Mathematics, the queen of sciences

We highlight how this year's awardees from some of the most important prizes in mathematics have had an impact in the computational science community.

On 5 July 2022, the International Mathematical Union (IMU), an international non-governmental and non-profit scientific organization, announced the awardees of some of the most prestigious and important prizes in mathematics. All of these awards represent important scientific contributions that substantially move the field of mathematics — and science as a whole — forward. Some of the awards from this year are also particularly noteworthy for the computational and computer science communities.

The Fields Medal, often described as the Nobel Prize of mathematics, recognizes outstanding mathematical achievements and is awarded to mathematicians under 40 years of age. This year, there were four medalists in total; among the awardees, Hugo Duminil-Copin, a professor at the Institute of Advanced Scientific Studies in France and at the University of Geneva in Switzerland, works on the intersection between mathematics and physics. One of his most notable contributions is the development of mathematical models that can be used to explore a fundamental physical phenomenon known as phase transition: as an example, when ice melts, a phase change occurs and solid transforms into liquid water. In their work, Duminil-Copin and colleagues extended the well-understood two-dimensional Ising model to higher dimensions; notably, this extension resolved the continuity problem of phase transition in three-dimensional Ising models.

The IMU Abacus Medal, previously known as the Rolf Nevanlinna Prize, is awarded to theoretical computer scientists under 40 years of age for outstanding contributions in the mathematical aspects of information sciences, including computer science, scientific computing and numerical analysis. Notable winners of the previous Rolf Nevanlinna Prize include, for instance, Leslie Valiant, for his many contributions to theoretical computer science; Peter Shor, for his work on quantum computation, and more specifically, for deriving Shor's algorithm; and Jon Kleinberg, for his contributions to the mathematical theory of the global information environment, including small-world networks and the theory underlying search engines. This year, the Abacus Medal goes to Mark Braverman, a professor of computer science at Princeton University, for bringing mathematical rigor — from information theory — into communication complexity, an area that considers scenarios where there are multiple parties performing computation. Braverman's work focuses on developing techniques for proving precise estimates on the amount of communication needed between multiple parties, with the goal of minimizing the amount of information that they need to share to complete their task: in other words, how can the task be accomplished with each party learning as little as possible from each other? Practically, this has implications on various real-world settings that depend on interactive communication, such as information security, data compression, and the design of streaming algorithms.

Another notable awardee for the computational science community is Elliott Lieb, a professor of mathematics and Higgins professor of physics at Princeton University, who is the recipient of this year's Carl Friedrich Gauss Prize. This prize is awarded for outstanding mathematical contributions that have found important applications outside of mathematics; in Lieb's case, his contributions have had extraordinary breadth, with implications in fields such as quantum mechanics, quantum information theory, and computational chemistry. Among many achievements, Lieb and colleagues solved the two-dimensional Ising model; proved the strong subadditivity of quantum entropy, which is a basic theorem in quantum information theory; and provided various proofs of thermodynamic functions, including in the homogenous electron gas, which serves as the basis of many functionals in density functional theory. Lieb's work on determining various inequalities has contributed to the calibration of density functionals, the understanding of the stability of matter, and the establishment of constants in functional analysis to assess nonlinear quantum systems.

It is certainly not surprising that the concepts and advances in the field of mathematics are widely important to other areas of research, including computational science. Carl Friedrich Gauss, the famous mathematician after which one of the prizes is named, is said to have stated that mathematics is 'the queen of sciences'. We could not agree more with such a statement. ❐

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