Lecture 4: What is a system?

- **Basic Principles:**
  - Everything is connected to everything else
  - You cannot eliminate the observer
  - Most truths are relative
  - Most views are complementary
- **Defining Systems**
  - Elements of a system description
  - Example systems
  - Purposefulness, openness, hardness, …
- **Describing systems**
  - Choosing a boundary
  - Describing behaviour

General Systems Theory

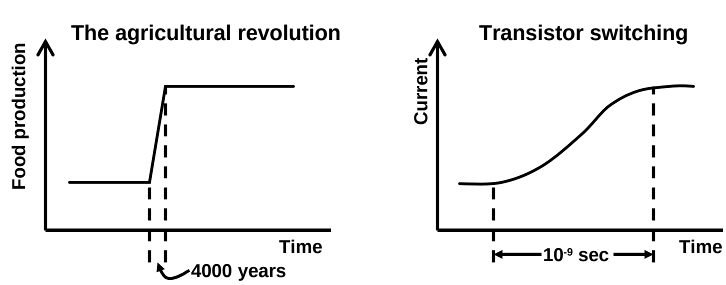
- **How scientists understand the world:**
  - Reductionism - break a phenomena down into its constituent parts
    - E.g. reduce to a set of equations governing interactions
  - Statistics - measure average behaviour of a very large number of instances
    - E.g. gas pressure results from averaging random movements of zillions of atoms
    - Error tends to zero when the number of instances gets this large
- **But sometimes neither of these work:**
  - Systems that are too interconnected to be broken into parts
  - Behaviour that is not random enough for statistical analysis
- **General systems theory**
  - Originally developed for biological systems:
    - E.g. to understand the human body, and the phenomena of 'life'
  - Basic ideas:
    - Treat inter-related phenomena as a system
    - Study the relationships between the pieces and the system as a whole
    - Don't worry if we don't fully understand each piece

Role of the Observer

- **Achieving objectivity in scientific inquiry**
  1. Eliminate the observer
     - E.g. ways of measuring that have no variability across observers
  2. Distinguish between scientific reasoning and value-based judgement
     - Science is (supposed to be) value-free
     - (but how do scientists choose which theories to investigate?)
- **For complex systems, this is not possible**
  - Cannot fully eliminate the observer
    - E.g. Probe effect - measuring something often changes it
    - E.g. Hawthorne effect - people react to being studied
  - Our observations biased by past experience
    - We look for familiar patterns to make sense of complex phenomena
    - E.g. try describing someone's accent
- **Achieving objectivity in systems thinking**
  - Study the relationship between observer and observations
  - Look for observations that make sense from many perspectives

Relativism

- **Truth is relative to many things**
  - The meanings of the words we use
    - E.g. law of gravity depends on correct understanding of "mass", "distance", "force" etc
  - The assumptions we make about context
    - E.g. law of gravity not applicable at subatomic level, or near the speed of light
    - E.g. Which is the step function:



Relativism is everywhere

- **Truth often depends on the observer**
  - "Emergent properties of a system are not predictable from studying the parts"
    - Whose ability to predict are we talking about?
  - "Purpose of a system is a property of the relationship between system & environment"
    - What is the purpose of: General Motors? A University? A birthday party?
- **Weltanshaungen (~ "worldviews")**
  - Our Weltanshaungen permeate everything
    - The set of categories we use for understanding the world
    - The language we develop for describing what we observe
- **Ethno-centrism (or ego-centrism)**
  - The tendency to assume one's own category system is superior
    - E.g. "In the land of the blind, the one-eyed man is king"
    - But what use would visually-oriented descriptions be in this land?

The principle of complementarity

- **Raw observation is too detailed**
  - We systematically ignore many details
    - E.g. the idea of a 'state' is an abstraction
  - All our descriptions (of the world) are partial, filtered by:
    - Our perceptual limitations
    - Our cognitive ability
    - Our personal values and experience
- **Complementarity:**
  - Two observers' descriptions of system may be:
    - Redundant - if one observer's description can be reduced to the other
    - Equivalent - if redundant both ways
    - Independent - if there is no overlap at all in their descriptions
    - Complementary - if none of the above hold
  - Any two partial descriptions (of the same system) are likely to be complementary
  - Complementarity should disappear if we can remove the *partiality*
    - E.g. ask the observers for increasingly detailed observations
  - But this is not always possible/feasible

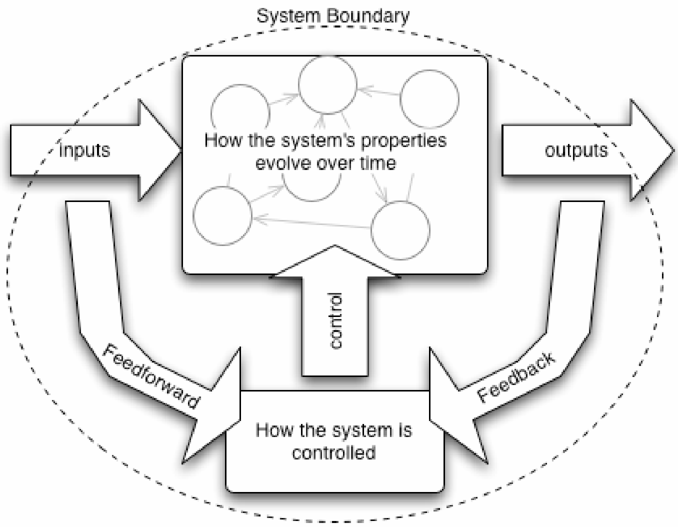
Definition of a system

- **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"
- **Other views:**
  - Weinberg: "A system is a collection of parts, none of which can be changed on its own"
    - …because the parts of the system are so interconnected
  - Wieringa: "A system is any actual or possible part of reality that, if it exists, can be observed"
    - …suggests the importance of an observer
  - 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')

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



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 (?)

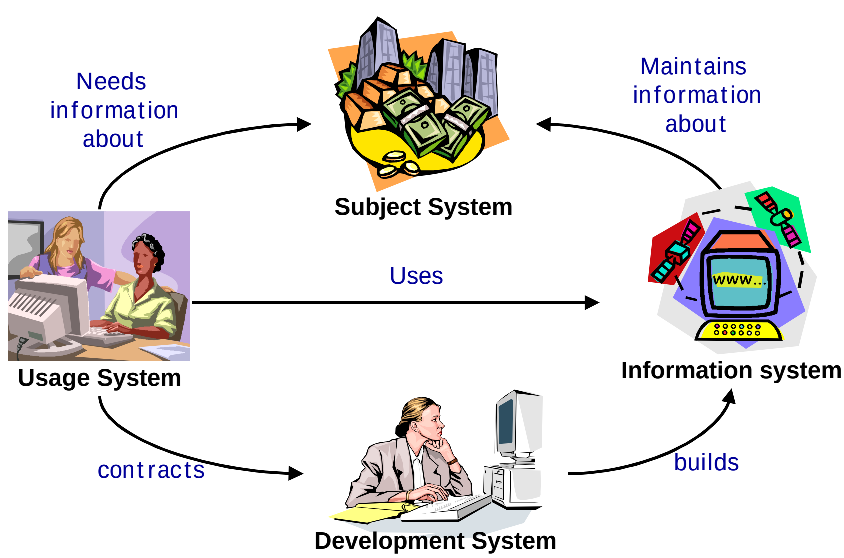
Soft Systems:

- 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

Types of System

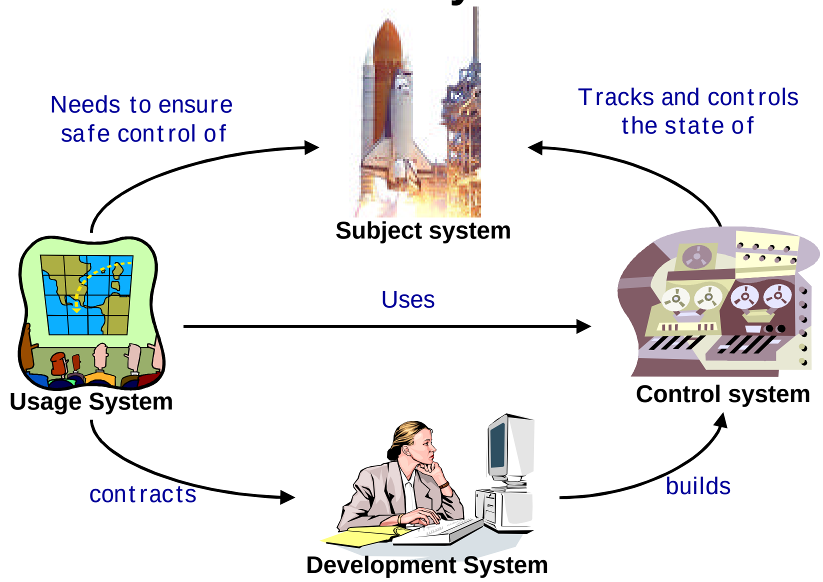
- **Natural Systems**
  - E.g. ecosystems, weather, water cycle, the human body, bee colony,…
  - Usually perceived as hard systems
- **Abstract Systems**
  - E.g. set of mathematical equations, computer programs,…
  - Interesting property: system and description are the same thing
- **Symbol Systems**
  - 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, …

Information Systems

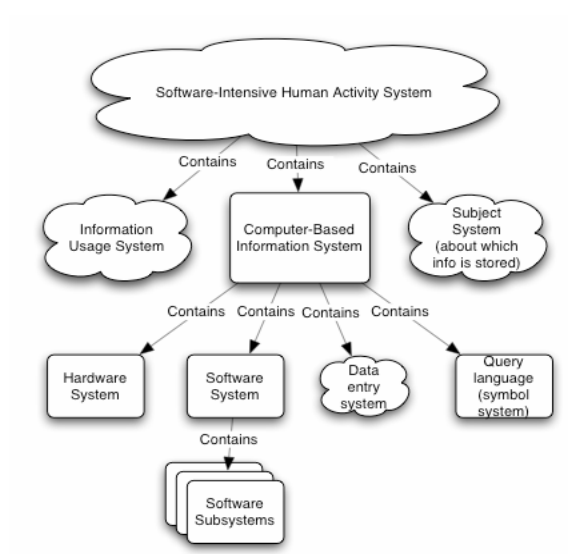


Source: *Adapted from Loucopoulos & Karakostas, 1995, p73*

Control Systems



Software-Intensive 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

Purposefulness

- **Types of behaviours:**
  - **Reaction** to a stimulus in the environment
    - The stimulus is necessary and sufficient to cause the reaction
  - **Response** to a stimulus in the environment
    - The stimulus is necessary but not sufficient to cause the response
  - **Autonomous act**:
    - A system event for which a stimulus is not necessary
- **Systems can be:**
  - State-maintaining
    - System **reacts** to changes in its environment to maintain a pre-determined state
    - E.g. thermostat, some ecosystems
  - Goal-directed
    - System can **respond** differently to similar events in its environment and can **act autonomously** in an unchanging environment to achieve some pre-determined goal state
    - E.g. an autopilot, simple organisms
  - Purposive
    - System has **multiple goals**, can choose how to pursue them, but no choice over the goals themselves
    - E.g. computers, animals (?)
  - Purposeful
    - System has multiple goals, and can choose to **change its goals**
    - E.g. people, governments, businesses, animals

Scoping a system

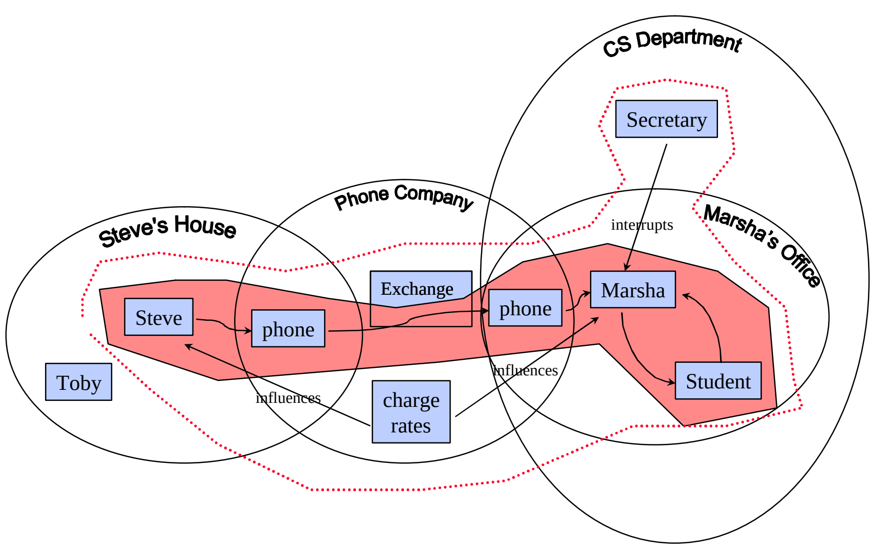
➲ Choosing the boundary

- Distinction between system and environment depends on your viewpoint
- Choice should be made to maximize modularity
- Examples:
  - Telephone system - include: switches, phone lines, handsets, users, accounts?
  - Desktop computer - do you include the peripherals?
- Tips:
  - Exclude things that have no functional effect on the system
  - Exclude things that influence the system but which cannot be influenced or controlled by the system
  - Include things that can be strongly influenced or controlled by the system
  - Changes within a system should cause minimal changes outside
  - More 'energy' is required to transfer something across the system boundary than within the system boundary

➲ System boundary should 'divide nature at its joints'

- Choose the boundary that:
  - increases regularities in the behaviour of the system
  - simplifies the system behavior

Example Scoping Problem



Source: Adapted from Carter et. al., 1988, p6

Layers of systems

appropriate for:	*Subsystems*	*System*	*Environment*
Analysis of repair problems	Wires, connectors, receivers	SubscriberÕs household phone system	Telephone calls.
Analysis of individual phone calls	SubscribersÕ phone systems	Telephone calls	Regional phone network
Analysis of regional sales strategy	Telephone calls	Regional phone network	National telephone market and trends
Analysis of phone companyÕs long term planning	Regional phone networks	National telephone market and trends	Global communication systems

Describing System Behaviour

- **State**
  - a system will have memory of its past interactions, i.e. 'state'
  - the state space is the collection of all possible states
- **Discrete vs continuous**
  - a discrete system:
    - the states can be represented using natural numbers
  - a continuous system:
    - state can only be represented using real numbers
  - a hybrid system:
    - some aspects of state can be represented using natural numbers
- **Observability**
  - the state space is defined in terms of the observable behavior
  - the perspective of the observer determines which states are observable

Source: *Adapted from Wieringa, 1996, p16-17*

Summary: Systems Thinking