2021 Issue 05

SUTD Honours And Research Programme (SHARP) Newsletter

Innovating Research with Design

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SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

SELF-REFLECTION ON 2021 NOBEL PRIZE IN PHYSICS AND COMPLEXITY PROBLEMS

By **Ricky Ang**, Head of Science, Mathematics and Technology (SMT) and Ng Teng Fong Chair Professor for SUTD-ZJU IDEA

The Nobel Prize in Physics 2021 (Press Release) was awarded to Prof. Syukuro Manabe, Prof. Klaus Hasselmann and Prof. Giorgio Parisi for their groundbreaking contributions to the understanding of complex physical systems.

One half of the prize was jointly awarded to Prof. Manabe and Prof. Hasselmann to recognize the "physical modeling" of Earth's climate, which predicts the global warming issue that could be the most critical crisis that humankind is facing now, other than COVID-19. The other half of the prize was awarded to Prof. Parisi on his evolutional theories in understanding disordered materials and random systems.

The accomplishments can be considered as particularly difficult as the study of the physics of complex systems is a relatively new field when compared to long history of physics tradition. It is great to recognise such "dirty and diverse problems" as most of the physicists like to deal with "clean and narrow problems".

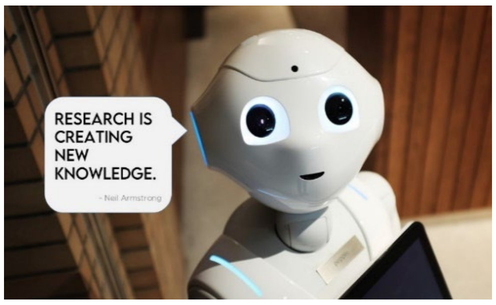
In Physics, we now know that the long-term behavior in a deterministic (and nonlinear) system is not possible to be predicted accurately. This is term as CHAOS. A Chaos-based system shows that aperiodic long term unpredictable outcome is very sensitive to the initial condition. It is NOT due to "random" or "noisy" inputs, but due to the intrinsic nonlinear dynamics of the system (at least n = 3 nonlinear problem). The most famous chaotic problem is the "Lorentz equations" developed by Prof. Edward Lorenz in 1963, in order to predict the convention flows in the atmosphere (this is related to climate modeling too). For such a simple-looking deterministic set of 3 coupled equation, the "erratic" dynamics or "chaos" suggest that the obtained solutions are not repeating but confined into a bound region called strange attractor.

During the Term 1 SHARP Honours Session, I introduced nonlinear dynamics leading to Chaos by using many examples in physics, chemistry, biology, engineering or any course of study that can be written down in mathematical form. The objective is to educate students that nonlinear systems (part of the complexity problems) are prevalent in many areas, not restricted to physics. In general, Complexity is a very broad area, and there are some diverse views on the definition of Complexity. I recommend students who are interested to read a simple write-up by Prof. Parisi on Complexity* from the view of a physicist. It is clear to me that strong mathematical background (like Applied Mathematics) is important for students who are keen to work on complexity. Many of the physical problems or known equations remain unsolved mathematically. For example, the well-known Navier-Stokes equations that are widely used by researchers as simulation tools to understand fluid dynamics, remains an unsolved problem in terms of the existence and smoothness of its solutions. Another example is the mathematical understanding of the quantum version of Yang-Mills equations in quantum field theory. Both outstanding problems were listed as 2 out of the 7 Millennium Problems (announced in May 2000) by mathematicians, as top problems to be solved in next 100 years.

In summary, I believe that the problem must be consistently built into a model and its prediction must be verified independently in order for a research problem to be claimed as solved or fully understood. Thus, well-grounded trainings in science, mathematics and computational skills are critical for a top researcher to tackle difficult problems in complexity that many of them can be viewed as user-inspired basic research.

* G. Parisi, *Physica A* **263**, 557 (1999). [Preprint available at: https://arxiv.org/pdf/cond-mat/0205297.pdf]

SHARP DISCOVERIES SESSION



SHARP office organised the inaugural SHARP Discoveries Session on 22 September 2021. Our students presented their diversified research works and achievements to the SUTD community.

The aim of this session is to provide an opportunity for all students who have joined the SHARP Honours Session to practice their oral presentation skills and to present their research results.

These are some of the research works that students have worked on or are currently working on:

Student Name	Programme	Project Title
AY2019 Students		
Vanessa Chia Yun Yao (EPD)	SHARP	Identifying Prototyping Competencies: An Interview Study
Jia Shuyi (ISTD)	SHARP	Periodic Noise-induced Framework for History-dependent Parrondo's Switching
Koh Hui Juan (EPD)	SHARP	Interventions to Support Children with Communication Developmental Delays
Shyam Sridhar (ESD)	Non-SHARP	Developing a Deep Reinforcement Learning Based Framework to Automate the Detection of Incentive Mechanism Attacks on the Ethereum Blockchain
AY2020 Students		
Sim Shang Hong (Freshmore)	SHARP	Efficacy of Synthesized Aspirin and Other Commercial Drugs at Reducing Inflammation in Endothelial Cells
Feng Zhuoer (Freshmore)	Non-SHARP	Designing, Prototyping, and Analysing Nonlinear and Topological Circuits: Behaviour, Interplay, and Applications

Click here to view the presentation(s) during the SHARP Discoveries Session.

WHY SHARP? HEAR FROM OUR NEW STUDENT

Isaac Tay Eng Hian
NUS High School alumnus
SUTD Class of 2024

What do you think of SHARP programme and why did you choose to apply for it?

I choose SHARP as I had always been interested in research, especially within the field of Artificial Intelligence (AI). There are so many things in the world yet to be explored, and I think it would be fun being at the edge of human knowledge.

What do you hope to gain from SHARP?

SHARP is where I hope to gain new insights into various fields, research experience, and the sufficient knowledge to publish research paper(s). I had always been interested in Robotics and Artificial Intelligence, an ever expanding field that I hope to contribute to. It would also be interesting to be exposed to the research done in other fields, so that I can incorporate new ideas from different fields into my own research. I hope that I can meet other peers interested in research through SHARP, so that I can learn more about new ideas/research areas that might generate from our interactions.

Could you share more about your research-related experience in high school?

Sure! In high school, my main research was on swarm robotics and computer vision. My team and I built a coaxial dual-motor drone, with a single font mounted camera, which had an Intel Edison for computing. Due to the massive limitation of computational power we could put on the drone, I had to come up with efficient ways to do environment mapping through swarm capabilities. Other projects that I've worked on include: trying out different neural network architectures, and implementing code for different architectures and modifying them to see what happens. Unfortunately, due to the lack of resources I had back in high school, I didn't have adequate resources to properly train the neural networks.

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