Information theory and complex systems: Wrap-up

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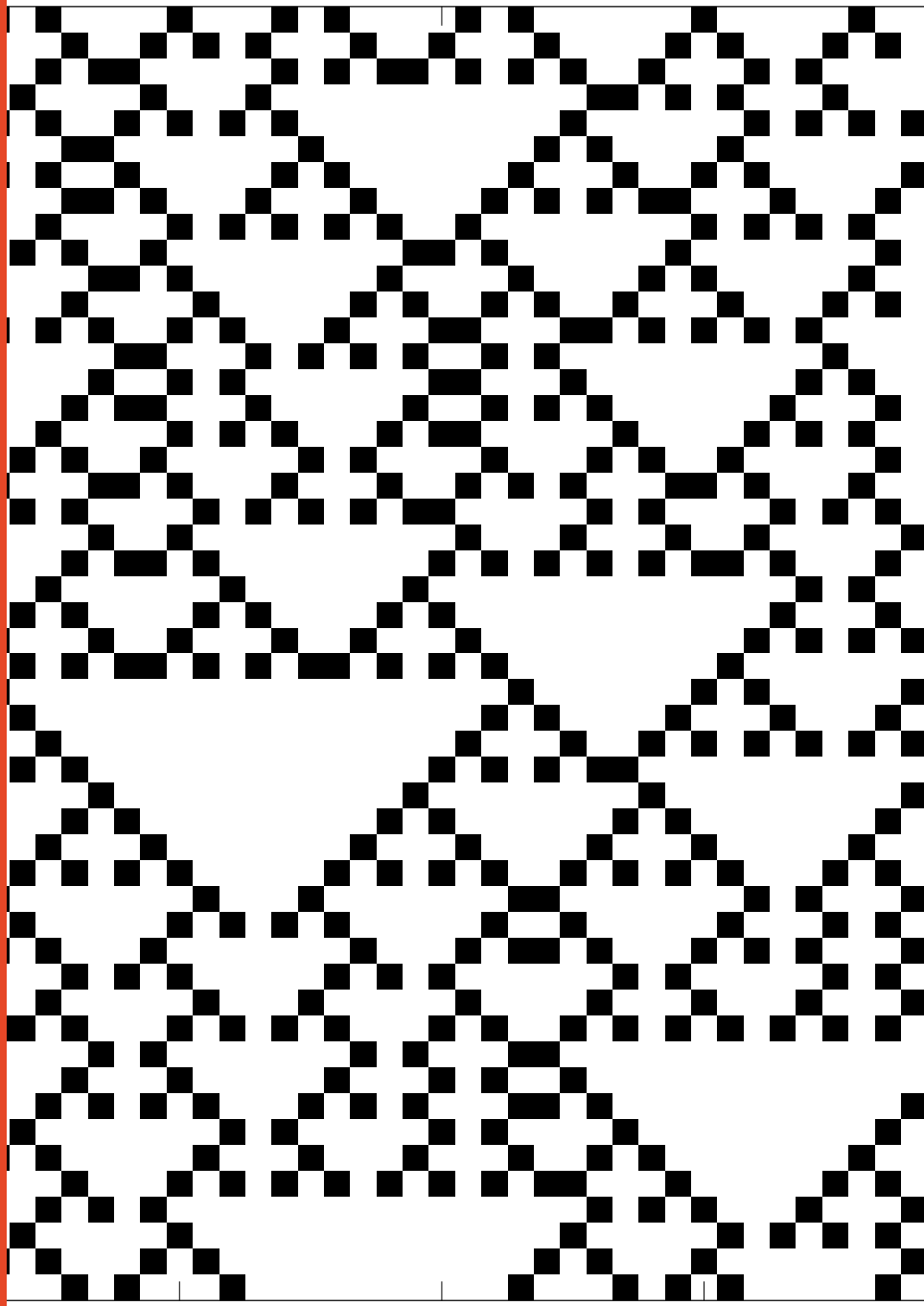

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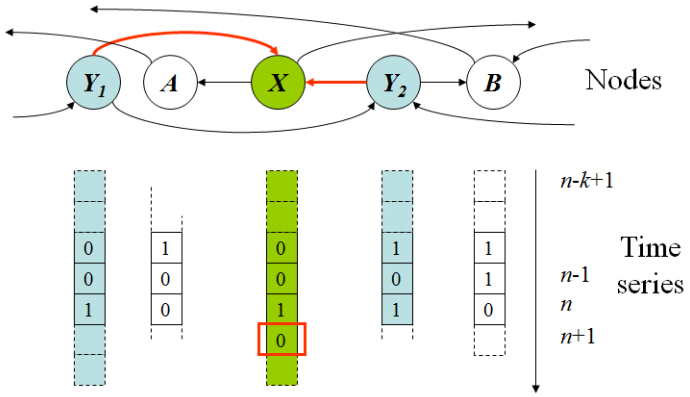
Learning outcomes

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 covered

Lectures/activities

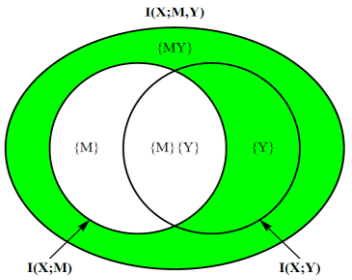
1. Introduction to information theory and entropy
2. What is information?
3. Introduction to JIDT
4. Information-theoretic estimators and JIDT
5. Statistical significance and undersampling
6. Information theory and self-organisation
7. Information processing in complex systems
8. Information storage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

Resources:

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

Final messages: context and perspectives

- There are many perspectives on information theory.
- I've given you mine, focussing on empirical analysis of complex systems.
- We've necessarily left out a lot, including:
  - Traditional use of information theory and coding
    - Channel capacity (noisy channel coding theorem)
    - Relating channel capacity to SNR
    - Coding, etc.
  - Other uses in complex systems:
    - Maximum entropy methods
    - Information bottleneck
    - Sensor-actuator loop
    - Phase transitions (see Bossomaier et al., 2016)
  - Areas of research:
    - Information theory and thermodynamics
    - Partial information decomposition (still evolving …)



Final messages: info theory, questions and answers

- Information theory is all about **questions** and **answers.**
  - Your estimator will always give you an answer. But is it answering the same question that you think you are asking?
  - Think hard about the question you want to ask of the data, and whether and how information theory can help you get an answer to that question.

Final messages: info theory and complex systems

- Information theory is a very powerful approach for investigating dynamics of and relationships in complex systems
  - Many pros: data-type agnostic, nonlinear, mathematically rigorous.
  - And many features of complex systems that we're interested in (e.g. information processing) can be measured/modelled by information theory!

- Shannon famously argued to restrict the application of information theory to communications engineering though.
- What do you think?

C. E. Shannon, "The Bandwagon", IRE Transactions on Information Theory, vol. 2(1), p. 3, 1956

Questions

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