"The best theory is inspired by practice. The best practice is inspired by theory."



Concluding Lecture Chi-Ning Chou @ 2022 January Mini-Course "What is Computation? From Turing machines to Black Holes and Neurons"

- Donald Knuth



What is Computation? Concluding Lecture

"The best theory is inspired by practice. The best practice is inspired by theory."

Chi-Ning Chou @ 2022 January Mini-Course "What is Computation? From Turing machines to Black Holes and Neurons"

- Donald Knuth













Now that We've Gone So Far...

Can You Please Tell Me What Computation is Now!?

Responses from You!!

Converting inputs to outputs

Turing machines

Super Al

Information processing

Changes of the energy of a system

- Mechanical procedure
- Rationalize a natural process in a formulated way

- Evolution of a system
 - A way to think about a physical system



My Response

- Attempt 1 (Traditional view): Computation is a type of mechanical procedure, mathematical calculation, and information processing.
- Attempt 2 (Generalized view): Computation generally contains the
 - observation, description, analysis, understanding, and interpretation
- to the change of objects. It could be
 - mechanical, or semantical, or even intuitive.
- In the end, computation is not only a comfortable way of thinking, but could also be one of the fundamental principles behind the reality.
 - This is just a (biased) working definition, the point is how to provide more insights, discoveries, and understanding in the future!

Recap on the Mini-Course

Mathematics

Three Modules

Physics

Biology





I encourage you to follow your instinct and feel the underlying story like watching an art movie!

Why Math?

Module I: The mathematical foundation of computation

Fundamentals

Departure: Reasoning about Computation via Mathematics

Module I: The Mathematical Foundation of Computation

"If we understand an idea then it is only by mathematically recreating it." – Misha Gromov

Chi-Ning Chou © 2022 January Mini-Course "What is Computation? From Turing Machines to Black Holes and Neurons

Lecture I.a (Jan. 10 11am-11:50am ET)

Modern approach

Modern Developments: Models, Resources, Reductions

Module I: The Mathematical Foundation of Computation

"Every new body of discovery is mathematical in form, because there is no other suidance we can have. Charles Darwin Chi-Ning Chou @ 2022 January Mini-Course "What is Computation? From Turing Machines to Black Holes and Neurons

Lecture I.b (Jan. 11 10am-10:50am ET)

Philosophy

Reflection: Turing Machine and Reality

Module I: The Mathematical Foundation of Computation

As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality.

Albert Einstein

Lecture I.c (Jan. 17 10am-10:50am ET)



Thoughts and Feedbacks from Students!

Chih-Fu

Mostafa

Why Physics? Module II: Computations in the physical world





I encourage you to focus on the different world views and postulates physicists used for studying reality!

Module II: Computations in the Physical World

Classical approach

After the Falling Apple: **Classical and Statistical Mechanics**

Module II: Computations in the Physical World

"Nature is pleased with simplicity. And nature is no dummy.

Chi-Ning Chou @ 2022 January Mini-Course "What is Computation? From Turing Machines to Black Holes and Neurons

– Isaac Newton

Lecture II.a (Jan. 12 10am-10:50am ET)

Modern approach

Two Extremes: Quantum and Gravitational Theories

Module II: Computations in the Physical World

"As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain they do not refer to reality. – Albert Einstein

Chi-Ning Chou @ 2022 January Mini-Course "What is Computation? From Turing Machines to Black Holes and Neurons"

Lecture II.b (Jan. 13 10am-10:50am ET)

Philosophy

The Road to Reality: **New Insights from Computation?**

Module II: Computations in the Physical World

"Science is a differential equation. Religion is a boundary condition."

Lecture II.c (Jan. 19 10am-10:50am ET)







Thoughts and Feedbacks from Students!

CJ

Lisa

Why Biology? Module III: Computations in the biological world



I encourage you to enjoy the many examples we are going to see throughout the lectures and build up your own story!

Module III: Computations in the Biological World

Many Examples

Entering the Living World: Algorithms & Computations in Biology

Module III: Computations in the Biological World

"In the first place, there can be no living science unless there is a widespread instinctive conviction in the existence of an Order of Things. and, in particular, of an Order of Nature."

Chi-Ning Chou @ 2022 January Mini-Course "What is Computation? From Turing Machines to Black Holes and Neurons

- Alfred Whitehead

Lecture III.a (Jan. 12 11am-11:50am ET)

Evolution & Brain

Two Mysteries: Evolution and Neuroscience

Module III: Computations in the Biological World

"Natural science, does not simply describe and explain nature; it is part of the interplay between nature and ourselves. Werner Heisenberg

Chi-Ning Chou © 2022 January Mini-Course "What is Computation? From Turing Machines to Black Holes and Neurons

Lecture III.b (Jan. 14 10am-10:50am ET)

Philosophy

Challenges and Hopes: A Tango between Biology & Computation Module III: Computations in the Biological World

"All models are wrong, but some are useful."

- George Box

Chi-Ning Chou @ 2022 January Mini-Course "What is Computation? From Turing Machines to Black Holes and Neurons

Lecture III.c (Jan. 20 10am-10:50am ET)





Thoughts and Feedbacks from Students!

Dhruv

Wei-Ping

What's Covered and What's Not?

Consciousness

Creativity

Art

Math Appreciations

Intelligence

"Our knowledge can only be finite, while our ignorance must necessarily be infinite." - Karl Popper

Coding theory

Game theory Examples Physics Information Computation **Stories** Cryptography Biology Learning







A Warning & A Wish

We are still human beings and are finite... We all make mistakes from time to time... So...

Wish we all

- don't think that you've learned everything and
 - be critical to what I taught you

- be confident and also be humble
- be curious and also be rigorous

Mathematics

Goals Physics Biology

This is just the beginning of a lifelong journey!

Acknowledgement





GSAS Student Council Graduate School of Arts and Sciences (GSAS)









Guest Speakers







Aman



Pawan

Teaching Staff Thank you all for volunteering!



Reijo (Jan. 11 2pm-3pm ET)

"Undecidability of the Halting Problem and Gödel's incompleteness Theorem"



Prahlad (Jan. 12 9am-10am ET)

"The Four Color Theorem"



Sowmya (Jan. 18 10am-11am ET)

"Basic of Quantum Computing and Future Direction"



Avantika (Jan. 18 11am-12pm ET)

"Quantum Complexity Theory"



Mostafa



Aaron



Erick (Jan. 13 2pm-3pm ET)



Simone (Jan. 14 2pm-3pm ET)

"Information Geometry"

"Simulated Annealing"



Salvador (Jan. 19 2pm-3pm ET)



Kartikeya (Jan. 20 9am-10am ET)

"Quantum Computing from a Condensed Matter Perspective"

"DNA Computing, Cellular Automata, and Beyond"



















Special Thanks...























The Stage is Yours!

I'd be more that happy to assist your journey in the future U The initiative is on your side!