulting convergence gave rise to the basic concept underlying the quantum annealing computation model which corresponds to finding solutions for combinatorial optimization problems. Prof. Nishimori conducted exhaustive numerical experiments showing that QA techniques consistently outperform SA techniques in solving optimization problems. Moreover, the professor proved the convergence of QA; in other words, he provided a mathematical proof that the theory of convergence guarantees the discovery of the optimal solution. In this and other ways, he provided the mathematical foundation of QA. His findings have captured the attention of the world and have led to the development of the quantum annealing machine, the world’s first commercially available machine in 2011 (from D-Wave Systems, Inc.). The advent of this machine capable of solving specific problems extremely quickly triggered the development of new QA applications that go beyond finding solutions for combinatorial optimization problems. For instance, a range of innovative approaches leveraging QA’s remarkable capability of finding optimal solutions quickly are being developed in the field of artificial intelligence that brings together the methods of machine learning and deep learning which require vast amounts of data to be analyzed.

Prof. Nishimori’s quantum annealing, as a technique of quantum computing, has greatly enhanced possibility of quick resolutions for complex combinatorial optimization problems that were difficult to solve with traditional methods. His innovative achievements, particularly, his fresh ideas from a field of theoretical research in random spin systems that is away from the information science field, are worthy of special mention. In recent years, Prof. Nishimori has participated in an IEEE Standards Association group to promote standardization of a quantum computer language. He is also involved in the Quantum Enhanced Optimization program, which was launched by the U.S. Government’s Intelligence Advanced Research Projects Activity (IARPA) to develop high-performance quantum annealers. Through his involvement in these projects, Prof. Nishimori continues to actively contribute to the development, expansion, and dissemination of quantum computing technology. Quantum annealers are interesting not only for their high-speed performance, but also for their ability of low power consumption to utilize superconducting qubits. In light of the high expectations set on quantum computing in promoting sustainability and solving the increasingly complex issues facing our information society, Prof. Nishimori’s remarkable achievements make him an excellent recipient of the C&C Prize.

ATTACHMENT 2: Profile and Detailed Achievements of the Group B Recipient of the 2018 C&C Prize

Prof. Ching W. Tang

Current Positions:
Professor Emeritus, University of Rochester
IAS Bank of East Asia Professor, The Hong Kong University of Science and Technology

Personal History (born in 1947, Hong Kong):
1970 BS in chemistry from The University of British Columbia
1975 PhD in physical chemistry from Cornell University
1975 Research Scientist, Eastman Kodak
1981 Senior Research Scientist、Eastman Kodak
1990 Research Associate, Eastman Kodak
1998 Senior Research Associate, Eastman Kodak
2006 Professor, University of Rochester
2013 Professor, The Hong Kong University of Science and Technology

Major awards:
2001 Jan Rajchman Prize, from the Society for Information Display;
2001 Carothers Award, from the American Chemical Society;
2001 Northeast Regional Innovation Award, from the American Chemical Society
2002 Rochester Law Association Inventor of the Year Award, from the Rochester Intellectual Property Law Association
2003 Team Innovation Award, from the American Chemical Society
2003 Distinguished Fellow of the Kodak Research Laboratories, from the Eastman Kodak Company
2005 Humboldt Research Award, from the Alexander von Humboldt Foundation
2007 Daniel E. Noble Award, from the IEEE
2010 Lifetime Achievement Award, from the Hajim School of Engineering and Applied Sciences, the University of Rochester
2011 Wolf Prize in Chemistry, from the Wolf Foundation
2013 Eduard Rhein Award, from the Eduard Rhein Foundation
2014 Nick Holonyak Jr. Award, from the Optical Society
2017 IEEE Jun-ichi Nishizawa Medal, from the IEEE
2018 Inductee Award, from the National Inventors Hall of Fame

Achievements

Interface technologies are the backbone of today's information and communication society. Flat panel displays (FPDs) in particular play a vital role as general interfaces as well as in compact information devices like smartphones that support everyone within the reach of the mobile internet. While liquid crystal displays (LCDs) have long dominated the FPD market, organic light-emitting diode (OLED) displays, which work on the principle of organic electroluminescence (EL), are becoming more and more popular. OLEDs are characterized by their thin, shape-free, flexible, and surface-emitting design, and their low-voltage characteristics that are ideal for portable devices. They outperform LCDs in providing high-contrast images, high-speed response, and wide viewing angles. OLEDs have already acquired a substantial share of the compact information device market and have begun to be used in TVs and other large devices. Their myriad features may lead to revolutionary new device interfaces that will enrich the lives of people in the information society.

Professor Ching W. Tang recognized the potential of organic EL in the 1970s, while working for Eastman Kodak. His subsequent research aimed at increasing the luminosity and efficiency of organic EL. His paper titled, “Organic electroluminescent diodes,” which he jointly published with his colleague, Steven Van Slyke in 1987, is lauded as a breakthrough in the field of organic EL. The paper reported on a new organic EL structure comprised of two extremely thin layers of organic material with different properties and electrodes made of a new material. The innovative device was the first practical OLED, and it showed exceedingly high luminosity and efficiency. The publication inspired researchers to accelerate studies on organic EL and triggered industrial growth.

As mentioned above, organic EL devices generate light through a phenomenon known as electroluminescence wherein holes and electrons are injected into an insulating organic material by applying an electric field. The holes and electrons recombine and emit energy. In 1953, Andre Bernanose discovered a method to emit light using thin organic film doped with dye. This discovery prompted researchers to conduct experiments aimed at achieving high luminosity and efficiency in the electroluminescence process. It was not until the mid-1980s, however, that significant results were achieved. The main issue for researchers at the time was their inability to find an organic material and electrode material that could assure stable and efficient electron injection. They also had to contend with challenges such as the unstable nature of the thin organic film that caused it to rupture when an electric field was applied to it.

Prof. Tang and his colleagues met the above challenges by combining the following techniques. First, they separated the carrier-transport and light-emission functions by building a two-layer heterojunction thin film. Second, they improved the stability of the thin organic film by switching from a polycrystalline film to an amorphous film. Third, they created a high-quality organic layer with a thickness on the order of 100 nm to obtain a high electric field. Lastly, they made improvements to the magnesium electrodes that, although conducive to electron injection, had a low work function and was unstable in the atmosphere. This was done by alloying small amounts of silver to form stable cathodes with excellent adhesive properties. These and other modifications made to the layered organic thin film device helped it to achieve an extremely high external quantum luminous efficiency of 1%. Obtained brightness level of 1,000 candela or more per square meter using 10 V or less, is comparable to that of today's commercial products. Researchers worldwide were astonished by this development and by the 1990s, research on organic EL had expanded across the globe. The breakthrough of Prof. Tang and his colleagues also had important influence that have been instrumental in the development and commercialization of organic EL applications. One such example is the realization of high luminous efficiency through the use of phosphorescent materials incorporating transition heavy metals.

Prof. Tang's extensive research on organic electronics, especially OLEDs, culminated in his discovery of a highly luminous and efficient layered thin-film structure with separated functions, has remained one of the most important technological contributions in today's display industry. Since their commercialization in the late 1990s, OLEDs have surpassed LCDs to become the mainstream mobile displays. Furthermore, OLED TVs have been on the market since the late 2000s, and their sales are expected to grow in the future. Besides outstanding image quality and design, OLEDs feature low power consumption, enabling compact devices that connect people and have minimal impact on the environment. These and other aspects have made OLEDs crucial elements in various information devices and display devices; they will help to ensure the sustainability of Computers & Communications (C&C) and the information and communication society. In recognition of the enormous impact his pioneering work on OLEDs has had on the world, we believe that Prof. Tang would be an excellent recipient of the C&C Prize.