**Slide 1**

DEPARTMENT OF COMPUTER SCIENCE
HONG KONG BAPTIST UNIVERSITY
香港浸會大學計算機科學系

## 1) On *Philosophy* *(Nature)* *of Research*

**Jiming Liu**

Dean of Science & Chair Professor in Computer Science

Hong Kong Baptist University

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**Slide 2**

「 學問之道 無他，
　求其放心 而已矣。」

《孟子·告子上》

Meng Ke (Meng Zi)
(372-289 BC)

www.Wikipedia.com

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**Slide 3**

### "I think; therefore I am."

DISCOURS
DE LA METHODE
Pour bien conduire sa raison, & chercher
la verité dans les sciences.
PLUS
LA DIOPTRIQVE,
LES METEORES,
ET
LA GEOMETRIE.
Qui sont des effais de cete Methode.

- *"Je pense, donc je suis"*
- *Discourse on the Method of Rightly Conducting One's Reason and of Seeking Truth in the Sciences* (published in 1637)

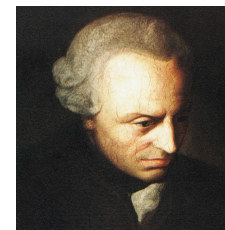- Since Descartes believed that all truths were ultimately linked, he sought to uncover the meaning of the natural world with a rational approach, through science and mathematics

René Descartes
(1596–1650)

www.Wikipedia.com
www.biography.com

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**Slide 4**

In *Critique of Pure Reason* (1781-1787), Immanuel Kant (1724-1804) tried to answer three questions:
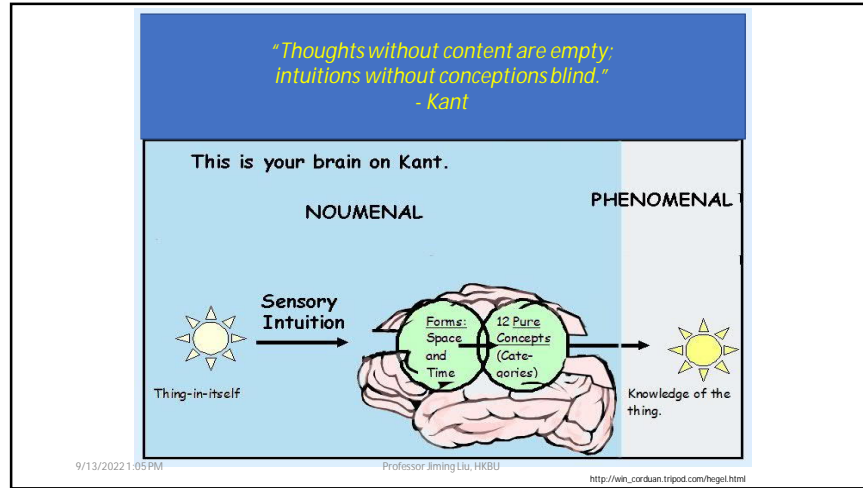
1. What can I know?
2. What should I do?
3. What may I hope?

"All our knowledge begins with the senses, proceeds then to the understanding, and ends with reason. There is nothing higher than reason."

Immanuel Kant

PENGUIN CLASSICS

IMMANUEL KANT
*Critique of Pure Reason*

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**Slide 1**

*"Thoughts without content are empty; intuitions without conceptions blind."*
- Kant

This is your brain on Kant.

NOUMENAL   PHENOMENAL

Sensory Intuition

Forms: Space and Time | 12 Pure Concepts (Cate-gories)

Thing-in-itself

Knowledge of the thing.

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**Slide 2**

### Kant's 4 Categories of Pure Understanding
(from his First Critique, 1781)

A New Look at Immanuel Kant @SourcePOV

| A.Quantity | B.Quality | C.Relation | D.Modality | 21st Century Interpretation? |
|---|---|---|---|---|
| [1A] UNITY (One) | [1B] REALITY | [1C] INHERENCE (Is A Property of) | [1D] POSSIBILITY | **1. Conceptual Dimension** Archetypes of Philosophic Knowledge |
| [2A] PLURALITY (Many) | [2B] NEGATION (Disproof) | [2C] CAUSALITY (Causes) | [2D] NECESSITY (Proof) | **2. Observable Dimension** Principles of Hypothetical, Empirical Science |
| [3A] TOTALITY (All) | [3B] LIMITATION (Constraint) | [3C] CORRELATION (Relates to) | [3D] CONTINGENCY (Adaptability & Emergence) | **3. Intuitive Dimension** Dynamics of Real World Complexity |

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**Slide 3**

**"To See a World..."**
(from "*Auguries of Innocence*" by William Blake, 1803)

To see a **World** in a **Grain of Sand**
And a **Heaven** in a **Wild Flower**,
Hold **Infinity** in the **palm of your hand**
And **Eternity** in an **hour**.

一沙一世界, 一花一天堂。
無限掌中置, 剎那成永恆。
徐志摩 譯

William Blake (1757–1827)  Source: Britannica

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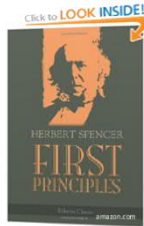
**Slide 4**

FIRST PRINCIPLES

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## Herbert Spencer: First Principles



Herbert Spencer
(1820-1903)

**Principle**s of Biology
**Principle**s of Psychology
**Principle**s of Sociology
**Principle**s of Ethics

"*Evolution is definable as a change from an incoherent homogeneity to a coherent heterogeneity*, accompanying the dissipation of motion and integration of matter. (Spencer, 1864)"

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• Spencer's synthetic philosophy

• Sciences are classified according to the decreasing simplicity and generality:

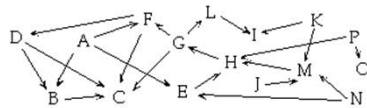  • Mathematics, astronomy, physics, chemistry, biology and sociology

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PRINCIPLE OF NON-INTERVENTION

Society is more like an ECOSYSTEM than an organism, and it is more COMPLEX than any organism or ecosystem

ECOSYSTEM : set of interacting species-populations:



unintended consequences — "results are not proportional to appliances"
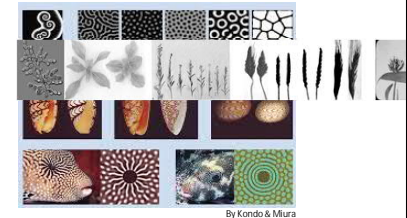
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## Alan Turing: How Nature Works



?

By Kondo & Miura

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**Alan Turing:** How Nature Works

*Reaction-Diffusion* Systems
(Turing Systems)

$$\partial_t q = \underline{D}\Delta q + R(q)$$

THE CHEMICAL BASIS OF MORPHOGENESIS

By A. M. TURING, F.R.S. *University of Manchester*

(*Received 9 November 1951—Revised 15 March 1952*)

It is suggested that a system of chemical substances, called morphogens, reacting together and diffusing through a tissue, is adequate to account for the main phenomena of morphogenesis. Such a system, although it may originally be quite homogeneous, may later develop a pattern or structure due to an instability of the homogeneous equilibrium, which is triggered off by random disturbances. Such reaction-diffusion systems are considered in some detail in the case of an isolated ring of cells, a mathematically convenient, though biologically unusual system.

Turing, A., On the chemical basis of morphogenesis, in *Philosophical Transactions of the Royal Society of London*. Series B, 237, 1952, pp 37-72.

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**Herbert Spencer:** First Principles



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First Principles should be
sound & insightful

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## Slide 1: Zipf's law

**George Zipf**
(1902-1950)

### Zipf's law

- Observation: frequent words and rare words
  - "of" and "the" make up 10% of all occurrences
  - hardly ever see "aardvark"
- Rank words by frequency
- Zipf's law:
  - rank of the word times its probability (frequency) is approximately a constant

$$r \times P_r \approx const$$

| Word | Freq. | r | $P_r$ (%) |
|------|-------|---|-----------|
| the | 2,420,778 | 1 | 6.49 |
| of | 1,045,733 | 2 | 2.80 |
| to | 968,882 | 3 | 2.60 |
| a | 892,429 | 4 | 2.39 |
| and | 865,644 | 5 | 2.32 |
| in | 847,825 | 6 | 2.27 |
| said | 504,593 | 7 | 1.35 |
| for | 363,865 | 8 | 0.98 |
| that | 347,072 | 9 | 0.93 |

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## Slide 2: Least effort principle

- Let $C_j$ be the cost of transmitting the j-th most frequent word

$$C_j \sim \log_m j$$

- The average cost is

$$C = \sum_{j=1}^{n} p_j C_j$$

- The average information content is

$$H = -\sum_{j=1}^{n} p_j \log_2 p_j$$

- Minimizing cost per information unit C/H yields

$$p_j \sim j^{-\alpha}$$

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## Slide 3: Human Behavior and the Principle of Least Effort

**George Zipf**
(1902-1950)

- Crashes in financial markets
- Dynamics of online popularity
- Scientific correspondence
- Human mobility patterns
- Spread of infectious diseases

*HUMAN BEHAVIOR AND THE PRINCIPLE OF LEAST EFFORT*
*An Introduction to Human Ecology*
*George Kingsley Zipf*

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## Slide 4: Multi-Scale Mobility Networks and Gravity Law Fit

$$w_{ij} = C \frac{N_i^{\alpha} N_j^{\gamma}}{f(d_{ij})}$$

Duygu Balcan et al. PNAS 2009;106:21484-21489

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## Conventional Wisdom…

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Occam's Razor: No more things should be presumed to exist than are absolutely necessary, i.e., the fewer assumptions an explanation of a phenomenon depends on, the better the explanation.

(William of Occam)

izquotes.com

"…In physics, parsimony was an important heuristic in Albert Einstein's formulation of special relativity, in the development and application of the principle of least action by Pierre Louis Maupertuis and Leonhard Euler, and in the development of quantum mechanics by Max Planck, Werner Heisenberg and Louis de Broglie."

wikipedia.org