Advanced Software Engineering

Dr. Cheng

Overview of Software Engineering and Development Processes

CSE870

FYI

• Professor in CSE
• Here at MSU for > 20 years
  – Software Engineering and Network Systems (SENS) Lab
  – Digital Evolution (DEVOLab)
  – BEACON: NSF Science and Technology Center (“Evolution in Action”)
• Research and Instruction areas:
  – High-assurance systems
  – Model-driven engineering
  – Autonomic (self-adaptive) systems
  – Recently, also working in following areas:
    • Evolutionary-based computing
    • Systems Biology
  – Work extensively with industrial collaborators (e.g., Ford, GM, Continental Automotive, Motorola, BAE Systems, Siemens)
• Recently completed a one-year sabbatical with time in France and other parts of Europe.
  – Focus: How computing systems deal with uncertainty
What is Software Engineering?

- Systematic approach for developing software
- Methods and techniques to develop and maintain quality software to solve problems. (Software Engineering: Methods and Management, Pfleeger, 1990)
- Study of the **principles** and **methodologies** for developing and maintaining software systems. (``Perspectives on Software Engineering,'' Zelkowitz, 1978)

What is Software Engineering?

- *Practical* application of scientific knowledge in the design and construction of computer programs and the associated *documentation* required to develop, operate, and maintain them. (``Software Engineering,'' Boehm, 1976)
- Deals with establishment of *sound engineering principles and methods* in order to *economically* obtain software that is reliable and works on real machines. (``Software Engineering,'' Bauer, 1972)
Questions addressed by Software Engineering

- How do we ensure the quality of the software that we produce?
- How do we meet growing demand and still maintain budget control?
- How do we avoid disastrous time delays?

Why apply Software Engineering to Systems?

- Provide an understandable process for system development.
- Develop systems and software that are maintainable and easily changed.
- Develop robust software and system.
- Allow the process of creating computing-based systems to be repeatable and manageable.
Objectives of Course

- Provide exposure to leading-edge topics
  - Emphasize model-driven engineering
  - Emphasize requirements and design
  - Emphasize assurance of computing-based systems
- Provide hands-on experience to reinforce concepts
  - Homework assignments
  - Modeling and specification assignments
- Synthesize several topics into mini-projects
  - Programming/design Project with written component
  - Prepare presentation materials for lay audience.

- Overarching application theme: assurance for onboard automotive systems

Tentative Topics

- Requirements Engineering
- Unified Modeling Language (UML)
- Architectural Styles
- Design Patterns
- Security
- Aspect-Oriented Programming
- (Search-based Software Engineering)
- (Software Product Lines)
Administrative Work

- Background Survey
- Initial Assessment
- Tentative Evaluation Mechanisms:

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PAUSE
Historical Perspective

- **1940s**: computers invented
- **1950s**: assembly language, Fortran
- **1960s**: COBOL, ALGOL, PL/1, operating systems
  
  _1969: First conference on Software Eng_
- **1970s**: multi-user systems, databases, structured programming

Historical Perspective (cont.)

- **1980s**: networking, personal computing, embedded systems, parallel architectures
- **1990s**: information superhighway, distributed systems, OO in widespread use.
- **2000s**: virtual reality, voice recognition, video conferencing, global computing, pervasive computing...
- **2010s**: EMRs, autonomous vehicles, new security awareness, ...
Why is software so expensive?

- Hardware has made great advances
- But, software has made great advances ...
- We do the least understood tasks in software.
  - When task is simple & understood, encode it in hardware
  - Why?
- Demand more and more of software
  - Consider your cell phone
Size of programs continues to grow

- **Trivial**: 1 month, 1 programmer, 500 LOC,
  - Intro programming assignments
- **Very small**: 4 months, 1 programmer, 2000 LOC
  - Course project
- **Small**: 2 years, 3 programmers, 50K LOC
  - Nuclear power plant, pace maker
- **Medium**: 3 years, 10s of programmers, 100K LOC
  - Optimizing compiler

Size of programs continues to grow

- **Large**: 5 years, 100s of programmers, 1M LOC
  - MS Word, Excel
- **Very large**: 10 years, 1000s of programmers, 10M LOC
  - Air traffic control,
  - Telecommunications, space shuttle
- **Very, Very Large**: 15+ years, 1000s programmers, 35M LOC
  - W2K
- **Ultra-Large Scale**: ? years, ? developers distributed,
  - 1000s of sensors, decision units,
  - Heterogeneous platforms, decentralized control
  - Intelligent transportation systems; healthcare systems
New Scale
Ultra-Large Scale SW-Intensive Systems

Healthcare Infrastructure

Intelligent Transportation and Vehicle Systems
The ULS Ecosystem

Key elements:
- Computing devices
- Business and organizational policies
- Environment (including people)

Forces:
- Competition for resources
- Unexpected environmental changes
- Decentralized control
- Demand for assurance

Context: “Sufficient” System Health

High-level Objective:
- How to design a safe adaptive system with incomplete information and evolving environmental conditions

Execution environment
- How to model environment
- How to effectively monitor changing conditions
- Adaptive monitoring

Decision-making for dynamic adaptation
- Decentralized control
- Assurance guarantees (functional and non-functional constraints)

Adaptation mechanisms:
- Application level
- Middleware level
What’s the problem?

- Software cannot be built fast enough to keep up with
  - H/W advances
  - Rising expectations
  - Feature explosion
- Increasing need for high reliability software

What’s the problem?

- Software is difficult to maintain
  “aging software”
- Difficult to estimate software costs and schedules
- Too many projects fail
  - Arianne Missile
  - Denver Airport Baggage System
  - Therac
Why is software engineering needed?

- To predict time, effort, and cost
- To improve software quality
- To improve maintainability
- To meet increasing demands
- To lower software costs
- To successfully build large, complex software systems
- To facilitate group effort in developing software

Software Engineering Phases

- Definition: What?
- Development: How?
- Maintenance: Managing change
- Umbrella Activities: Throughout lifecycle
Definition

- Requirements definition and analysis
  - Developer must understand
    - Application domain
    - Required functionality
    - Required performance
    - User interface

Definition (cont.)

- Project planning
  - Allocate resources
  - Estimate costs
  - Define work tasks
  - Define schedule

- System analysis
  - Allocate system resources to
    - Hardware
    - Software
    - Users
Development

• Software design
  – User interface design
  – High-level design
    • Define modular components
    • Define major data structures
  – Detailed design
    • Define algorithms and procedural detail

Development (cont.)

• Coding
  – Develop code for each module
  – Unit testing

• Integration
  – Combine modules
  – System testing
Maintenance

- Correction - Fix software defects
- Adaptation - Accommodate changes
  - New hardware
  - New company policies
- Enhancement - Add functionality
- Prevention - make more maintainable

Umbrella Activities

- Reviews - assure quality
- Documentation - improve maintainability
- Version control - track changes
- Configuration management - integrity of collection of components
### Development Process

- Step-by-step procedure to develop software
- Typically involves the major phases:
  - analysis
  - design
  - coding
  - testing

### Waterfall Process Model

```
Requirements ----> Design ----> Coding ----> Testing ----> Maintenance
```

- Requirements
- Design
- Coding
- Testing
- Maintenance
When to use prototyping?

- Help the customer pin down the requirements
  - Concrete model to "test out"
  - Often done via the user interface
- Explore alternative solutions to a troublesome component
  - E.g., determine if an approach gives acceptable performance
- Improve morale
  - Partially running system provides visibility into a project
Spiral Process Model

Planning → Risk Analysis

Customer Evaluation → Engineering

Process Models

- Idealized views of the process
- Different models are often used for different subprocesses
  - may use spiral model for overall development
    - prototyping for a particularly complex component
    - waterfall model for other components
Capability Maturity Model

- **Level 1: Initial**
  - ad hoc
  - success depends on people

- **Level 2: Repeatable**
  - track cost, schedule, functionality

- **Level 3: Defined**
  - use standardized processes

- **Level 4: Managed**
  - collect detailed metrics

- **Level 5: Optimizing**
  - continuous process improvement
  - “built-in” process improvement

Software Engineering Institute:
http://www.sei.cmu.edu/cmm/

Why is software development so difficult?

- **Communication**
  - Between customer and developer
    - Poor problem definition is largest cause of failed software projects
  - Within development team
    - More people = more communication
    - New programmers need training

- **Project characteristics**
  - Novelty
  - Changing requirements
    - 5 x cost during development
    - up to 100 x cost during maintenance
  - Hardware/software configuration
  - Security requirements
  - Real time requirements
  - Reliability requirements
Why is software development difficult? (cont.)

- Personnel characteristics
  - Ability
  - Prior experience
  - Communication skills
  - Team cooperation
  - Training

- Facilities and resources
  - Identification
  - Acquisition

- Management issues
  - Realistic goals
  - Cost estimation
  - Scheduling
  - Resource allocation
  - Quality assurance
  - Version control
  - Contracts

Summary

- Software lifecycle consists of
  - Definition (what)
  - Development (how)
  - Maintenance (change)

- Different process models concentrate on different aspects
  - Waterfall model: maintainability
  - Prototype model: clarifying requirements
  - Spiral model: identifying risk

- Maintenance costs much more than development
Bottom Line

• U.S. software is a major part of our societal infrastructure
  – Costs upwards of $200 billion/year

• Need to
  – Improve software quality
  – Reduce software costs/risks