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:
    - Search-based SE (e.g., evolutionary computing, MOO, ML, etc.)
    - Cybersecurity for Automotive and onboard Systems
  - Work extensively with industrial collaborators (e.g., Ford, GM, Continental Automotive, Motorola, BAE Systems, Siemens
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.
- 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:

<table>
<thead>
<tr>
<th>Task</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Exams (2)</td>
<td>50 %</td>
</tr>
<tr>
<td>Homework/Design Exercises</td>
<td>20 %</td>
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<tr>
<td>Mini-Project(s)</td>
<td>30 %</td>
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Special Class: Continental Automotive Seminar

- Tuesday, Jan 17, 2017
- 2-3 pm, 3540 Engineering Bldg.
- **Speaker**: Guner Sarioglu,
  - Head of Engineering for North America, ADAS Business Unit, Continental Automotive Systems
- **Topic**: Engineering Challenges for Automated Driving
- **Overview**: Presentation and dialogue regarding the time to market for ADAS and Automated Driving components and systems, including complexity of functions and software, testing, validation and integration into vehicles.

Writing Assignment for Seminar

1-page writeup with the following contents:
- Brief summary of seminar
- Three key “take home messages”
- Your reaction to the points made in the seminar:
  - Weaknesses:
  - Strengths:
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
Requirements definition and analysis

- Developer must understand
  - Application domain
  - Required functionality
  - Required performance
  - User interface

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**
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
**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

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<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Notes</th>
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<tbody>
<tr>
<td><strong>Level 1</strong>: Initial</td>
<td>- ad hoc</td>
<td>- success depends on people</td>
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<tr>
<td><strong>Level 2</strong>: Repeatable</td>
<td>- track cost, schedule, functionality</td>
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<tr>
<td><strong>Level 3</strong>: Defined</td>
<td>- use standardized processes</td>
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<td><strong>Level 4</strong>: Managed</td>
<td>- collect detailed metrics</td>
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<td><strong>Level 5</strong>: Optimizing</td>
<td>- continuous process improvement</td>
<td>- “built-in” process improvement</td>
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Software Engineering Institute: [http://www.sei.cmu.edu/cmm/](http://www.sei.cmu.edu/cmm/)

### Why is software development so difficult?

<table>
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<th>Communication</th>
<th>Project characteristics</th>
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<tbody>
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<td>- Between customer and developer</td>
<td>- Novelty</td>
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<tr>
<td>- Poor problem definition is largest cause of failed software projects</td>
<td>- Changing requirements</td>
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<td>- Within development team</td>
<td>- 5 x cost during development</td>
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<tr>
<td>- More people = more communication</td>
<td>- up to 100 x cost during maintenance</td>
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<td>- New programmers need training</td>
<td>- Hardware/software configuration</td>
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<td>- Security requirements</td>
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<td>- Real time requirements</td>
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<td>- Reliability requirements</td>
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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