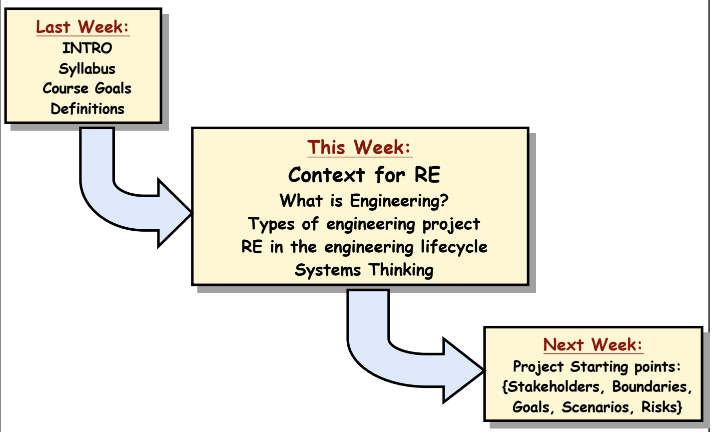
Lecture 2: Context for RE



What is Engineering?

→ Definition of Engineering:
- Engineering is the development of cost-effective solutions to practical problems, through the application of scientific knowledge
  - "…cost-effective…" - involves trade-offs, especially with resource usage
  - "…solutions…" - engineering is creative and interventionist
  - "…practical problems…" - the problems must matter to people
  - "…scientific knowledge…" - uses analytical techniques based on applied science

→ Normal or Radical design?
- 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
- Radical design: never been done, or past solutions have failed
  - Often the challenge is to deal with a very complex problem
  - Bring together complex assemblies of devices into new systems
  - Systems Engineering is always radical design (by definition)!

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 key variables:**
  - 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)
- **Approach (applies to any management)**
  - Understand the goals and objectives
    - quantify them where possible
  - Understand the constraints
    - if there is uncertainty, use probability estimates
  - Plan to meet the objectives within the constraints
  - Monitor and adjust the plan
  - Preserve a calm, productive, positive work environment
- **Note:**
  - You cannot control what you cannot measure!

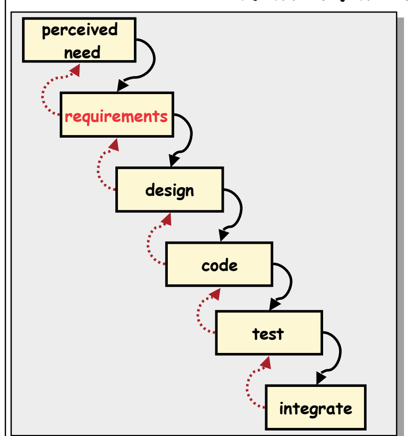
Where Projects Come From

- **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.

Waterfall Model

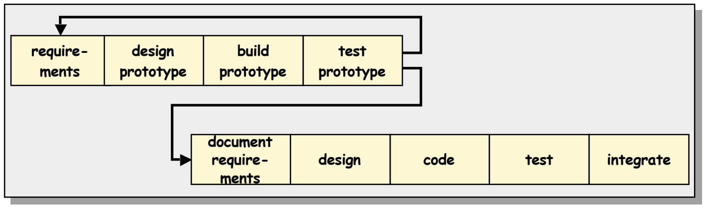


- **View of development:**
  - a process of stepwise refinement
  - largely a high level management view
- **Problems:**
  - Static view of requirements - ignores volatility
  - Lack of user involvement once specification is written
  - Unrealistic separation of specification from design
  - Doesn't accommodate prototyping, reuse, etc.

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

Prototyping lifecycle

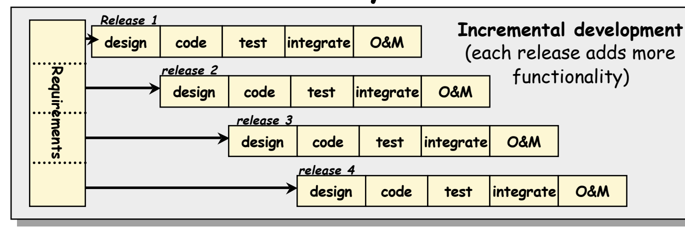
Source: Adapted from Dorfman, 1997, p9

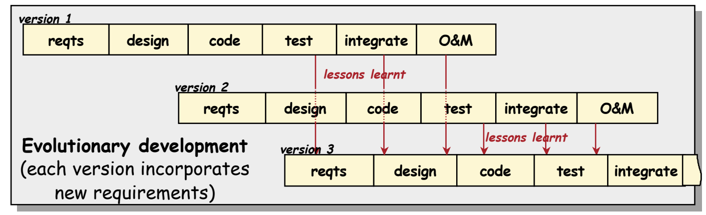


→ **Prototyping is used for:**
- understanding the requirements for the user interface
- examining feasibility of a proposed design approach
- exploring system performance issues

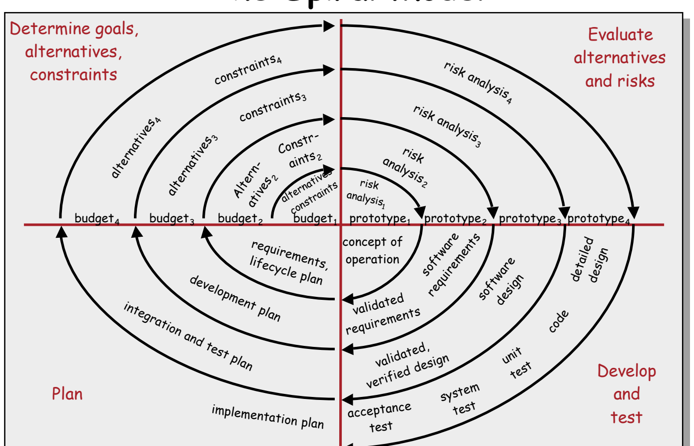
→ **Problems:**
- users treat the prototype as the solution
- a prototype is only a partial specification

Phased Lifecycle Models





The Spiral Model



Requirements in the Spiral Model

→ **Spiral model is a risk management model**

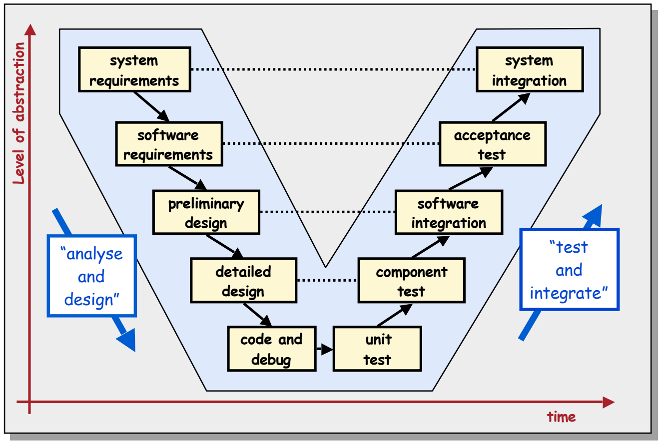
→ **For each iteration:**
- plan next phases;
- determine objectives & constraints;
- evaluate alternatives;
- resolve risks;
- develop product

→ **Includes as Requirements processes:**
- Requirements risk analysis (using simulation and prototyping)
- Planning for design

(these reduce the risk that requirements process has to be repeated because requirements cannot be met)

→ **Problems:**
- Spiral model cannot cope with unforeseen changes during development
  - e.g. emergence of new business objectives

V-Model



Agile Models

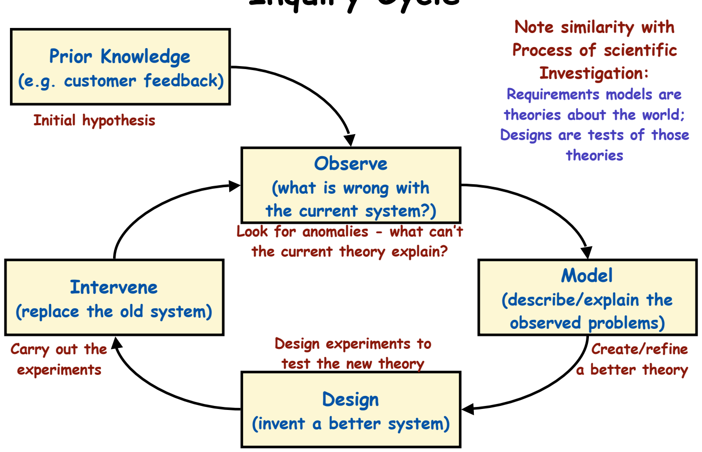
- **Basic Philosophy**
  - Reduce communication barriers
    - Programmer interacts with customer
  - Reduce document-heavy approach
    - Documentation is expensive and of limited use
  - Have faith in the people
    - Don't need fancy process models to tell them what to do!
  - Respond to the customer
    - 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

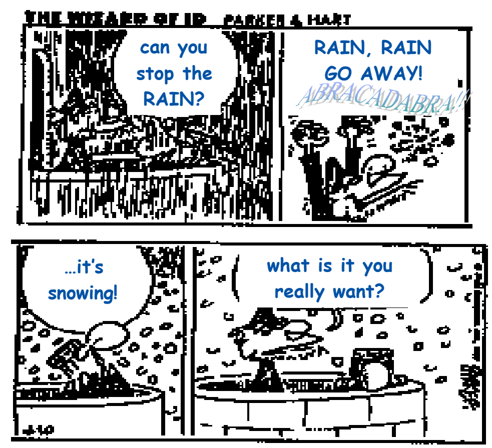
E.g. Extreme Programming

- 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

Inquiry Cycle





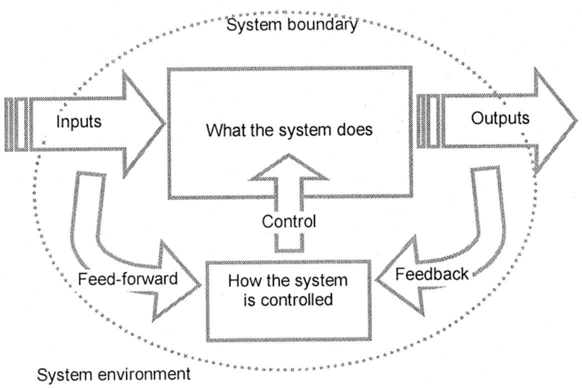
Systems Theory

What is a system?

- **Definition of a System:**
  - Some part of reality that can be observed to interact with its **environment**
    - Separated from its environment by a **boundary**
    - A system receives **inputs** from the environment & send **outputs** to the environment
    - A system usually have **subsystems**
    - Systems that endure have a **control mechanism**
    - Systems have interesting **emergent properties**
  - Examples:
    - cars, cities, houseplants, rocks, spacecraft, buildings, weather,...
    - operating systems, DBMS, the internet, an organization
  - Non-examples (there aren't many!):
    - numbers, truth values, letters.
  - A ***closed system*** doesn't interact with its environment (there aren't many!)
- **Systems might have no physical existence**
  - Only manifestations are symbolic/analogical representations of the system
  - Such systems are **social constructs**: they exist because we agree on ways to observe them

 Source: *Adapted from Wieringa, 1996, p10*

Conceptual picture of a system



Types of System

- **Natural Systems**
  - E.g. ecosystems, weather, water cycle, the human body, bee colony, ...
- **Abstract Systems**
  - E.g. set of mathematical equations, computer programs, etc
- **Designed Systems**
  - E.g. cars, planes, buildings, interstates, telephones, the internet, ...
- **Human Activity Systems**
  - E.g. Organizations, markets, clubs, …
- **Information Systems (exist to support a HAS)**
  - E.g. MIS, transaction processing, real-time control systems,…

 Source: *Adapted from Carter et. al., 1988, p12*

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
  - ?

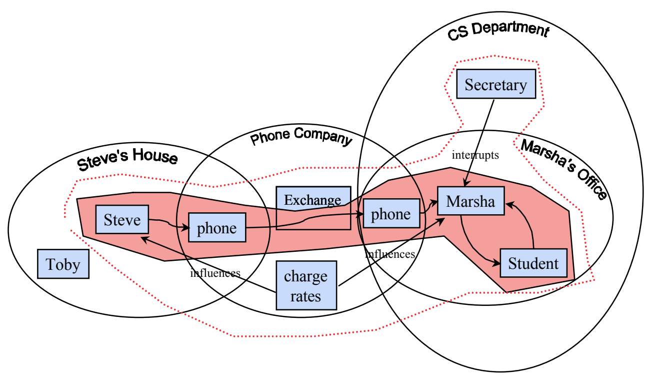
Soft Systems:

- 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
  - (what else?)

System Boundary

- System Environment:
  - the part of the world with which the system can interact
    - every system has an environment
    - the environment is itself a system
  - Distinction between system and environment depends on your viewpoint
- Choosing the boundary
  - Choice should be made to maximize modularity
  - Examples:
    - Telephone system - include: switches, phone lines, handsets, users, accounts?
    - Desktop computer - do you include the peripherals?
    - Flight control system - do you include the ground control?
  - 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
    - Balance between totally open and totally closed systems

Example System Boundary



Achieving Modularity

- Guidelines:
  - does the system have an underlying idea that can be described in one or two sentences?
  - Interaction among system components should be greater than interaction between the system and it's environment
    - 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
  - The system boundary should 'divide nature at its joints'
- Choose the boundary that:
  - increases regularities in the behaviour of the system
  - simplifies the system behavior

Control

- Control holds a system together
  - A system with no control won't endure
- A system can be characterized by the kind of control present
  - Self-maintaining causal network
    - a self-enhancing process: e.g. growth of the internet
    - a self-confirming process: e.g. visibility of a footpath
    - a self-limiting process: e.g. pricing of commodities
  - Purposive Control
    - System has a recognizable purpose or goal
    - control of sub-systems is directed towards achieving this goal
    - "purpose without choice"
  - Purposeful Control
    - special arrangements exist for decision making and control
    - Free choice among competing alternatives
    - "purpose with choice"

System Structure

- Subsystems…
  - A system is an organised collection of subsystems acting as a whole
    - subsystems are systems too!
  - Subsystem boundaries should be chosen so that subsystems are modular
- An *Aspect* of a system
  - is a restricted subset of the interactions between its subsystems
    - E.g. for a car: all interactions to do with safety
    - note fluidity between safety as an aspect, and safety as a subsystem
- Visibility
  - Interactions between subsystems only are *internal* to the system
  - Interactions between subsystems and the environment are *external*
  - Engineers usually try to hide internal interactions
    - For social systems, the internal interactions can be hidden too.
- Observability
  - the state space is defined in terms of the observable behavior
  - the perspective of the observer determines which states are observable

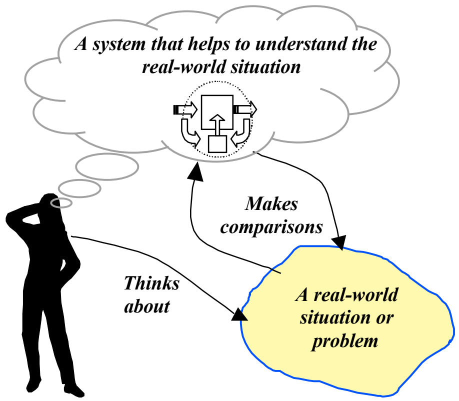
System State

- 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
- For modelling purposes:
  - Can approximate a continuous system with a discrete model
    - All models are approximations anyway!
  - But make sure the inaccuracies don't matter…

System Properties

- A system property
  - is an aspect of system behavior
    - often referred to as 'attributes' or 'quality attributes'
    - in software engineering, also known as the "ilities"
- Specifying properties:
  - A property is specified behaviorally if an experiment has been specified that will tell us unambiguously whether the system has the property
    - A property is specified non-behaviorally if no such experiment has been identified
  - Compare with: functional vs. non-functional requirements
  - Testing for non-behavioral properties requires a subjective (consensual) decision
- Proxies
  - Sometimes it is hard to specify a desired property behaviorally
    - can use a different property to indicate the presence of the desired property
  - E.g. 'easy to learn', 'easy to use' as proxies for 'user friendly'

Systems Thinking



Phenomena

- **A little Philosophy:**
  - Phenomenology
    - the study of the things that appear to exist when you observe the world
  - Ontology
    - the study of what really does exist (independently from any observer)
  - Epistemology
    - the study of what people are capable of knowing (or what they believe)
  - Weltanschauung
    - a world view that defines the set of phenomena that an observer is willing (likely) to observe ('viewpoint')
- **Each method has its own Weltanschauung**
  - Examples:
    - OO sees the world as objects with internal state that respond to stimuli
    - SA sees the world as processes that transform data
    - Natural language also defines a viewpoint
  - Each method restricts the set of phenomena you can describe
    - ...and therefore what you can model
  - Choose a method that emphasizes the appropriate kinds of phenomena

Source: *Adapted from Jackson, 1995, p143, and Blum 1996, chapter 2*