

Software Development Methods Course Introduction

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Course Introduction

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Stages/Activities in Software Development



- 📀 Requirements Solicitation/Analysis
- Specification
- 😚 Design
- 📀 Validation + Verification
- 😚 Implementation
- 📀 Verification + Validation
 - 🌷 testing
 - 🌻 simulation
 - 🌻 formal verification
- 🖻 Deployment and Maintenance
- 😚 Others: code review, documentation, etc.

About Software Development Process



- The stages do not necessarily follow one another sequentially; jumping back to a previous stage is common.
- Different parts of a software application may be in different stages.
- The ultimate goal is to deliver quality software on schedule, not following a particular process.
- Best practices give you helpful guidelines, but you should try to do whatever is best for the project.

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Challenge of Quality Software Development



What do people ask of a program/software?

- Correct, doing what it is supposed to do
- Efficient, performing its tasks efficiently
- Friendly, easy to (install and) use
- Well-structured and hence easy to maintain
- Fast and cheap to develop
- Secure as it should be
- 🏓 Etc.

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- Secure as it should be
- 🖲 Etc.
- These demands pose quite a challenge!

Are You Up to That Challenge?



Many students (who would become practicing programmers)

- 🌻 rarely care about writing "good" programs,
- 🌻 know few useful programming techniques, and
- cannot use development tools effectively.

Note: in this course, a good program is one that is at least correct and well-structured.

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Consequence: low quality software!

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- Consequence: low quality software!
- Shouldn't you start to get serious?

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Software Development in Class



- Environment is controlled.
- Problems are well-defined (sorting, BFS, etc.).
- Solutions are well-defined (in your algorithm textbooks).
- Programs seldom change (write once, use once).
- 😚 Correctness may not be an issue.
- Robustness has rarely been an issue.

Software Development in the Real World



📀 Environment is open.

- Problems are not well-defined.
- 😚 There may be multiple options available.
- Programs change all the time.
- 😚 Correctness is most important.
- 😚 Robustness is necessary.

Example: An Inventory System



A 24-hour store asks you to develop an inventory system:

- 😚 The system will be used by many people.
- It is impossible to know what goods or categories the store will have.
- What database and user interface packages would you use?
- What if they ask you to add new features?
- Your system should better not be confused by different calendar systems (particularly in Taiwan).
- 😚 Your system should better be able to be working all year long.

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Course Objectives



- Learn how to develop correct and high-quality software with better engineering skills:
 - 🌞 Software modeling: UML, domain/data modeling
 - 🌻 Design patterns
 - Development/productivity tools
 - Verification/analysis tools
- Practice these skills and team work with a substantial term project that reflects real-world situations.
- Also, get exposed to a bit of formality so that you will be able to describe and reason about programs more precisely.

Note: there are numerous other software development methods. You are encouraged to explore them through course taking or self-study.

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About Software Project Management



- Software development, after all, will be done by engineers.
- Project leaders need to know what engineering options they have.
- We will look at the software development problem from an engineer's point of view.
- The course material should be complementary to related software project management courses.

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The Starting Point: Requirements



- First of all, one must distinguish two different (but not disjoint) domains:
 - The application/problem domain
 - The solution domain
- Requirements are about the phenomena of the application domain.
- You describe requirements by referring to those phenomena.
- The solution (software) can ensure the requirements only through the phenomena (events and/or states) shared with the application domain.
- Not all phenomena in the application domain are shared with, or observed by, the software.

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Software Specification



- After several meetings with your client, you have an informal idea of what your client wants (the requirements).
- You bring the informal idea back and start developing the system with your colleagues.
- But your colleagues did not participate in the meetings. They are not as familiar with the domain knowledge as you are.
- 😚 What would you do?

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- Suppose you would like to develop a sorting function/operation for any totally ordered set.
 (Note: a set S is totally ordered if either a < b, a = b, or a > b for any a, b ∈ S.)
- How do you convey the idea to your colleague?

A Probable Attempt



- I a totally ordered set is an object of class TOSet.
- 😚 We can create an object and assign its value.
- The class TOSet has a static member function compare(TOSet &, TOSet &) that compares two elements.
- 😚 The sorting function accepts an array of TOSet objects as inputs.
- 😚 It uses compare to compare elements in the array.
- It outputs a permutation of the input array such that the elements in the permutation are ordered by the compare function.

Problems



- It is still ambiguous. (What do you mean by "ordered by the compare function?")
- It is incomplete. (What is a permutation?)
- It is written in natural language (often imprecise and ill-structured).
- It is already very complicated. (What if you have 30 classes in your system?)

About the Unified Modeling Language



- The UML is designed for software/program specification.
- 📀 It is a graphical language.
- 😚 It can be used to describe the relation among different classes.
- It is convenient to illustrate the interactions among different objects.
- 😚 It has a more rigorous semantics.
- There are tools that can simulate your UML designs or convert them into code skeleton.
- 😚 Etc.

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From Specification to Design



- Software development is more than writing down the specification.
- UML specification is a way of communication.
- Like using natural languages, you may know the words and grammar of English, but you may not be able to compose a good essay in English.
- After learning some basics of UML, we will discuss useful programming techniques for system design.

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It's Like Solving a Mathematical Problem



Compute

 $\int x^3 \ln^3 x dx = ?$

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Solution



$$\int x^{3} \ln^{3} x dx = \frac{x^{4}}{4} \ln^{3} x - \int \frac{x^{4}}{4} \frac{3 \ln^{2} x}{x} dx$$

$$= \frac{x^{4}}{4} \ln^{3} x - \frac{3}{4} \int x^{3} \ln^{2} x dx$$

$$= \frac{x^{4}}{4} \ln^{3} x - \frac{3}{4} \left(\frac{x^{4}}{4} \ln^{2} x - \int \frac{x^{4}}{4} \frac{2 \ln x}{x} dx \right)$$

$$= \frac{x^{4}}{4} \ln^{3} x - \frac{3}{16} x^{4} \ln^{2} x + \frac{3}{8} \int x^{3} \ln x dx$$

$$= \frac{x^{4}}{4} \ln^{3} x - \frac{3}{16} x^{4} \ln^{2} x + \frac{3}{8} \left(\frac{x^{4}}{4} \ln x - \int \frac{x^{4}}{4} \frac{1}{x} dx \right)$$

$$= \frac{x^{4}}{4} \ln^{3} x - \frac{3}{16} x^{4} \ln^{2} x + \frac{3}{32} x^{4} \ln x - \frac{3}{32} \int x^{3} dx$$

$$= \frac{x^{4}}{4} \ln^{3} x - \frac{3}{16} x^{4} \ln^{2} x + \frac{3}{32} x^{4} \ln x - \frac{3}{128} x^{4}$$

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Strategies and Patterns



• What strategies, or patterns of solution, do we have?

- 🌻 polynomial integration
- 🏓 integral of In x
- 鯵 variable substitution
- integration by parts
- 😚 The problem is solved by choosing combinations of strategies.
- What about program development?
- Is there any strategy or pattern for programming?

Note: integration by parts

$$\int f(x)g'(x)dx = f(x)g(x) - \int f'(x)g(x)dx$$

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Data Structures and Algorithms



- Suppose you want to implement a database system.
- The user may ask you to search or sort by field.
- You may use sorting algorithms, search algorithms, even balanced tree data structures.
- For different situations, you may use different sorting algorithms (e.g., memory versus disk-based).
- 📀 You do not develop your program from scratch.

What about System/Software Architecture?



Suppose you want to develop a system for

- 鯵 vehicle controller,
- 鯵 (graphical) user interface, and/or
- 鯵 data management

Is there any known strategy or pattern that could be applied?

Example: Beachside Vehicle Rental



- Let's suppose we want to develop a vehicle rental system for beachside resorts.
- 😚 They have bikes, cars, sailboats, and yachts.
 - Class LandVehicle for bikes and cars
 - Elass WaterVehicle for sailboats and yachts
- One day, a resort management team decides to introduce hovercrafts.
- How would you modify the class hierarchy to include the new product?

Design Patterns

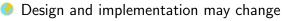


- A design pattern is the re-usable form of a solution to a design problem.
- For software, design patterns are formalized best practices that a programmer can use to solve common problems when designing an application.
- Object-oriented design patterns typically show relationships and interactions between classes or objects.
 - 🏓 structural
 - 🖲 behavioral
- They are frequently used in commercial tools and systems.

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Managing Changes





- How should the changes be managed?
 - 鯵 version control
 - 🔅 issues/bugs tracking

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From Design/Implementation to Validation/Verification

- Developing software by proper methodologies does not necessarily entail quality.
- UML specifications allow clients, system architects, and programmers to communicate.
- Design patterns help system architects and programmers to deploy software structures sensibly.
- But they do not imply the system cannot go wrong.

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Some Systems Are Critical



Device drivers

- Medical instruments
- Automotive control
- Online banking P
- 😚 Stock exchange

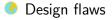
📀 Etc.

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What Are the Problems?





Programming errors

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A Lesson from the Hardware Industry



- The first Pentium was found to have the infamous F00F bug.
- IC manufacturing costs lots of money.
- No company would want to have a buggy design to be sent to the foundry.
- 😚 But how?

Note: the "Pentium floating point divide" bug (in 1993) ultimately cost Intel US\$ 475 million.

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Testing and Formal Verification



IC design houses use tools to help them catch bugs.

- Testing: run simulation on designs to find bugs
- Verification: analyze designs to prove they are correct

Software houses are increasingly using similar tools.

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- Testing is usually performed after the system is implemented.
- Nonetheless, one can test the system design before it is implemented.
- Simulator generates random inputs.
- Erroneous behaviors can be observed if the proper inputs are generated.

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- It can check the system before it is implemented.
- Verification tools try all possible inputs.
- Erroneous behaviors can be observed if the proper inputs are generated.
- S Correctness can be ensured if all inputs have been tested.

Ingredients of Formal Verification



- Behavior modeling (when the actual code is not available or too complicated with nonessential details)
- Property specification
- Verification algorithm/tool (or, if that fails, proof and proof checker)



- It describes system behaviors at a suitable abstraction level, hiding irrelevant details.
- We need a formal language to avoid ambiguity.
- The actual control flow of a program (at run time) is of main concern.
- 😚 Users specify their systems as models in modeling languages.

Property Specification



😚 It specifies what properties are of interest.

- Safety: nothing bad happens
- 🏓 Liveness: good things eventually happen
- Another formal language is needed.
- High-level properties are independent of the implementation.
- The user (of the verification tool) specifies the requirements in property specification languages.

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Automatic Verification Tools



- A verification tool takes the model and property specification as input.
- It checks whether the model satisfies the property or not.
- Many verification problems are undecidable and some work-around techniques (e.g., abstraction) may help.

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Correctness Proofs and Proof Checking



- S Correctness proofs are the last resort, when everything else fails.
- 📀 Unfortunately, proofs are usually hard to produce.
- 📀 Even worse, you can make mistakes in a proof.
- Fortunately, checking whether a proof is really a proof can be automated.

Programming in the Small



- We will also study development methods that probably only work for small programs.
- However, a large program is usually composed of smaller ones.
- A large program may also be the result of refinement from a smaller program.
- Making the smaller programs correct helps improve the overall quality of the larger ones.

Conclusion



- This is a course that views software development from an engineer's viewpoint.
- It covers design and programming techniques for software development.
- 😚 It also introduces you to useful verification methods and tools.
- We hope you will appreciate the methodologies and improve software quality with better engineering skills.

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