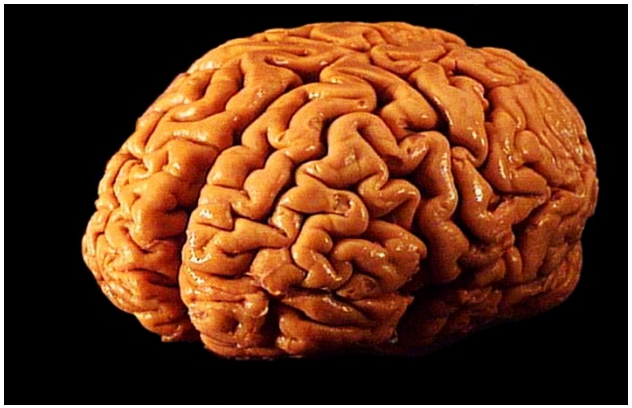
Information Theory and Self-organisation

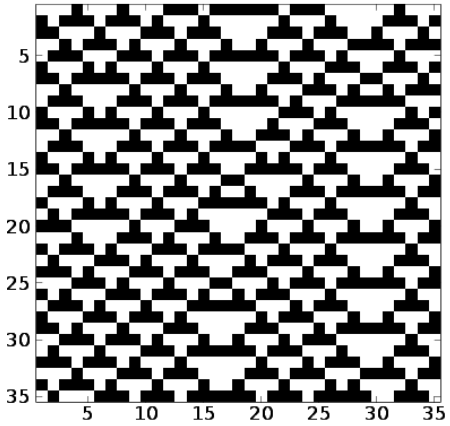
Overview

A/Prof. Joseph Lizier

THE UNIVERSITY OF SYDNEY

Complex systems and information





Information and complex systems concepts

- "Edge of chaos" – order and randomness interplay
  - Ordered systems have less uncertainty, less information
  - Disordered or random systems (more outcomes at system level) have more uncertainty, more information
  - Lower probability states are more surprising, carry more information
- Self-organisation as an increase in order over time (without external control) – Sayama p.6
- Emergence as increase in order over scale – Sayama p.6

Fish by Bruno de Giusti; CC BY SA 2.5 IT

H. Sayama, "*Introduction to the Modeling and Analysis of Complex Systems*", Geneseo, NY: Open SUNY Textbooks, 2015; chapter 1

Complex systems and information

- "*Although they (complex adaptive systems) differ widely in their physical attributes, they resemble one another in the way they handle information. That common feature is perhaps the best starting point for exploring how they operate.*"

  Murray Gell-Mann

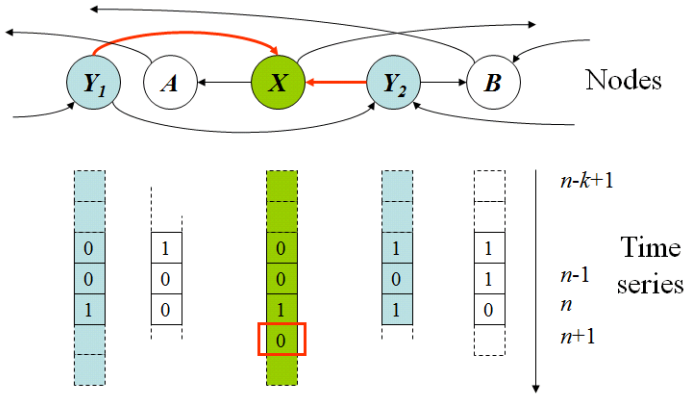
- In order to quantify these key concepts, we turn to information theory

M. Gell-Mann, The Quark and the Jaguar. New York: W.H. Freeman, 1994
in
M. Mitchell, "*Complexity: A guided tour*", New York: Oxford University Press, 2009

Learning outcomes

1. **Understand** basic information-theoretic measures, and advanced measures for time-series, and how to use these to **analyse** and **dissect** the nature, structure, function and evolution of complex systems.
2. Develop scientific programming skills which can be **applied** in complex system analysis and design.
3. To be able to **understand** the design of and to extend the **design** of a piece of software using techniques from class and your own readings.
4. Ability to **apply** and make informed decisions in selecting and using information-theoretic measures and software tools to analyse complex systems.
5. Ability to **create** information-theoretic analyses of real-world data sets, in particular in a student's domain area of expertise.
6. Capacity to **critically evaluate** investigations of self-organisation and relationships in complex systems using information theory, and the insights provided.

$$\mathrm{H}(X) = -\sum_{x \in A_x} p(x) \log_2 p(x)$$



JIDT

Information theory: what we will cover

Lectures/activities

1. Introduction to information theory and entropy I
2. Introduction to information theory and entropy II
3. What is information? I
4. What is information? II
5. Introduction to JIDT
6. Information-theoretic estimators and JIDT
7. Statistical significance and undersampling
8. Information theory and self-organisation
9. Information processing in complex systems
10. Information storage
11. Information transfer
12. Effective network inference

Introduction to information-theoretic concepts

Advanced information-theoretic concepts for data analysis

Information processing in complex systems

Resources:

- Texts: Cover and Thomas, Mackay, Bossomaier et al., Lizier (JIDT)
- Software: JIDT

Questions

THE UNIVERSITY OF SYDNEY