Conclusion

Goals Revisited

1. Present some tools, models, paradigms that are useful in complex systems.
2. Discuss the applicability and un-applicability of these various tools.
3. Provide references and advice so you can learn more about these topics if you wish.
4. Present some thoughts about what makes the study of complex systems similar to, and different from, other types of science.
5. Provide some background which may help you get more out of other lectures.
6. Have fun.

Tools

In the introduction to my lectures, I said that:

Most tools and techniques for complex systems will need to:

1. Measure unpredictability, distinguish between different sorts of unpredictability, work with probabilities
2. Be able to measure and discover pattern, complexity, structure, emergence, etc.
3. Be inferential; be inductive as well as deductive. Must infer from the system itself how it should be represented.

I hope to have given you some tools that you can use, apply, modify, and/or reject as you see fit.

Many Possible Open Questions

- Two-dimensional systems.
  - Formally, a 2D system can be converted into a 1D string.
  - However, I think this is the wrong way to think about 2D.
  - 2D problems are much harder, conceptually and practically, than 1D problems.
  - Measures of complexity for 2D systems is a wide open area.
  - See Feldman and Crutchfield, *Physical Review E*,**67**:051104, 2003 and references therein.
- Complexity of networks?
- More closely relating complexity measures to the theory of critical phenomena and/or extending results to disordered systems.
- Applying these tools in new and creative ways.
- And many more...

Complex Systems Science?

Is there a science or theory of complex systems? Can there be one? My hunch is that the answer is no, at least not in the usual sense of theory.

- Perhaps looking for a unifying theory of complex systems is to forget the message of emergence: that the whole is the greater than the sum of its parts, and that innovation and novelty is the norm.
- On the other hand, I don't think it's the case that every complex system is different. There may be some unifying tools, principles and ideas.
- My strong hunch is that a theory of complex systems will be primarily concerned with **methods** and **tools** as opposed to universal governing principles or equations.

What Good are Complex Systems?

- Complex systems provide a new set of paradigms or exemplars: e.g., logistic equation, random graphs, CAs, Schelling's tipping model, etc.) These serve as stories we tell about what the world is like, and provide an important counterbalance to linear, reductive, "rational" models that still are predominant in many fields.
- The model systems of the sort I've focused on here may have little to say directly about complicated, real-world phenomena. However, these systems provide a very clear setting in which to explore the discovery of pattern, and fundamental tradeoffs between randomness and order. This can hone intuition when considering other, real-world complex systems.

What Good are Complex Systems?, continued

- I believe that there is an aesthetic and perhaps even normative component to the study of complex systems. Part of what the field has in common is a group of people with similar tastes and concerns and a sense of what is interesting:
  - How the world is put together, rather than how it's taken apart.
  - A fascination with patterns and their formation.
  - A fascination with diversity.
  - A willingness to take risks.
  - A recognition of interrelationships and complexity.

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