當代系統科學思想

複雜
Complexity

產業研發碩士專班課程

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本週主題

1. Complex system
2. Characteristics of complex system
3. Complexity and Organization

複雜系統

簡單系統(simple system)的例子

- An oscillator
- A pendulum
- A wheel
- An orbiting planet

複雜系統(complex system)的例子

- Governments
- Families
- The human body—physiological perspective
- A person—psychosocial perspective
- The brain
- The ecosystem of the world
- Subworld ecosystems: desert, rain forest, ocean
- Weather
- A corporation

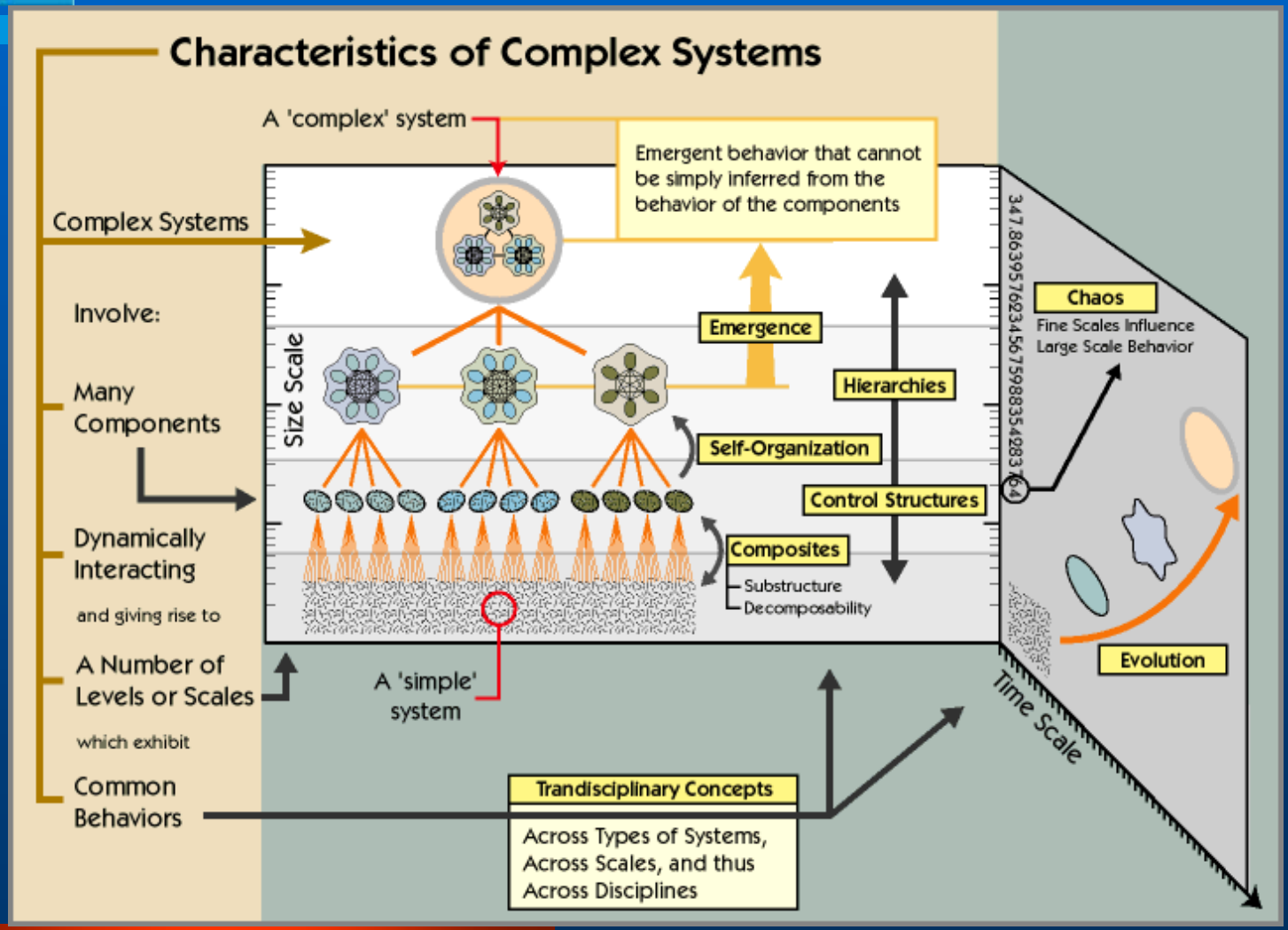
如何觀察一個複雜系統

- Elements (and their number)
- Interactions (and their strength)
- Formation/Operation
- Diversity/Variability
- Environment
- Activity(and its objective)

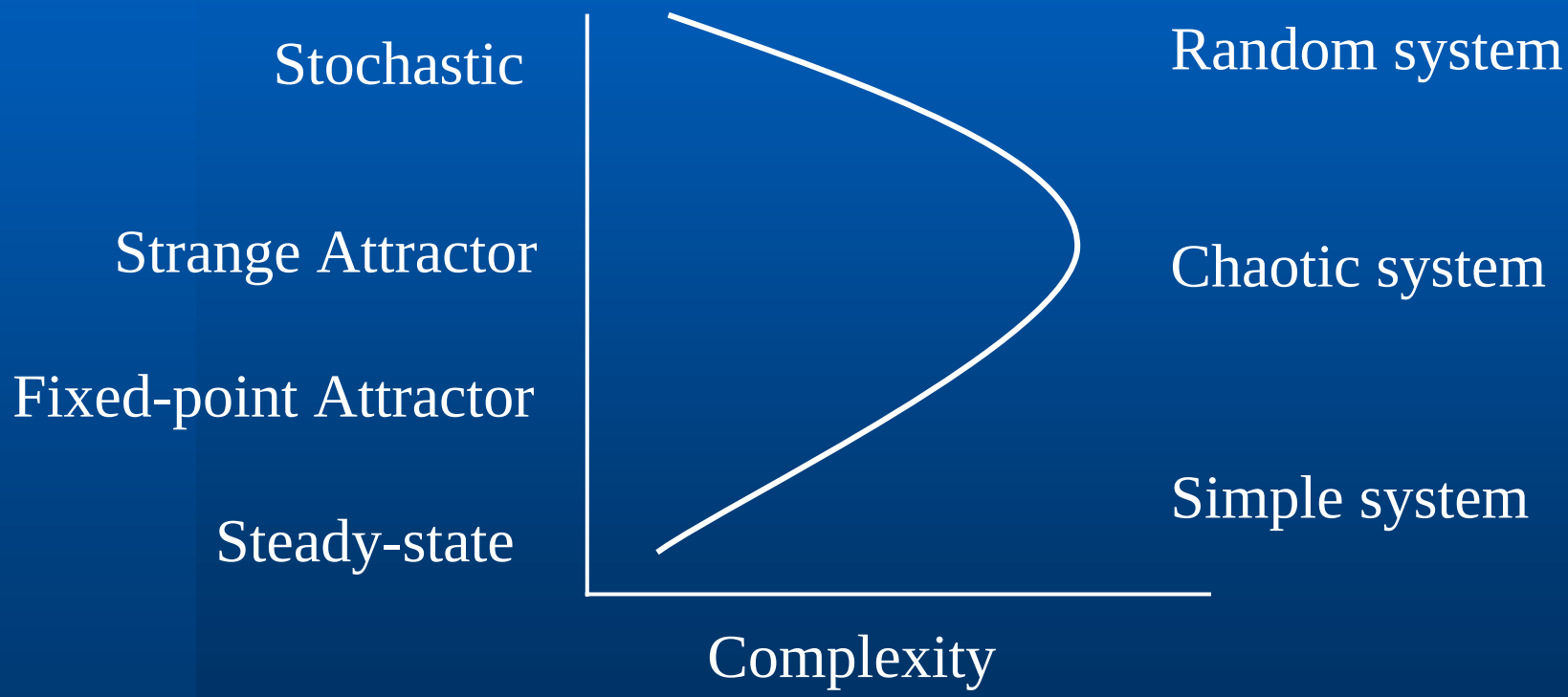
如何描述一個複雜系統

1. Space: What are the characteristics of the structure of complex systems?
2. Time: How long do dynamical processes take in complex systems?
3. Self-organization and/versus organization by design: How do complex systems come into existence? What are the dynamical processes that can give rise to complex systems?
4. Complexity: What is complexity? Complex systems have varying degrees of complexity.

複雜系統圖示


Characteristics of Complex Systems
A 'complex' system
Emergent behavior that cannot be simply inferred from the behavior of the components
Complex Systems
Involve:
Many Components
Dynamically Interacting
and giving rise to
A Number of Levels or Scales
which exhibit
Common Behaviors
Size Scale
Emergence
Hierarchies
Self-Organization
Control Structures
Composites
Substructure
Decomposability
A 'simple' system
Chaos
Fine Scales Influence Large Scale Behavior
Evolution
Time Scale
Trandisciplinary Concepts
Across Types of Systems, Across Scales, and thus Across Disciplines

複雜系統與複雜度


Stochastic
Strange Attractor
Fixed-point Attractor
Steady-state
Random system
Chaotic system
Simple system
Complexity

複雜系統實例

System	Element	Interaction	Formation	Activity
Proteins	Amino Acids	Bonds	Protein folding	Enzymatic activity
Nervous system Neural networks	Neurons	Synapses	Learning	Behavior Thought
Physiology	Cells	Chemical messengers Physical support	Developmental biology	Movement Physiological functions
Life	Organisms	Reproduction Competition Predation Communication	Evolution	Survival Reproduction Consumption Excretion
Human economies and societies	Human Beings Technology	Communication Confrontation Cooperation	Social evolution	Same as Life? Exploration?

Characteristics of complex system

Emergence

突現；自發

Emergence is the process of deriving some new and coherent structures, patterns and properties in a complex system.

Emergent phenomena occur due to the local interactions between the elements of the system over time.

Emergent phenomena are observable at a macro-level, even though they are generated by micro-level elements.

Complexity

- Kolmogorov-Chaitin Complexity
- Computational Complexity
- Stochastic Complexity
- Statistical Complexity
- Structural Complexity
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Deterministic Complexity

The *Kolmogorov-Chaitin* complexity of an object *x* is the length, in bits, of the smallest program (in bits) that when run on a *Universal Turing Machine* outputs *x* and then halts.

Measures of Complexity

測量一個系統的資訊量：

$$I = \log_2(\Omega)$$

Ω式系統狀態的數目

Measures of Randomness

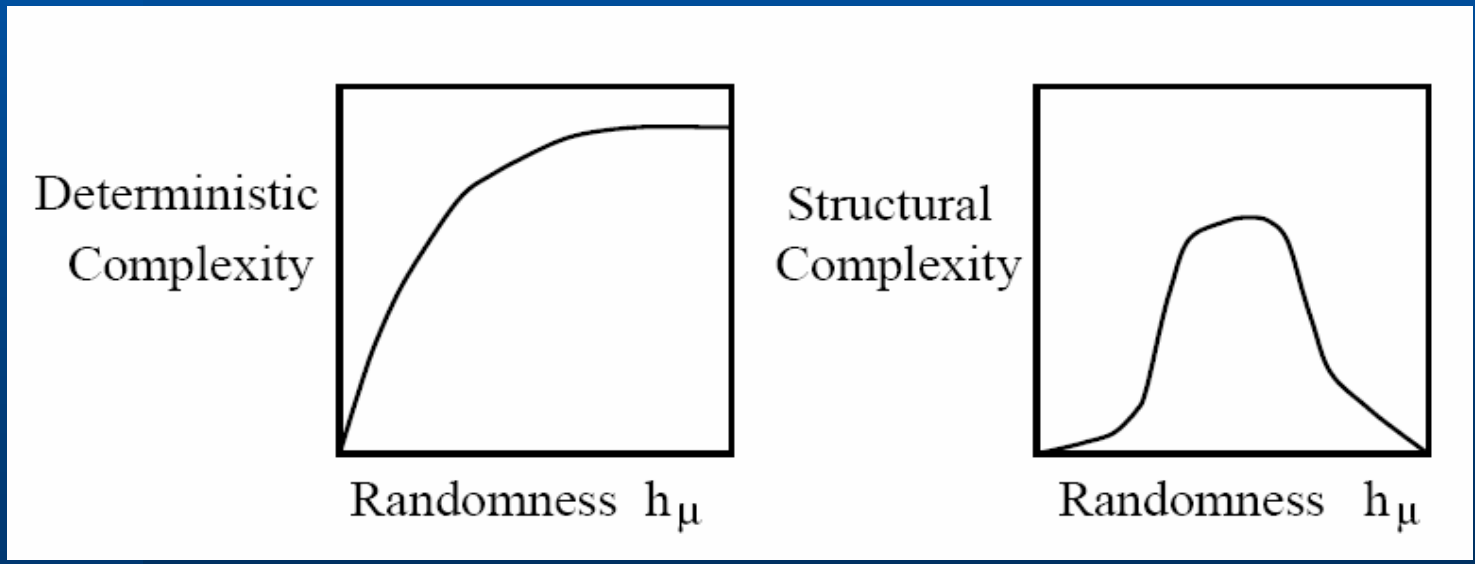
The entropy rate h_μ of a symbolic sequence measures the unpredictability (in bits per symbol) of the sequence.

Kolmogorov complexity

- The Kolmogorov complexity *K(x)* is maximized for random strings.
- The average growth rate of *K(x)* is equal to the entropy rate h_μ

Complexity Distinct from Randomness

The entropy rate h_μ and the Kolmogorov Complexity $K(x)$ do not measure pattern or structure or correlation or organization.



複雜系統特徵

1. 複雜系統由三個以上的元素(constituents)所構成
2. 系統的元素彼此交互關聯(inter-dependent)
3. 具有不同展開比例(spanning scale)的結構
4. 混沌與非混沌交互作用
5. 合作與競爭交互作用

Complexity and Organization

複雜系統方法論策略

1. Don’t take it apart.
2. Don’t assume smoothness
3. Don’t assume that only a few parameters are important.

複雜度管理(Frizelle, 1998)

	Structural complexity	Operational complexity
對策	Simplification	Management & control
預防	Better design	Improved reliability
治療	Process analysis and restructuring	Enhanced planning and scheduling

複雜系統組織的管理課題

- People Are Agents
- The Importance of Teams
- A New Role for Leaders
- Learning Organizations
- Communication Is Vital
- A Few Simple Rules
- Diversity Enhances Creativity

結語

生命恆朝向複雜度增加的方向演化。