Lecture 3: What is Engineering?

- What is engineering about?
  - Engineering vs. Science
  - Devices vs. Systems
  - How is software engineering different?
  - Engineering as a profession

- Engineering Projects
  - Project Management
  - Project Initiation

- Project Lifecycles
  - Software Engineering lifecycles: Waterfalls, spirals, etc
  - Requirements Lifecycles

---

Engineering vs. Science

- Traditional View:
  - Scientists...
    - create knowledge
    - study the world as it is
    - are trained in scientific method
    - use explicit knowledge
    - are thinkers
  - Engineers...
    - apply that knowledge
    - seek to change the world
    - are trained in engineering design
    - use tacit knowledge
    - are doers

- More realistic View
  - Scientists...
    - create knowledge
    - are problem-driven
    - seek to understand and explain
    - design experiments to test theories
    - prefer abstract knowledge
    - but rely on tacit knowledge
  - Engineers...
    - create knowledge
    - are problem-driven
    - seek to understand and explain
    - design devices to test theories
    - prefer contingent knowledge
    - but rely on tacit knowledge

Both involve a mix of design and discovery
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
    - its purpose is to configure some hardware to do something useful
  - 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
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!

Reasons for initiating a software development project
- Problem-driven: competition, crisis, ...
- Change-driven: new needs, growth, change in business or environment, ...
- Opportunity-driven: exploit a new technology, ...
- Legacy-driven: part of a previous plan, unfinished work, ...

Relationship with Customer(s):
- Customer-specific - one customer with specific problem
  - May be another company, with contractual arrangement
  - May be a division within the same company
- Market-based - system to be sold to a general market
  - In some cases the product must generate customers
  - Marketing team may act as substitute customer
- Community-based - intended as a general benefit to some community
  - E.g. open source tools, tools for scientific research
  - funder ≠ customer (if funder has no stake in the outcome)
- Hybrid (a mix of the above)
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
  - A 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.

V-Model

- **System requirements**
- **Software requirements**
  - Preliminary design
  - Detailed design
- **Code and debug**
- **Unit test**
- **Component test**
- **Software integration**
- **Acceptance test**
- **System integration**

“analyse and design”

“test and integrate”
Prototyping lifecycle

- Preliminary requirements
- Design prototype
- Build prototype
- Evaluate prototype

Specify full requirements
- Design
- Code
- Test
- Integrate

- 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

- Incremental development (each release adds more functionality)
- Evolutionary development (each version incorporates new requirements)

Source: Adapted from Dorfman, 1997, p10
### The Spiral Model

**Determine goals, alternatives, constraints**
- Alternatives
- Constraints
- Budget
- Timeline
- Requirements, lifecycle plan
- Development plan
- Implementation plan

**Evaluate alternatives and risks**
- Risk analysis
- Prototype
- Concept of operation
- Validation, verified design
- Acceptance test
- System test
- Unit test
- Code

**Plan**
- Plan budget
- Plan prototype
- Plan system test
- Plan unit test
- Plan code

**Develop and test**
- Develop prototype
- Test prototype
- Verify requirements
- Validate design
- Test system

### 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 focusing 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
Extreme Programming

Collect User stories

Planning game

Write test cases

code
integrate
test

Release

Each cycle: approx 2 weeks

Is there a “Requirements Lifecycle”

Specification

complete
fair
vague

Representation

informal semi-formal formal

Agreement

common view personal view
Inquiry Cycle

Prior Knowledge
(e.g. customer feedback)

Observe
(what is wrong with
the current system?)

Intervene
(replace the old system)

Model
(describe/explain the
observed problems)

Design
(invent a better system)

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

Look for anomalies - what can't
the current theory explain?

Create/refine
a better theory

Design experiments to
test the new theory

Initial hypothesis

Inquiry Cycle

Summary

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!