DGC2003h: Systems Thinking for Global Problems

- Course Intro
  - Website: http://www.cs.toronto.edu/~sme/DGC2003H
  - Books
  - Assignments
- Basic Definitions
  - Parts vs Wholes
  - Stocks & Flows
  - Feedback Loops

Look at the following list of words…

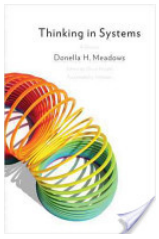
Slumber	Pillow
Dream	Night
Bed	Blanket
Quiet	Pajamas
Nap	Snooze

Now write down as many as you can remember

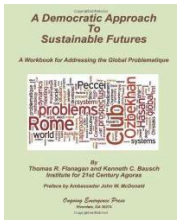
Course Goals

- → To change your perspective
- → To give you new thinking tools
- → To provide concepts & terms to help understand dynamic, complex systems
- → To persuade you to apply these ideas in your own research

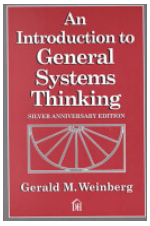
Books



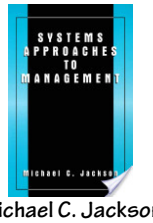
Donella Meadows
Thinking In Systems



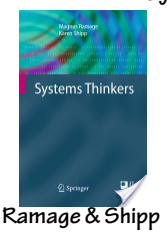
Flanagan & Bausch
A Democratic Approach
To Sustainable Futures



Gerald Weinberg
Intro to General
Systems Thinking



Michael C. Jackson
Systems Approaches to Management



Ramage & Shipp
Systems Thinkers

Assignments

- Class Participation
  - Show up
  - Do stuff
  - Get points
- A 5-minute talk about a prominent systems thinker
  - Must agree on who does whom
  - Sources: Ramage & Shipp, course website
  - Bonus marks: Make it a Pecha Kucha!
- Term Paper
  - Do a Case Study
  - Or…?

Why Systems Thinking?

- What makes a traffic jam?
- How do epidemics spread?
- Why does the stock market fluctuate?

So what is a system?

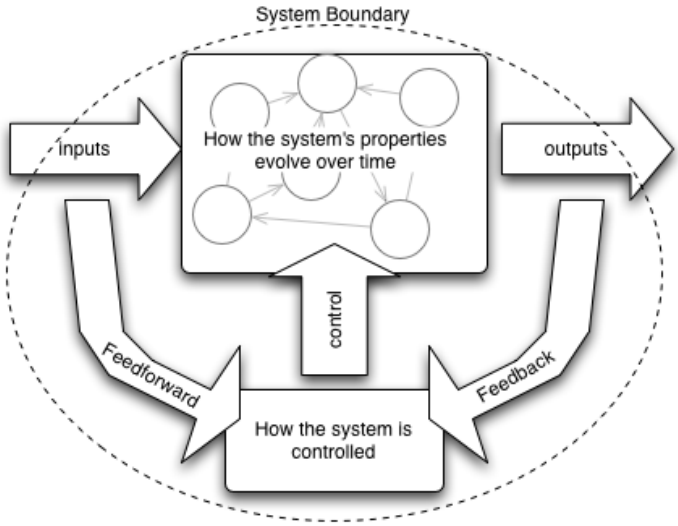
- Ackoff's definition:
  - "A system is a set of two or more elements that satisfies the following conditions:
    - The behaviour of each element has an effect on the behaviour of the whole
    - The behaviour of the elements and their effect on the whole are interdependent
    - However subgroups of elements are formed, each has an effect on the behaviour of the whole and none has an independent effect on it"
- Or, more simply:
  - Weinberg: "A system is a way of looking at the world"
    - Systems don't really exist!
    - Just a convenient way of describing things (like 'sets')

Here is a system

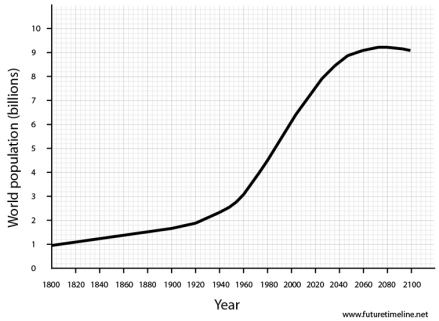
Elements of a system

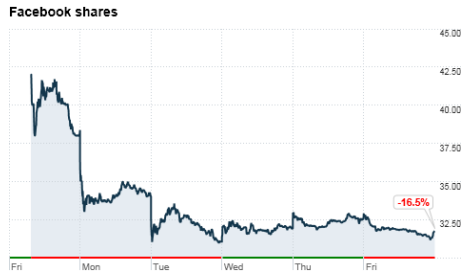
- **Boundary**
  - Separates a system from its environment
  - Often not sharply defined
  - Also known as an "interface"
- **Environment**
  - Part of the world with which the system can interact
  - System and environment are inter-related
- **Observable Interactions**
  - How the system interacts with its environment
  - E.g. inputs and outputs
- **Subsystems**
  - Can decompose a system into parts
  - Each part is also a system
  - For each subsystem, the remainder of the system is its environment
  - Subsystems are inter-dependent
- **Control Mechanism**
  - How the behaviour of the system is regulated to allow it to endure
  - Often a natural mechanism
- **Emergent Properties**
  - Properties that hold of a system, but not of any of the parts
  - Properties that cannot be predicted from studying the parts

Conceptual Picture of a System

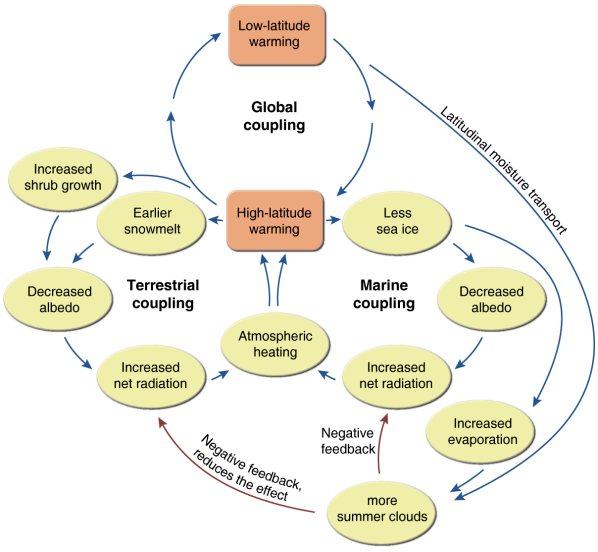


Picturing systems

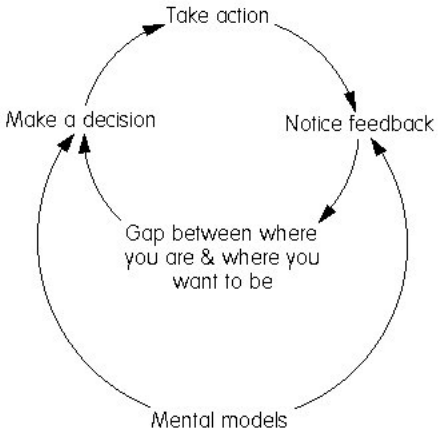




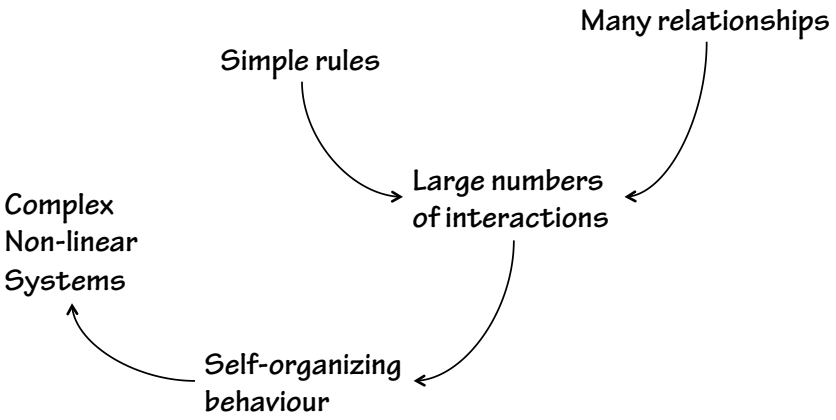
Causal Loop Diagrams



Double Loop Learning



Behaviour of Complex Systems

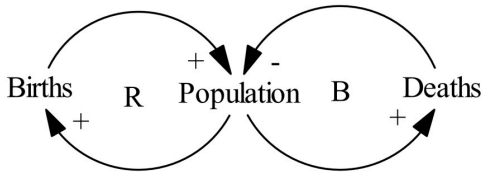


Two approaches to study systems

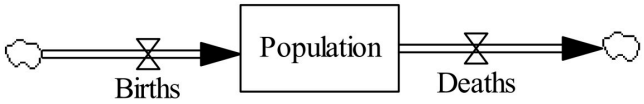
1. Focus on the rules followed by individuals
   - Study emergent behaviour
   - Build simulations
2. Understand system dynamics
   - Build causal diagrams
   - Study feedback loops

Stocks and Flows Diagrams

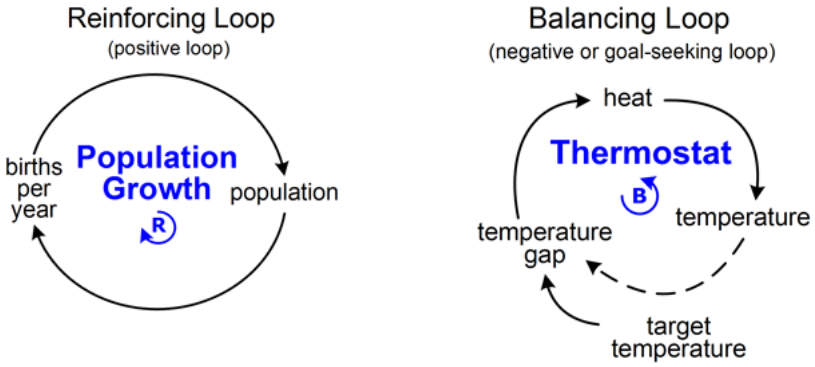
(a)



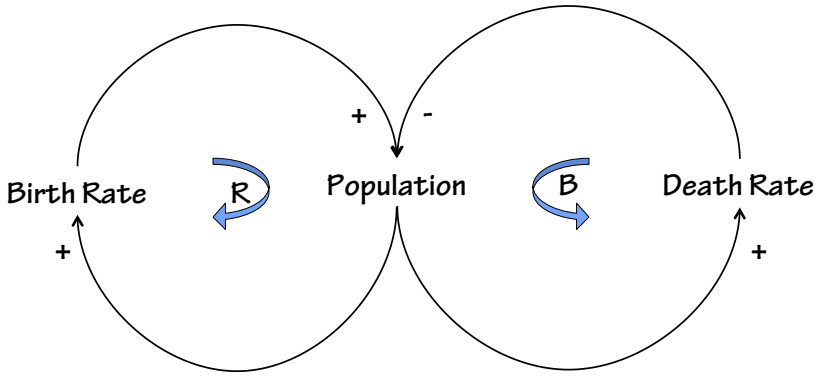
(b)



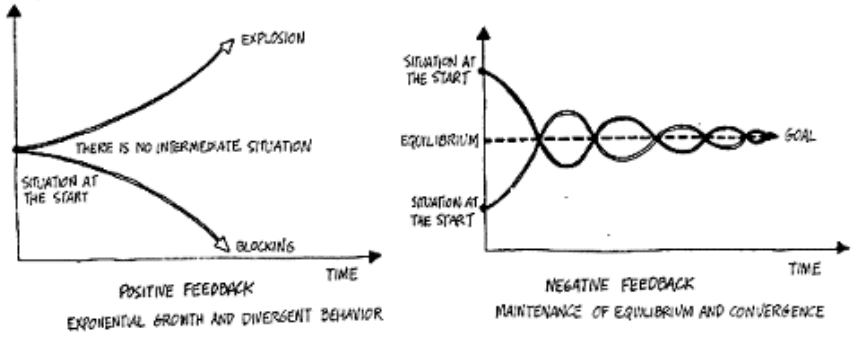
Feedback Loops



Multiple Loops



Effect of feedbacks



Key concepts

STATIC VISION (SIMPLE SYSTEMS)	DYNAMIC VISION (COMPLEX SYSTEMS)
SOLID	FLUID
FORCE	FLOW
CLOSED SYSTEM	OPEN SYSTEM
LINEAR CAUSALITY — (STABILITY) — (RIGIDITY) — (SOLIDITY)	CIRCULAR CAUSALITY — (DYNAMIC STABILITY) — (STATIONARY STATE) — (CONTINUOUS TURNOVER)
FORCE EQUILIBRIUM	FLOW EQUILIBRIUM
EXAMPLE: A CRYSTAL	EXAMPLE: A CELL
BEHAVIOR OF SYSTEMS — (FORESEEABLE). — (REPRODUCIBLE) — (REVERSIBLE)	BEHAVIOR OF SYSTEMS: — (UNFORESEEABLE) — (UNREPRODUCIBLE) — (IRREVERSIBLE)

Hard vs. Soft Systems

Hard Systems:

- The system is…
  - …precise,
  - …well-defined
  - …quantifiable
- No disagreement about:
  - Where the boundary is
  - What the interfaces are
  - The internal structure
  - Control mechanisms
  - The purpose ??
- Examples
  - A car (?)

Soft Systems:

- The system…
  - …is hard to define precisely
  - …is an abstract idea
  - …depends on your perspective
- Not easy to get agreement
  - The system doesn't "really" exist
  - Calling something a system helps us to understand it
  - Identifying the boundaries, interfaces, controls, helps us to predict behaviour
  - The "system" is a theory of how some part of the world operates
- Examples:
  - All human activity systems

Open and Living Systems

Openness

- The degree to which a system can be distinguished from its environment
- A closed system has no environment
  - If we describe a system as closed, we ignore its environment
  - E.g. an egg can be described as a closed system
- A fully open system merges with its environment

Living systems

- Special kind of open system that can preserve its identity and reproduce
  - Also known as "neg-entropy" systems
- E.g. biological systems
  - Reproduction according to DNA instructions
- E.g. Social systems
  - Rules of social interaction act as a kind of DNA

Types of System

- **Natural Systems**
  - E.g. ecosystems, weather, water cycle, the human body, bee colony,…
  - Usually perceived as hard systems
- **Abstract Systems**
  - E.g. set of mathematical equations, computer programs,…
  - Interesting property: system and its description are the same thing
- **Symbol Systems**
  - E.g. languages, sets of icons, streetsigns,…
  - Soft because meanings change
- **Designed Systems**
  - E.g. cars, planes, buildings, freeways, telephones, the internet,…
- **Human Activity Systems**
  - E.g. businesses, organizations, markets, clubs, …
  - E.g. any designed system when we also include its context of use
    - Similarly for abstract and symbol systems!
- **Information Systems**
  - Special case of designed systems
    - Part of the design includes the representation of the current state of some human activity system
  - E.g. MIS, banking systems, databases, …
- **Control systems**
  - Special case of designed systems
    - Designed to control some other system (usually another designed system)
  - E.g. thermostats, autopilots, …

Summary: Systems Thinking