Whats up with the weird vegetable ?

spm 9550: Introduction to Complexity

Dr. ir. Igor Nikolic

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Lecture goals

- Have a general understanding of (the history of) systems thinking and Complex Adaptive System properties
- Know and understand two definitions of complexity
  - Mikulecky
  - Kauffman
- Understand the difference between complexity and complicatedness
- Understand the concepts of generative science

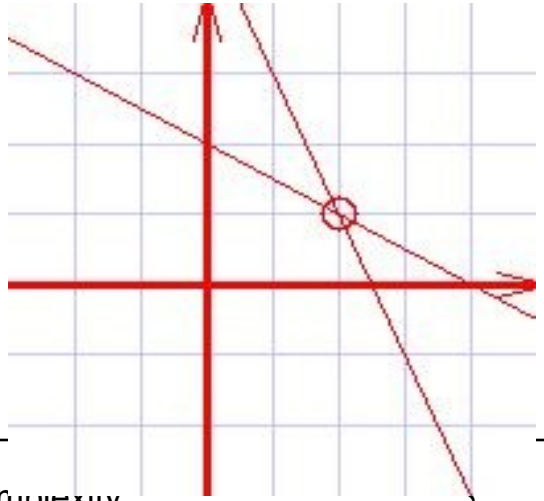
What is a System ?

- a regularly interacting or interdependent group of items forming a unified whole.
- an organized set of doctrines, ideas, or principles usually intended to explain the arrangement or working of a systematic whole.
- manner of classifying, symbolizing, or schematizing
- harmonious arrangement or pattern or order

http://www.merriam-webster.com/dictionary/system

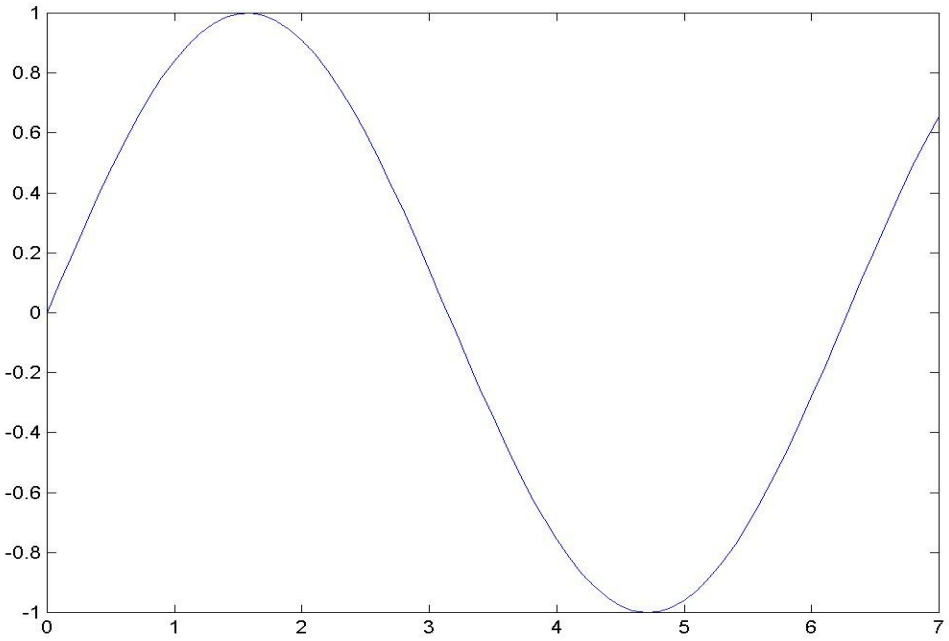
Linear system

- Linear systems are ``simple". An change in the systems setting results in a system response linearly proportional to the input. (y=Ax+B)
  - often used as an approximation of more complicated systems because they are easy to calculate. (matrix inversion)



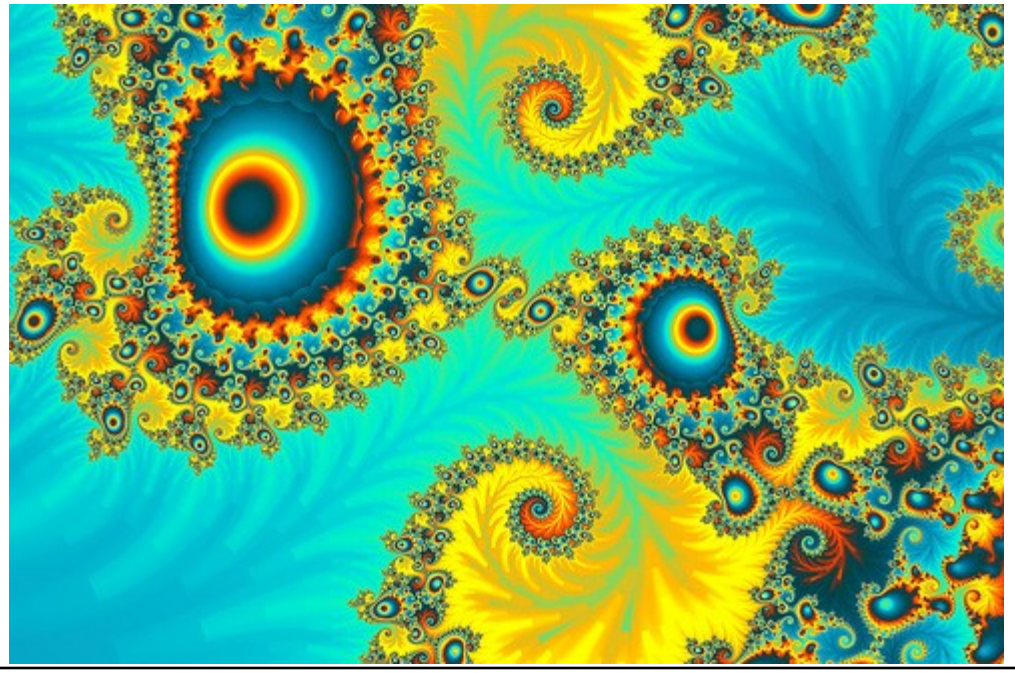
Nonlinear systems

- Nonlinear systems have a response that is not proportional to the input.
  - can be straightforward and predictable (y = sin x)



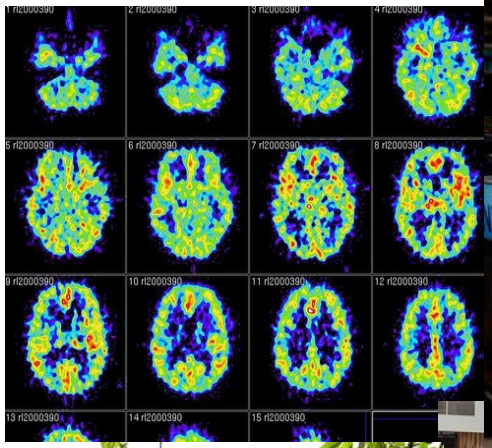
Nonlinear chaotic systems

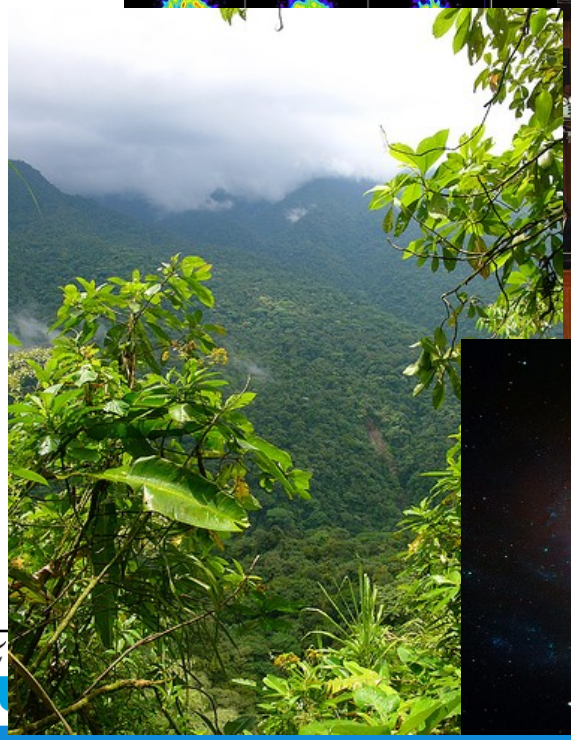
- Some non-linear systems express Chaotic behavior.
  - That is, extreme sensitivity to initial conditions,
  - Z = Z^2 + Ci



What is a complex system ?

Some examples I can think of :





What do all of these systems have in common ?

Some properties of *all* complex systems:

emergence

observer-dependency

robustness

diversity

self-similarity

order

randomness

adaptiveness

path-dependency

non-linearity

chaos

evolution

instability

Systems perspective I

- Taking into account all of the behaviors of a system as a whole in the context of its environment is the systems perspective.

  While the concept of system itself is a general notion that indicates separation of part of the universe from the rest, the idea of a systems perspective is to use a non-reductionist approach in the task of describing the properties of the system itself.

Y. Bar-Yam. Concepts in complex systems: Systems perspective. http://necsi.edu/guide/concepts/system_perspective.html, 2008.

Systems perspective II

- In the systems perspective, once one has identified the system as a separate part of the universe, one is not allowed to progressively decompose the system into isolated parts.

  Instead, one is obligated to describe the system as a whole. If in describing system properties one separates them into parts, this produces an incomplete description of the behavior of the whole.

  Any description of the whole must include an explanation of the relationships between these parts and any additional information needed to describe the behavior of the entire system.

Y. Bar-Yam. Concepts in complex systems: Systems perspective. http://necsi.edu/guide/concepts/system_perspective.html, 2008.

Complexity is …

- …the property of a real world system that is manifest in the inability of any one formalism being adequate to capture all its properties.
- It requires that we find distinctly different ways of interacting with systems.
- Distinctly different in the sense that when we make successful models, the formal systems needed to describe each distinct aspect are not derivable from each other.

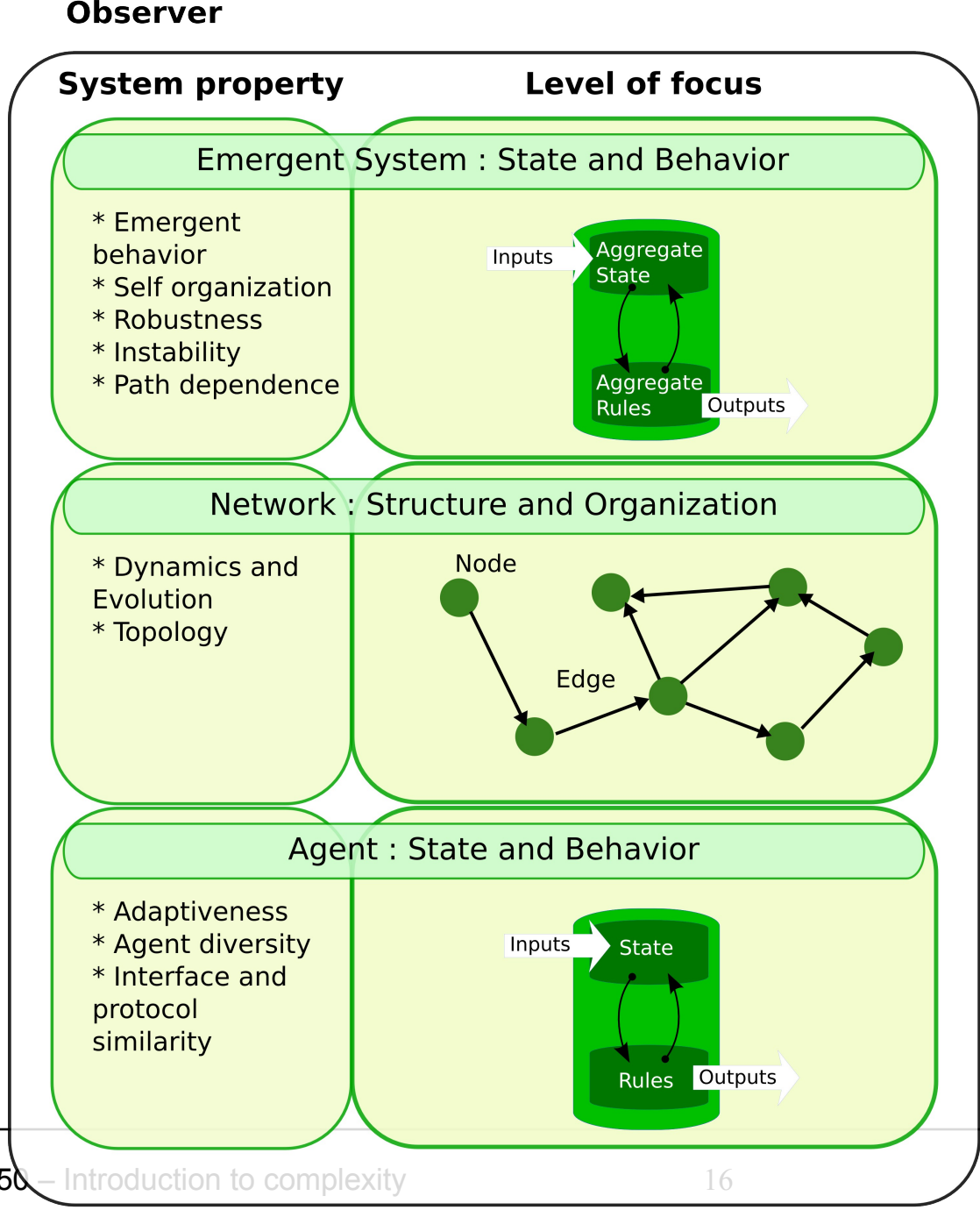
D.C. Mikulecky. The emergence of complexity: science coming of age or science growing old *Computers and Chemistry*, 25(4):341–348, 2001.

Complex Adaptive Systems are :

- ...a dynamic network of many agents (which may represent cells, species, individuals, firms, nations) acting in parallel, constantly acting and reacting to what the other agents are doing. The control of a CAS tends to be highly dispersed and decentralized. If there is to be any coherent behavior in the system, it has to arise from competition and cooperation among the agents themselves. The overall behavior of the system is the result of a huge number of decisions made every moment by many individual agents.

M.M. Waldorp. *Complexity: The emerging science at the edge of order and chaos*. Simon and Schuster, New York, 1992.

Complexity-on-a-stick

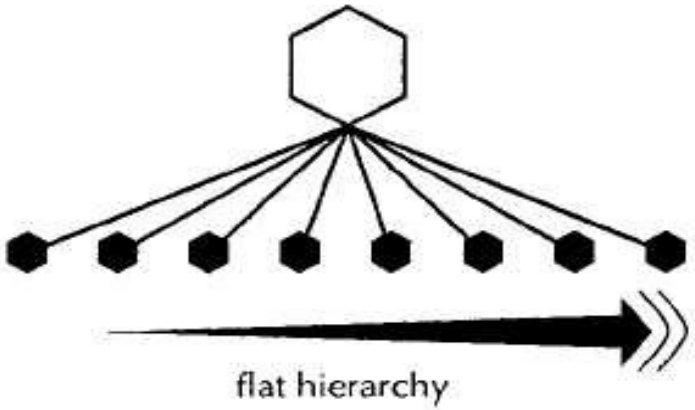


Unpredictable dynamic environment

Complex vs. Complicated

Horizontal Differentiation

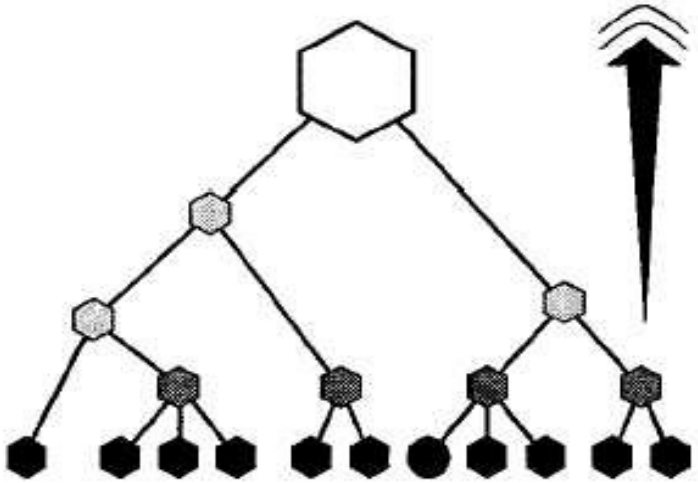
Elaboration of structure solves problems and moves on to the next problem, leaving structure behind. Evolution makes COMPLICATED structure that is difficult to control, predict, or mend. It causes horizontal differentiation.



flat hierarchy

Vertical Differentiation

Elaboration of organization creates energy dissipative far from equilibrium structures. It causes COMPLEX structure with many levels. Behavior becomes simple but energetic cost is high. Emergence causes vertical differentiation.



deep hierarchy

Supply side sustainability, Hoekstra, Allen and Tainter, Systems research and Behavioural Science, 16, 403-427,1999

The fact that it is on this screen makes it complex.