Lecture 2: Context for RE

Last Week:
INTRO
Syllabus
Course Goals
Definitions

This Week:
Context for RE
What is Engineering?
Types of engineering project
RE in the engineering lifecycle
Systems Thinking

Next Week:
Project Starting points:
{Stakeholders, Boundaries, Goals, Scenarios, Risks}

What is engineering?

"Engineering is the development of cost-effective solutions to practical problems, through the application of scientific knowledge"

"…Cost-effective…"
- Consideration of design trade-offs, esp. resource usage
- Minimize negative impacts (e.g. environmental and social cost)

"… Solutions …"
- Emphasis on building devices

"… Practical problems …"
- solving problems that matter to people
- improving human life in general through technological advance

"… Application of scientific knowledge …"
- Systematic application of analytical techniques

Devices vs. Systems

→ Normal design:
- Old problems, whose solutions are well known
  - Engineering codifies standard solutions
  - Engineer selects appropriate methods and technologies
- Design focuses on well understood devices
  - Devices can be studied independent of context
  - Differences between the mathematical model and the reality are minimal

→ Radical design:
- Never been done, or past solutions have failed
  - Often involves a very complex problem
- Bring together complex assemblies of devices into new systems
  - Such systems are not amenable to reductionist theories
  - Such systems are often soft: no objective criteria for describing the system

→ Examples:
- Most of Computer Engineering involves normal design
- All of Systems Engineering involves radical design (by definition!)
- Much of Software Engineering involves radical design (soft systems!)

Is software different?

→ Software is different!
- software is invisible, intangible, abstract
  - Software alone is useless - its purpose is to configure some hardware to do something
- there are no physical laws underlying software behaviour
- there are no physical constraints on software complexity
- software never wears out
  - …traditional reliability measures don't apply
- software can be replicated perfectly
  - …no manufacturing variability

→ Software Myths:
- Myth: Cost of software is lower than cost of physical devices
- Myth: Software is easy to change
- Myth: Computers are more reliable than physical devices
- Myth: Software can be formally proved to be correct
- Myth: Software reuse increases safety and reliability
- Myth? Computers reduce risk over mechanical systems

Professional Responsibility

ACM/IEEE code of ethics:

- PUBLIC - act consistently with the public interest.
- CLIENT AND EMPLOYER - act in a manner that is in the best interests of your client and employer, consistent with the public interest.
- PRODUCT - ensure that your products and related modifications meet the highest professional standards possible.
- JUDGEMENT - maintain integrity and independence in your professional judgment.
- MANAGEMENT - subscribe to and promote an ethical approach to the management of software development and maintenance.
- PROFESSION - advance the integrity and reputation of the profession consistent with the public interest.
- COLLEAGUES - be fair to and supportive of your colleagues.
- SELF - participate in lifelong learning and promote an ethical approach to the practice of the profession.

Of particular relevance in RE:

- Competence - never misrepresent your level of competence
- Confidentiality - respect confidentiality of all stakeholders
- Intellectual property rights - respect protections on ideas and designs
- Data Protection - be aware of relevant laws on handling personal data

Project Management

A manager can control 4 things:

- Resources (can get more dollars, facilities, personnel)
- Time (can increase schedule, delay milestones, etc.)
- Product (can reduce functionality - e.g. scrub requirements)
- Risk (can decide which risks are acceptable)

To do this, a manager needs to keep track of:

- Effort - How much effort will be needed? How much has been expended?
- Time - What is the expected schedule? How far are we deviating from it?
- Size - How big is the planned system? How much have we built?
- Defects - How many errors are we making? How many are we detecting?
  - And how do these errors impact quality?

Initially, a manager needs good estimates

- …and these can only come from a thorough analysis of the problem.

You cannot control that which you cannot measure!

Where Projects Come From

Initiation of the project

- Problem-driven
  - A problem has arisen that demands a response
  - e.g. existing system is "broken"
- Change-driven
  - Changes in the business or its environment
  - existing system becoming less useful
- Opportunity-driven
  - New technology opens up new possibilities;
  - New markets open up;
  - etc
- Legacy-driven
  - Project created because of prior commitment
  - e.g earlier work left unfinished

Source of Requirements:

- Customer-specific
  - Specific customer with a specific problem
  - The customer is the ultimate authority
- Market-based
  - System designed to be sold widely
  - Marketing team acts as proxy for customers & users
  - Product must generate customers
- Socially-useful
  - System is intended as a general benefit to society
  - No (paying) customer
  - E.g. some open source / free software; software created in scientific research
- Hybrid
  - developed for a specific customer, but want to market the software eventually

Software Types

Information Systems

- software to support organizational work
- includes files/databases as well as applications
- More than 70% of all software falls in this category, written in languages such as COBOL, RPG and 4GLs.
  - Examples: Payroll and personnel, Financial transactions, Customer relations database, …

Control Systems

- software that drives some sort of a hardware process
  - Examples: flight control, industrial plant, an elevator system, credit card reader.

Generic Services

- systems that provide some services for other systems
  - Examples: many internet applications, e.g. search engines, stock quote services, credit card processing, etc.
- Such systems will be developed using a variety of languages and middleware, including Java, C++, CORBA, HTML/XML etc.

Project Context

→ **Existing System**
- There is nearly always an existing system
  - May just be a set of ad hoc workarounds for the problem
- Studying it is important:
  - If we want to avoid the weaknesses of the old system…
  - …while preserving what the stakeholders like about it

→ **Pre-Existing Components**
- Benefits:
  - Can dramatically reduce development cost
  - Easier to decompose the problem if some subproblems are already solved
- Tension:
  - Solving the real problem vs. solving a known problem (with ready solution)

→ **Product Families**
- Vertical families: e.g. 'basic', 'deluxe' and 'pro' versions of a system
- Horizontal families: similar systems used in related domains
  - Need to define a common architecture that supports anticipated variability

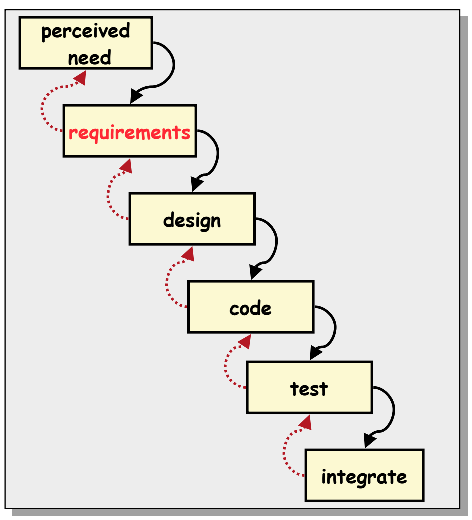
Lifecycle of an Engineering Project

→ **Lifecycle models**
- Useful for comparing projects in general terms
- Not enough detail for project planning

→ **Examples:**
- Sequential models: Waterfall, V model
- Rapid Prototyping
- Phased Models: Incremental, Evolutionary
- Iterative Models: Spiral
- Agile Models: eXtreme Programming

→ **Comparison: Process Models**
- Used for capturing and improving the development process

Waterfall Model

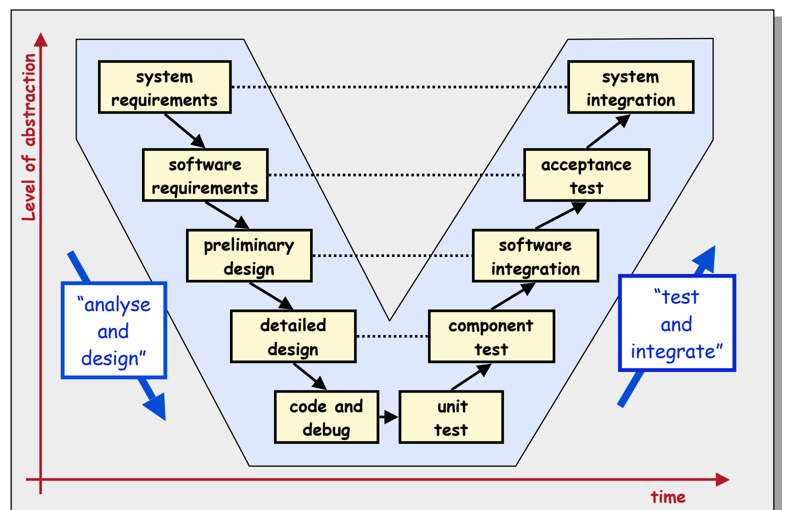


→ **View of development:**
- a process of stepwise refinement
- largely a high level management view

→ **Problems:**
- Static view of requirements - ignores volatility
- Lack of user involvement once specification is written
- Unrealistic separation of specification from design
- Doesn't accommodate prototyping, reuse, etc.

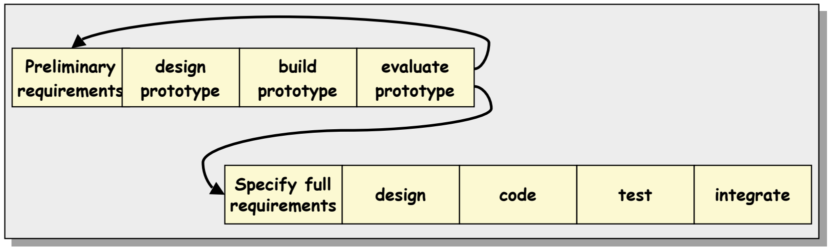
Source: Adapted from Dorfman, 1997, p7 & Loucopoulos & Karakostas, 1995, p29

V-Model



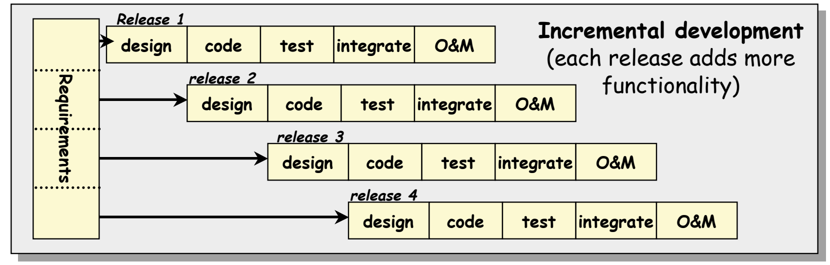
Prototyping lifecycle

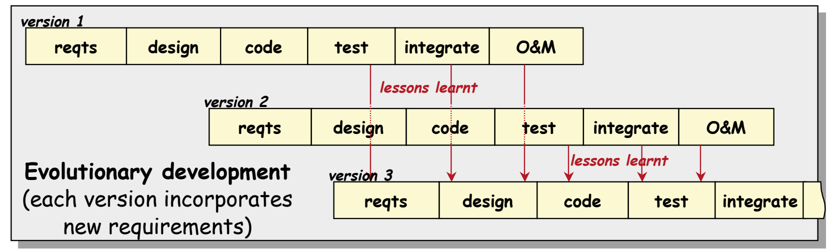
Source: Adapted from Dorfman, 1997, p9



- Prototyping is used for:
  - understanding the requirements for the user interface
  - examining feasibility of a proposed design approach
  - exploring system performance issues
- Problems:
  - users treat the prototype as the solution
  - a prototype is only a partial specification

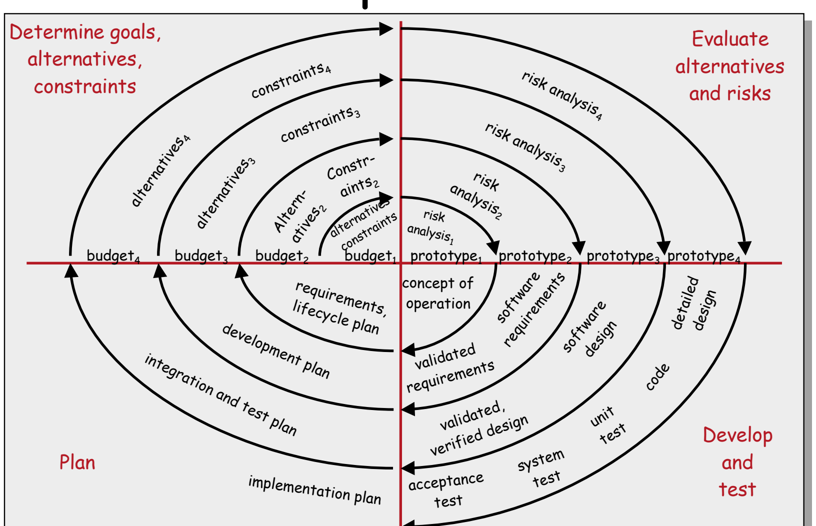
Phased Lifecycle Models





Source: Adapted from Dorfman, 1997, p10

The Spiral Model



Source: Adapted from Pfleeger, 1998, p57

Agile Models

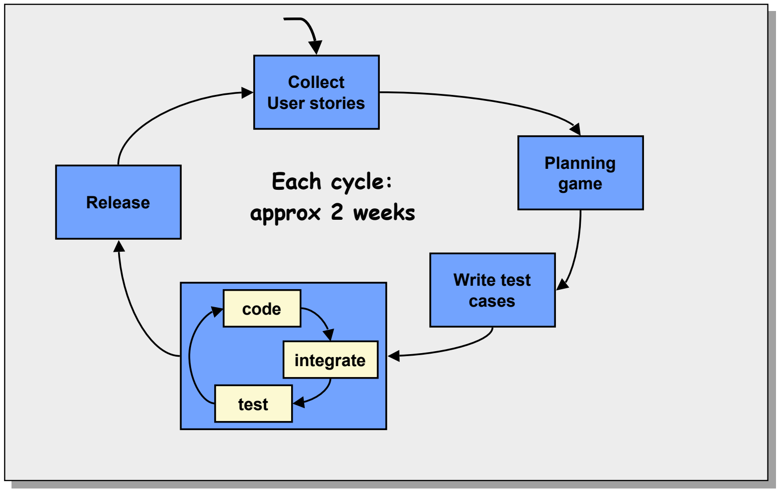
- Basic Philosophy
  - Reduce communication barriers
    - Programmer interacts with customer
  - Reduce document-heavy approach
    - Documentation is expensive and of limited use
  - Have faith in the people
    - Don't need fancy process models to tell them what to do!
  - Respond to the customer
    - Rather than focussing on the contract
- Weaknesses
  - Relies on programmer's memory
    - Code can be hard to maintain
  - Relies on oral communication
    - Mis-interpretation possible
  - Assumes single customer representative
    - Multiple viewpoints not possible
  - Only short term planning
    - No longer term vision

E.g. Extreme Programming

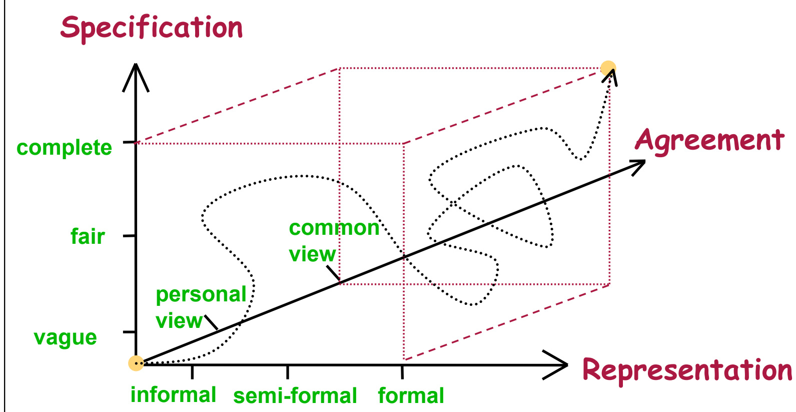
- Instead of a requirements spec, use:
  - User story cards
  - On-site customer representative
- Pair Programming
- Small releases
  - E.g. every three weeks
- Planning game
  - Select and estimate user story cards at the beginning of each release
- Write test cases before code
- The program code is the design doc
  - Can also use CRC cards (Class-Responsibility-Collaboration)
- Continuous Integration
  - Integrate and test several times a day

Source: Adapted from Nawrocki et al, RE'02

Extreme Programming

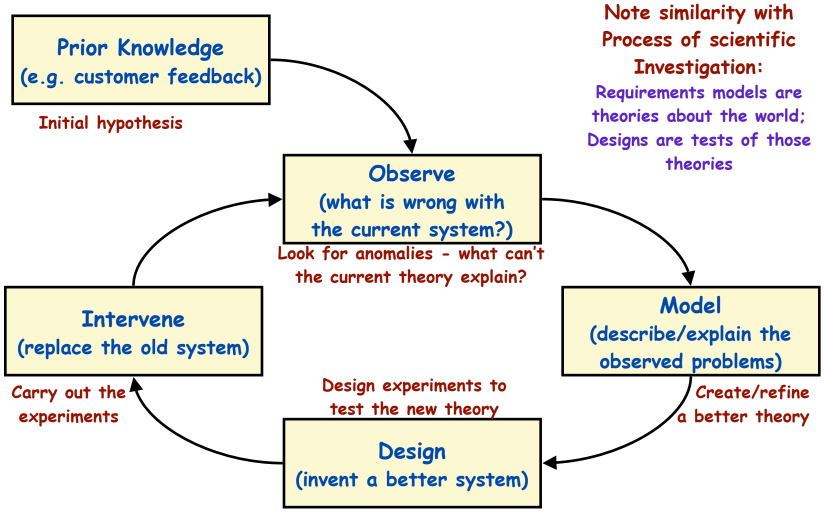


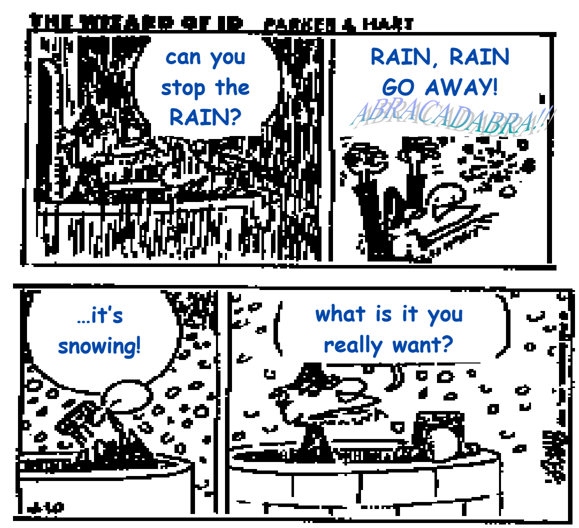
Is there a "Requirements Lifecycle"



Inquiry Cycle

Note similarity with Process of scientific Investigation:
Requirements models are theories about the world; Designs are tests of those theories





The story so far:

- **What is engineering?**
  - Not that different from science
  - Greater awareness of professional responsibility
    - because of immediate scope for harm to the public
  - Systems and Software Engineering involve radical design
- **Engineering Projects**
  - You cannot control that which you cannot measure
    - …and many important measures are derived from initial problem analysis
  - Constraints:
    - Is there a customer?
    - Existing system / existing components / existing product family
- **Project Lifecycles**
  - Useful for comparing projects in general terms
  - Represent different philosophies in software development
  - Requirements evolve through their own lifecycles too!

Systems Thinking

General Systems Theory

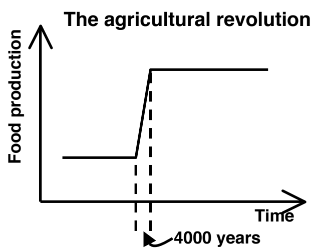
- **How scientists understand the world:**
  - Reductionism - break a phenomena down into its constituent parts
    - E.g. reduce to a set of equations governing interactions
  - Statistics - measure average behaviour of a very large number of instances
    - E.g. gas pressure results from averaging 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

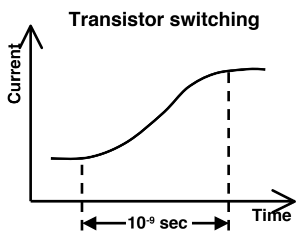
Role of the Observer

- **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

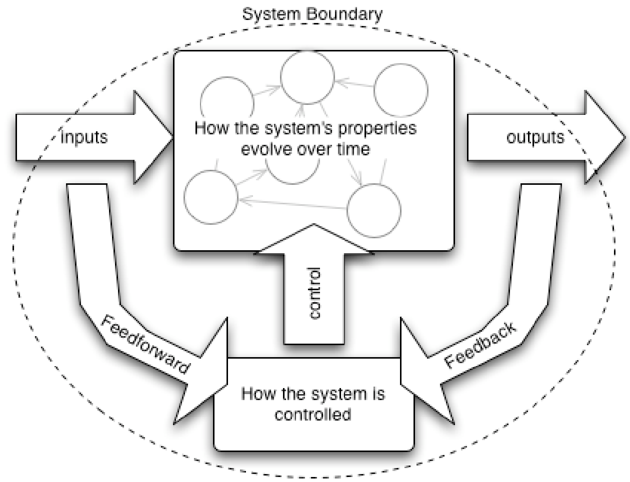
Definition of a system

- **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 (?)

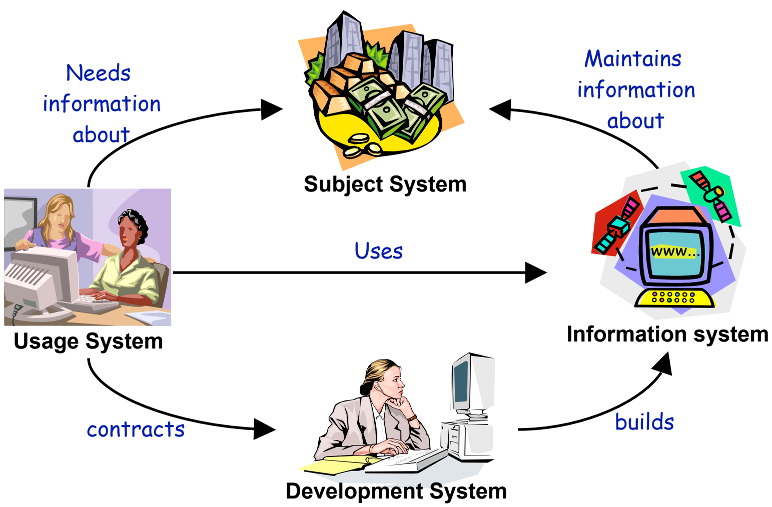
Soft Systems:

- **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

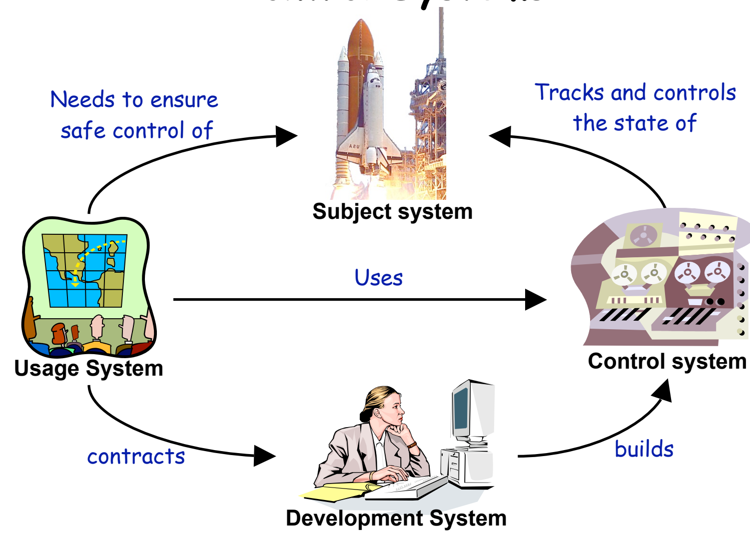
- **Natural Systems**
  - E.g. ecosystems, weather, water cycle, the human body, bee colony,…
  - Usually perceived as hard systems
- **Abstract Systems**
  - E.g. set of mathematical equations, computer programs,…
  - Interesting property: system and description are the same thing
- **Symbol Systems**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

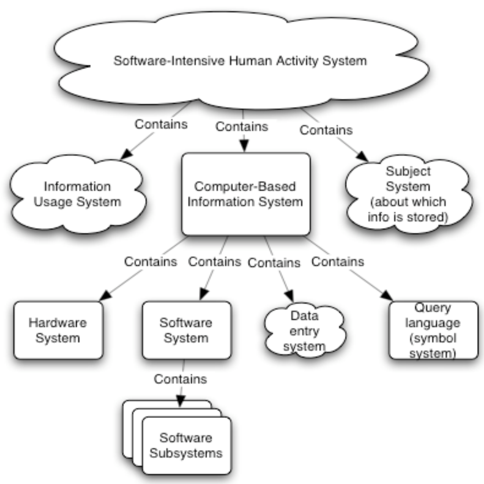


***Source:** Adapted from Loucopoulos & Karakostas, 1995, p73*

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

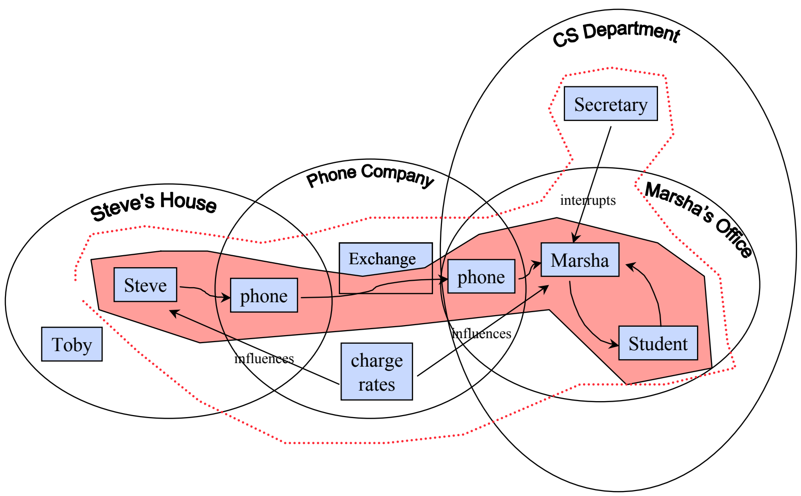
Purposefulness

- **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	Subscriber's household phone system	Telephone calls.
Analysis of individual phone calls	Subscribers' 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 company's 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