

Software Development Methods Course Introduction

Yih-Kuen Tsay (with contributions by Bow-Yaw Wang)

Department of Information Management National Taiwan University

Yih-Kuen Tsay (IM.NTU)

Course Introduction

SDM 2021 1 / 38

イロト イポト イヨト イヨト

Stages/Activities in Software Development



- 📀 Requirements Solicitation/Analysis
- 📀 Specification
- 😚 Design
- 🖻 Validation (+ Verification)
- 😚 Implementation
- Verification (+ Validation)
 - 🌷 testing
 - 鯵 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.

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 use
- Well-structured and hence easy to maintain
- Fast and cheap to develop
- Secure as it should be
- 🖲 Etc.

< ロ > < 同 > < 三 > < 三

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 use
- Well-structured and hence easy to maintain
- Fast and cheap to develop
- 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.

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.

S Consequence: low quality software!

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.

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

Course Objectives



Learn how to develop correct and high-quality software with better engineering skills:

- Software modeling (with the UML in particular)
- 🌻 Domain 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.

Yih-Kuen Tsay (IM.NTU)

Programming 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.

Programming 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.

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.



- After several meetings with your client, you have an informal idea of what your client wants.
- 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?



- Suppose you would like to develop a sorting algorithm 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.
- 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.

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.

It's Like Solving a Mathematical Problem



Compute

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

Yih-Kuen Tsay (IM.NTU)

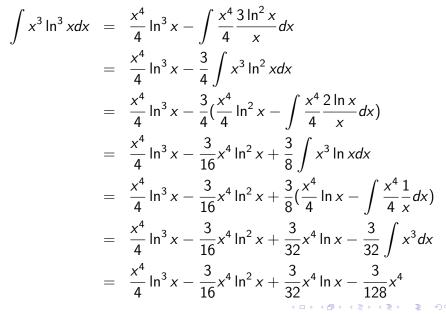
Course Introduction

E▶ ◀ E▶ E ∽ Q @ SDM 2021 17 / 38

イロト イポト イヨト イヨト

Solution





Yih-Kuen Tsay (IM.NTU)

Course Introduction

SDM 2021 18 / 38

Strategies and Patterns



- 📀 What strategies do we have?
 - 🌻 polynomial integration
 - 🏓 integral of ln x
 - 🌻 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

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

Yih-Kuen Tsay (IM.NTU)

Course Introduction

SDM 2021 19 / 38

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 Architecture?



📀 Suppose you want to develop a system for

- 鯵 vehicle controller
- 🏓 user interface
- 🌻 data management

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

Example: Vehicle



- Let's suppose we want to define a vehicle rental system at seashore 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

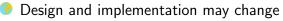


- A design pattern is the re-usable form of a solution to a design problem.
- For software, design patterns are formalized best practices that a programmer can use to solve common problems when designing an application.
- Object-oriented design patterns typically show relationships and interactions between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

イロト 不得下 イヨト イヨト 二日

Managing Changes





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

IM

From Design/Implementation to Validation/Verification

- A software developed 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.

Yih-Kuen Tsay (IM.NTU)

Course Introduction

SDM 2021 25 / 38

イロト 不得下 イヨト イヨト 二日

Some Systems Are Critical



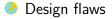
😚 Device drivers

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

😚 Etc.

What Are the Problems?





Programming errors

Yih-Kuen Tsay (IM.NTU)

Course Introduction

■ ◆ ■ ◆ ■ · ク < @ SDM 2021 27 / 38

(日) (同) (日) (日) (日)

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.

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.





- 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.



- 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
- 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.



- It specifies what properties are of interest.
- Another formal language is needed.
- High-level properties are independent of the implementation.
- Users specify the requirements in property specification languages.

• • • • • • • • • • • •

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.

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 if 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 a 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.