Developments of Mathematics at IPMU: in Honor of Kyoji Saito

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Kyoji Saito finished his term as Kavli IPMU Principal Investigator at the end of March 2017. This conference was held on this occasion, from April 25 through 28, with the purpose of surveying the wide influence of Kyoji Saito's works on the development of mathematics at the Kavli IPMU. Based on a grand ambition to revive the theory of elliptic integrals and period integrals of Euler, Abel, and Jacobi from the 18th to 19th century into contemporary mathematics, Saito developed the theory of universal deformation of isolated singularities, primitive forms, flat structures and semi-infinite Hodge structures. These notions are closely related to the non-commutative Hodge theory developed later by Kontsevich, and the theory of Frobenius manifold which was used for the study of quantum cohomology. From the point of view of realizing period integrals of primitive forms along vanishing cycles, Saito also investigated infinite dimensional Lie algebras such as elliptic Lie algebras. Saito's theory plays an essential role in mirror symmetry in mathematics and theoretical physics.

There were talks in various areas including integrable systems, algebraic analysis, representation theory, algebraic geometry and quantum field theory, that were all influenced by pioneering works by Saito, and we had stimulating discussions. The list of lecturers at the conference included Aleksander A. Belavin, Alexey Bondal, Claus Hertling, Kentaro Hori, Hiroshi Iritani, Michio Jimbo, Si Li, Takuro Mochizuki, Shigeru Mukai, Nikita Nekrasov, Kyoji Saito, Morihiko Saito, Yukinobu Toda and Alexander Varchenko. The talk by Kyoji Saito was entitled "Highest weight Integrable Representations of Elliptic Lie algebra" and described the representation theory of infinite dimensional Lie algebras beyond the classical correspondence between simple singularities and simple Lie algebras. At the end of the conference he mentioned that the subjects covered at the conference appeared different at first glance, but in fact each of them are deeply connected with one another. Through this event, we were able to appreciate the depth and wide-ranged aspects of mathematics initiated by Kyoji Saito.

Music performance by the Kavli IPMU Chamber Orchestra with the participation of Kyoji Saito at Tea Time on April 27.

The 3rd Joint Symposium of Osaka CTSR, RIKEN iTHES/iTHEMS, and Kavli IPMU "Deep Learning and Physics"

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On June 5, 2017, the 3rd Joint Symposium of Osaka CTSR, RIKEN iTHES/iTHEMS, and Kavli IPMU "Deep Learning and Physics" was held at the Nambu Hall of Osaka University. In contrast to the previous two symposia of this series, the theme of this symposium was the relationship between deep learning—a hot topic in the fields of artificial intelligence and machine learning—and fundamental physics. In deep learning, high performance of deep convolutional neural networks in image processing has been drawing attention. It was Kunihiko Fukushima who proposed this characteristic structure when he was a professor at the School of Engineering Science at Osaka University in the 1980s and 1990s. I enjoyed this coincidence, as I have been working around the field of machine learning.

The program consisted of seven talks. The first two talks were related to neural networks, where Masato Taki (iTHES) gave an overview of the mechanism and development of deep learning, and Shun-ichi Amari (RIKEN BSI) explained the relationship between the theory of neural fields, which he proposed about 40 years ago, and deep learning. The next two talks were related to the application of neural networks in physics. Methods of training neural networks to reproduce phase diagrams and their results were reported by Tomi Ohtsuki (Sophia Univ.) regarding quantum phase transitions in random electron systems, and by Akinori Tanaka (iTHES) regarding an Ising spin model. The importance of machine learning in astronomy was the subject of the two subsequent talks. The present author (ISM/Kavli IPMU) explained the significance of sparse modeling in the Event Horizon Telescope, and the use of machine learning for the automatic detection of transients in the Subaru/Hyper Supreme-Cam (HSC) project. Nao Suzuki (Kavli IPMU) spoke about the relationship between Type Ia supernovae captured by the HSC and precision cosmology, and the role of machine learning. Finally, Yoshinobu Kawahara (Osaka Univ./RIKN AIP) explained the way to extend the recently proposed Dynamic Mode Decomposition (DMD) by using a kernel method.

Having attended this symposium, it was surprising to learn that physicists have a keen interest in neural networks. But, because my background is close to machine learning, I understand the risks, and caution the use of those techniques. High performance in deep learning has not been fully understood theoretically, and in some aspects it is used as a black box. Sometimes it is dangerous to apply such a method to a problem which should be clarified through precise first-principles calculations. I hope that physicists will make great achievements through proper use of machine learning.