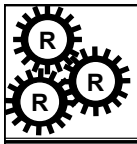
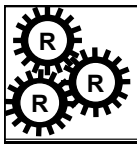


Advanced Software Engineering

Dr. Cheng

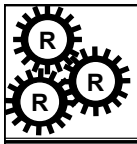
Overview of Software Engineering and Development Processes

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



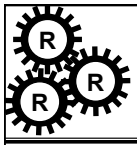
What is Software Engineering?

- 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)



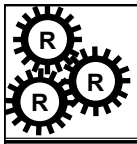
What is Software Engineering?

- *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)

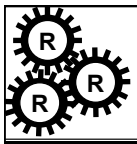
- Deals with establishment of *sound engineering principles and methods* in order to *economically* obtain software that is reliable and works on real machines.

(``Software Engineering,'' Bauer, 1972)



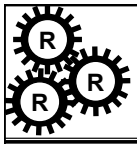
Questions addressed by Software Engineering

- 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?

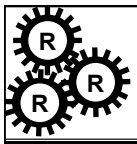
- Provide an understandable process for system development.
- Develop systems and software that are maintainable and easily changed.
- Develop robust software and system.
- Allow the process of creating computing-based systems to be repeatable and manageable.



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

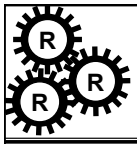
7



Tentative Topics

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

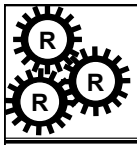
CSE870: Advanced Software Engineering (Cheng): Intro to Software Engineering 8



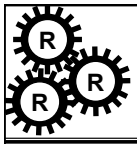
Administrative Work

- Background Survey
- Initial Assessment
- Tentative Evaluation Mechanisms:

Exams (2)	40 %
Homework/Design Exercises	25 %
Mini-Project(s)	35 %



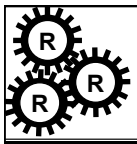
PAUSE



Historical Perspective

- **1940s:** computers invented
- **1950s:** assembly language, Fortran
- **1960s:** COBOL, ALGOL, PL/1, operating systems

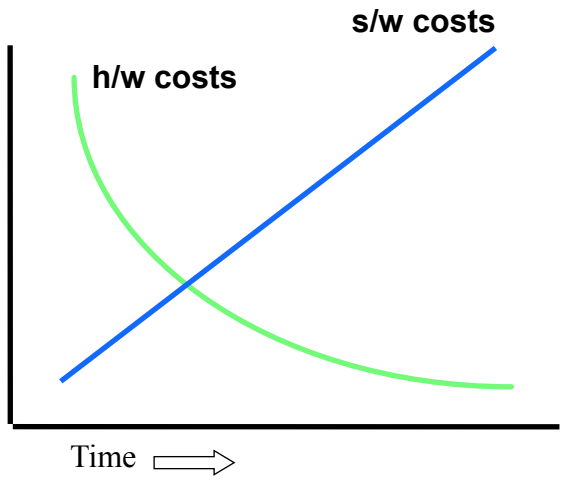
  1969: First conference on Software Eng
- **1970s:** multi-user systems, databases, structured programming



Historical Perspective (cont.)

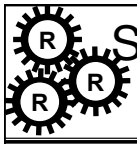
- **1980s:** networking, personal computing, embedded systems, parallel architectures
- **1990s**: information superhighway, distributed systems, OO in widespread use**.**
- **2000s:** virtual reality, voice recognition, video conferencing, global computing, pervasive computing...
- **2010s:** EMRs,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

Hardware Costs vs Software Costs (% of overall costs)



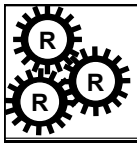
Why is software so expensive?

- 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

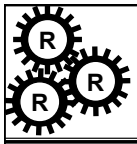
New Scale

Ultra-Large Scale SW-Intensive Systems

Healthcare Infrastructure

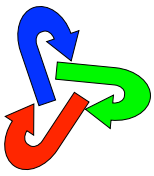
New Scale

Intelligent Transportation and Vehicle Systems

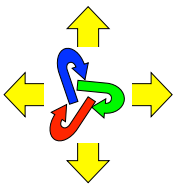


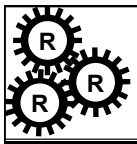
The ULS Ecosystem

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



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



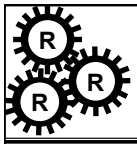


Context: "*Sufficient*" System Health

High-level Objective:

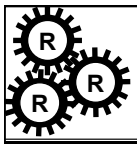
- ***How to design a safe adaptive system with incomplete information and evolving environmental conditions***

- **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



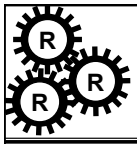
What's the problem?

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



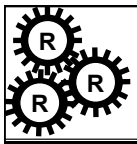
What's the problem?

- 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



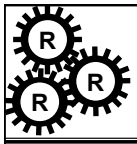
Why is software engineering needed?

- 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



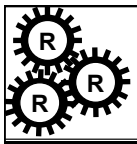
Software Engineering Phases

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



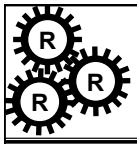
Definition

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



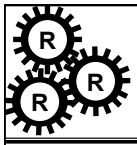
Definition (cont.)

- Project planning
  - Allocate resources
  - Estimate costs
  - Define work tasks
  - Define schedule
- System analysis
  - Allocate system resources to
    - Hardware
    - Software
    - Users



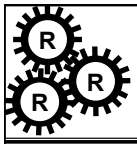
Development

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



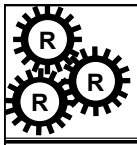
Development (cont.)

- Coding
  - Develop code for each module
  - Unit testing
- Integration
  - Combine modules
  - System testing



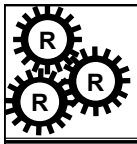
Maintenance

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



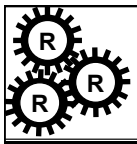
Umbrella Activities

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

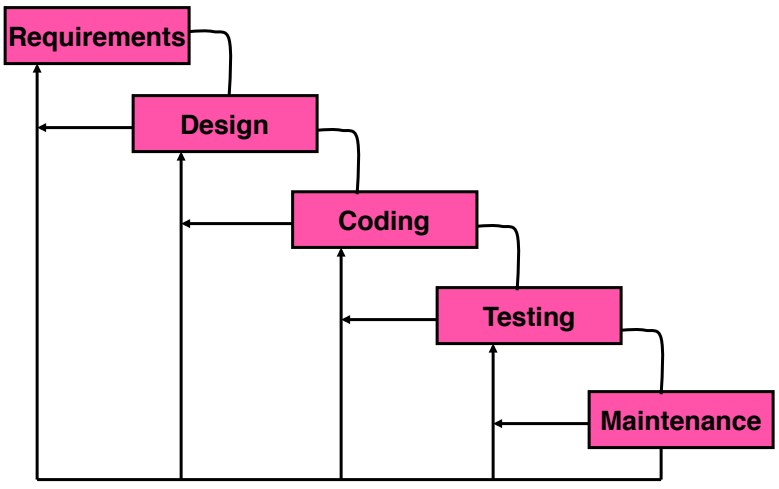


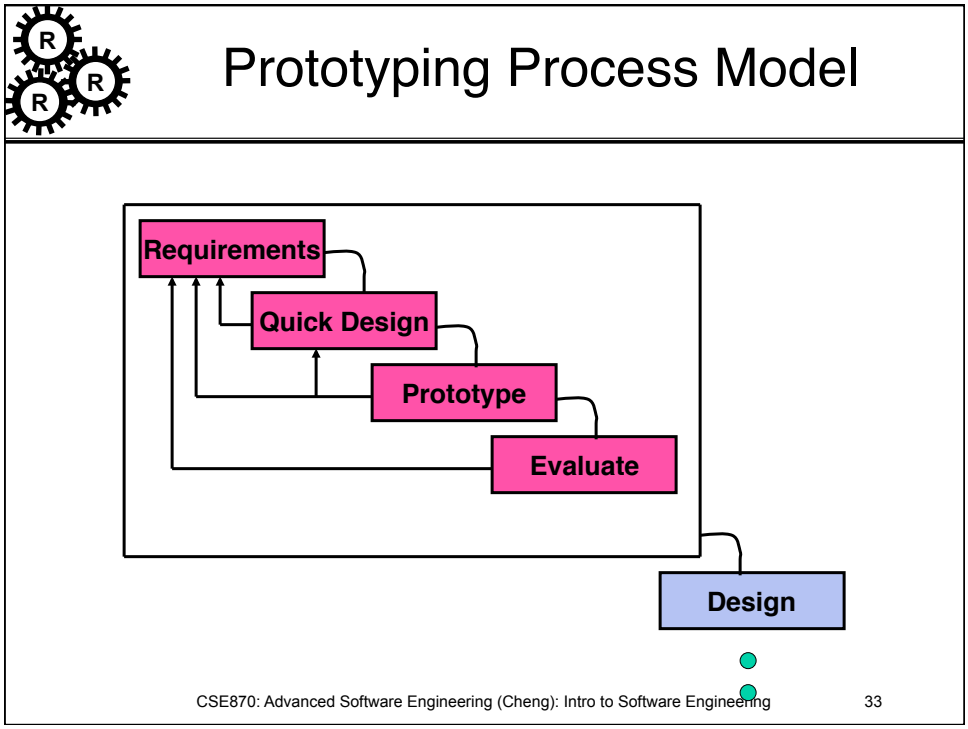
Development Process

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



Waterfall Process Model




Prototyping Process Model
Requirements
Quick Design
Prototype
Evaluate
Design
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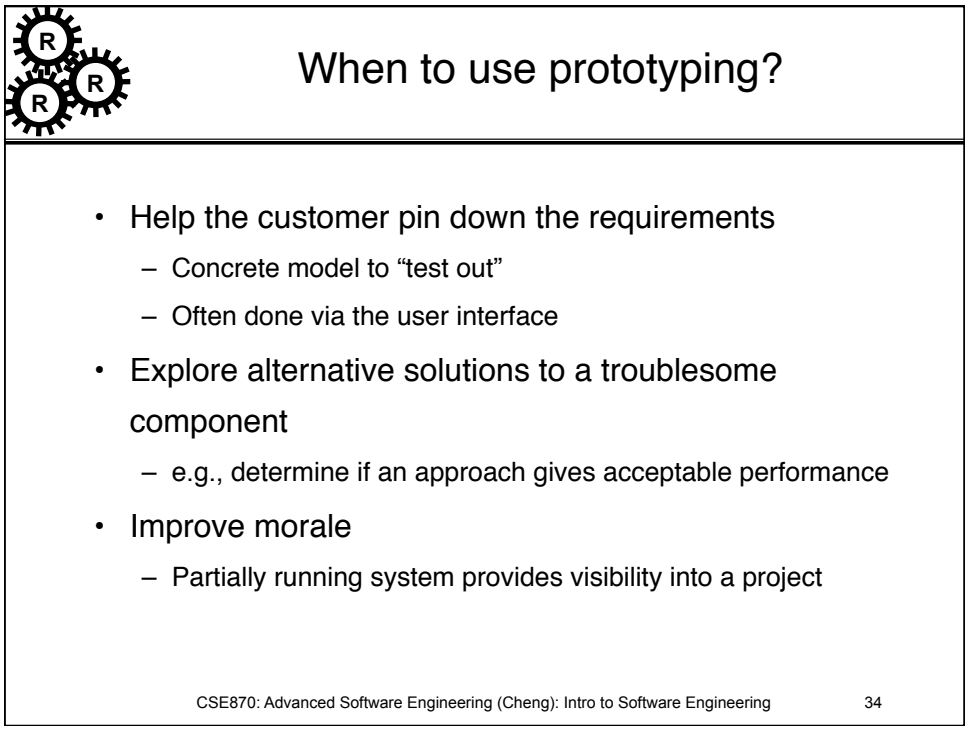
When to use prototyping?
• Help the customer pin down the requirements
– Concrete model to “test out”
– Often done via the user interface
• Explore alternative solutions to a troublesome component
– e.g., determine if an approach gives acceptable performance
• Improve morale
– Partially running system provides visibility into a project
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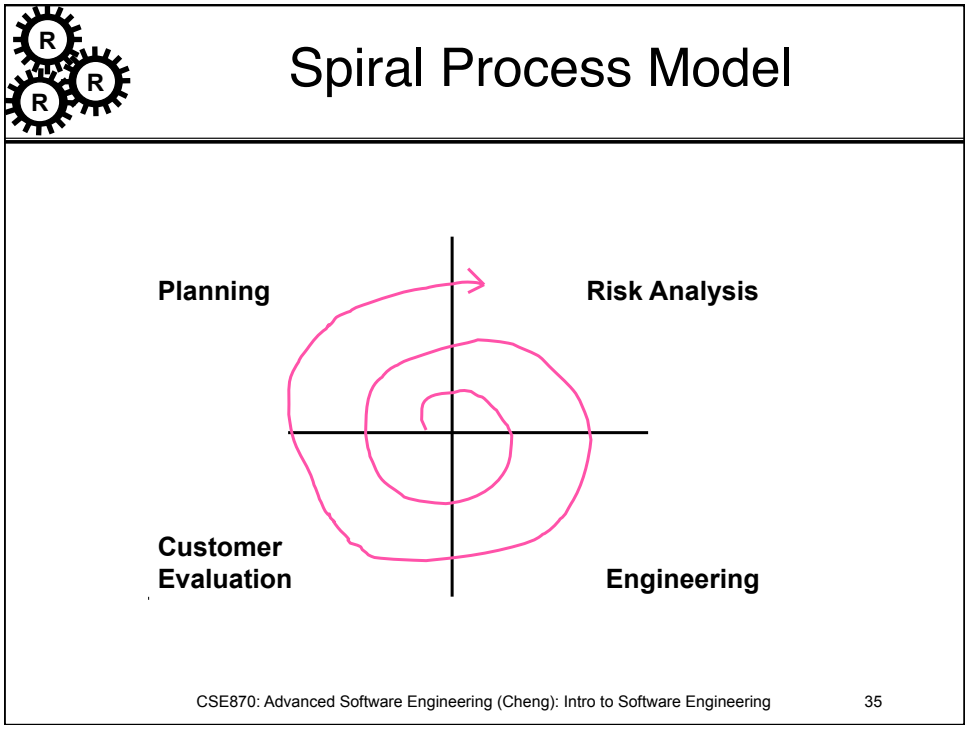
Spiral Process Model
Planning
Risk Analysis
Customer Evaluation
Engineering
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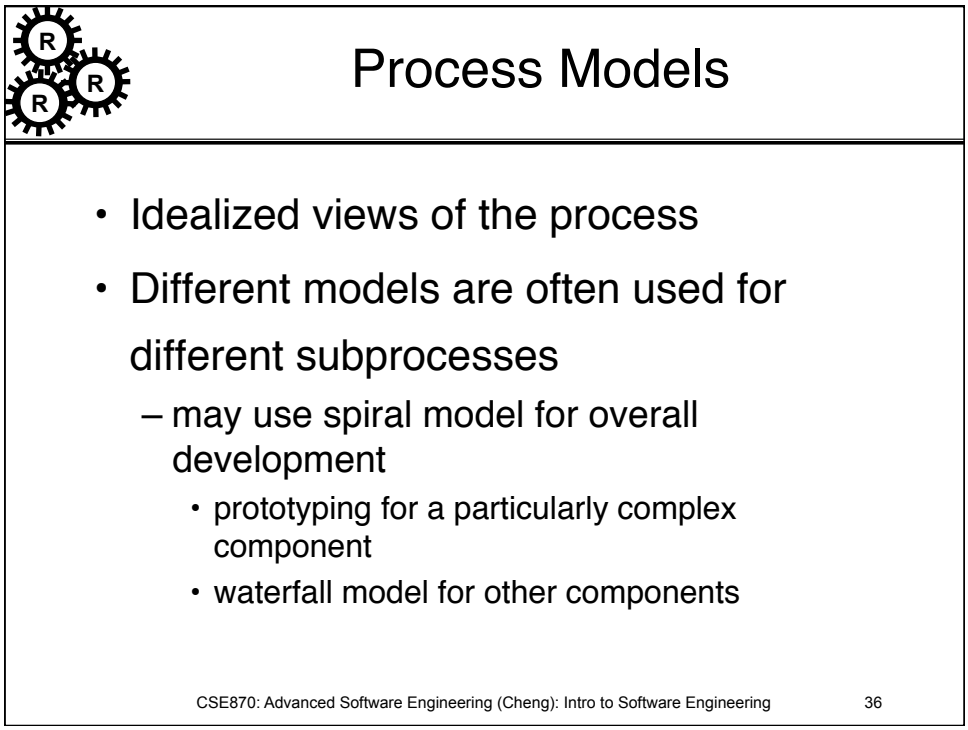
Process Models
• Idealized views of the process
• Different models are often used for different subprocesses
– may use spiral model for overall development
• prototyping for a particularly complex component
• waterfall model for other components
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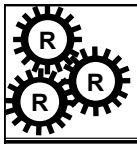
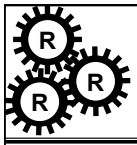


Capability Maturity Model

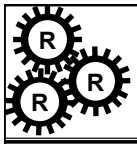
- Level 1: Initial
  - ad hoc
  - success depends on people
- Level 2: Repeatable
  - track cost, schedule, functionality
- Level 3: Defined
  - use standardized processes
- Level 4: Managed
  - collect detailed metrics
- Level 5: Optimizing
  - continuous process improvement
  - "built-in" process improvement

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



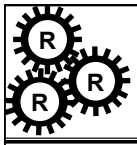
Why is software development so difficult?

- 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



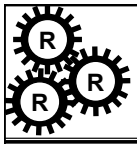
Why is software development difficult? (cont.)

- 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