CSE 435: Software Engineering

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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:
    o Evolutionary-based computing
    o Systems Biology
  ▪ Work extensively with industrial collaborators (e.g., Ford, GM, Continental Automotive, Motorola, BAE Systems, Siemens)
• Just completed a one-year sabbatical:
  ▪ Automotive cybersecurity and autonomous features
  ▪ Model-Driven Engineering for Sustainable Systems
  ▪ Enabling collaborative modeling for visually-impaired developers
High-Assurance Autonomic Computing

- **Autonomic computing [2001]:** Promises self-managed and long-running systems with limited human guidance.
- Systems must continue to **operate correctly** during exceptional situations, upgrades, and evolution under **uncertain** conditions.
- Need for assurance:
  - hardware component failures
  - network outages
  - software faults
  - security attacks

New Scale

**High-Assurance Cyberphysical Systems**

*Intelligent Transportation and Vehicle Systems*

**Requires increasingly complex systems**
- Thousands of platforms, sensors, decision nodes, complex systems
- Connected through heterogeneous wired and wireless networks.
The future...

Now...
Advanced Driver-Assistance Systems

- Onboard Autonomous Features
  - Safety
  - Convenience
Objectives of this course

Introduce industrial-strength software development:
- formal processes/artifacts for planning, specifying, designing, implementing, and verifying
- Individual and team-based development
- life-cycle issues and “umbrella” activities

Introduce key foundations underlying these activities
- E.g., requirements engineering
- E.g., software modeling
- E.g., assurance

Overview of Course

- Emphasis on analysis and design
- Learn/apply new techniques for software development
- Learn to work with a group
- Improve technical writing skills
- Become up to date on current trends in SE
- Explore presentation media and techniques
Structure of Course

- (Short) assignments over readings
- In lab assignments (various SE tools)
- Group projects (prototype, analysis, design): modeling and documentation
- Two exams (middle and final)
- Presentations: oral presentations, prototype demos

How “different” is this course?

Quite!

- Not a “programming course”
- Exercises aim to facilitate problem understanding, solutions, tradeoffs, and sensitivity to challenges that affect industrial software development
- Written and oral communication skills will be exercised, improved, and assessed
- Team work is critical and will be assessed
Relation to other courses?

Not a design/programming course (ala CSE 335)
- Much “higher-level” coverage of notations
- More emphasis on process than design methods

Not a capstone design experience (ala CSE 498)
- Smaller, more constrained project
- Smaller teams
- Projects will be industry-based

Ideal pre-capstone course:
CSE 335 → CSE 435 → CSE 498
(coding, design) → (design, reqts, process) → (synthesis)

PAUSE

- Syllabus
- HW1 due next Wednesday
- Survey
- Initial
What is Software Engineering ???

- The study of *systematic* and effective processes and technologies for supporting software development and maintenance activities
  - Improve quality
  - Reduce costs

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, ...

### Hardware Costs vs Software Costs (% of overall costs)

![Graph showing the comparison of hardware (h/w) and software (s/w) costs over time.](image)
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

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New Scale

**Ultra-Large Scale SW-Intensive Systems**

*Healthcare Infrastructure*
New Scale

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
Shaw’s model of engineering evolution [Shaw-IEEE-Computer90]

Characteristics: Craft

- Virtuosos and talented amateurs
- Intuition and brute force
- Haphazard progress
- Casual transmission of knowledge
- Extravagant use of available materials
- Manufacture for use rather than sale

- Examples: woodworking, artists
**Characteristics: Commercial production**

- Skilled crafts
- Established procedure
- Pragmatic refinement
- Training in specific domain (e.g., mechanics-- automotive technicians, structures-- construction worker, electricians)
- Economic concern for cost and supply of materials
- Manufacture for sale

Examples: automotive parts, chip manufacturing

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**Characteristics: Professional engineering**

- Educated professionals
- Analysis and theory
- Progress relies on science
- Educated professional class
- New applications enabled through analysis
- Market segmentation by product variety

Examples: civil engineering (bridges, buildings), automotive engineers (electronics, mechanical engineering)
Civil Engineering

Basis in theory.
- Actually two theories:
  - Statics: composition of forces.
  - Material strength: bending of a beam.
- Theories preceded real CE by 150 years!

Underlying science emerged 1700 years after commercial production evolved!
Software Engineering Evolution
(circa 1990)

Science: algorithms, logic, databases, languages

Science

Production

Commercial

Craft

Engineering

1980’s: Development Methodologies

Isolated Examples (5ESS, Shuttle)

Two “pillars” of SE education

Basis in:
- production processes and process frameworks
- rigorous theories addressing design problems that attend to the various phases of these processes

This course:
- organized around first pillar
- structured so that process issues will motivate introduction of theoretical content
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
- **Prevention** - make more maintainable
- **Enhancement** - Add functionality
Umbrella Activities

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

Software Engineering Costs

[Diagram showing cost distribution: Maintenance, Development, Definition]
Relative Costs to Fix Errors

This is why software process pays off