Software Engineering: Basics

Projet GL

Ensimag
Grenoble INP

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Software Engineering

Parallel with:

- Military engineering (oldest one): fortresses, siege & war machines
- Civil engineering: buildings, bridges
- Mechanical engineering
- Electrical engineering
- Chemical engineering...
- Software engineering & bio-engineering: the newest ones

Engineering: engineers are experts who

- master scientific and technical bases
- are able to design and guarantee quality
- organize the tasks and processes

Dual aspects of Software Engineering

Software engineering of *products*

- Tools and methods to make software *artefacts*
- Artefacts can be: source code, binary code, data structures or repositories, architecture diagrams etc.
- Example of tools: text editor (vim, Atom), IDE (Visual Studio), compiler, debugger, source code generator (ANTLR), model checkers (Avispa), link editor, configuration management (make, Maven), test harnesses, coverage analyzers (Jacoco), etc.

Software engineering of *processes*

- Methods to organize the production tasks
- In the case of software: mostly work of humans (developers)
- Backbone organization: known as (software development) “(life)cycles”
- Examples: Waterfall lifecycle, V lifecycle, Agile development

Ensimag Engineers

Engineers: are experts who

- master scientific and technical bases: **Computer science**
- are able to design and guarantee quality **Projet GL**
- organize the tasks and processes **SHEME, project Management**

What you will learn and practice (main skills)

- Software tools: git, mvn, antlr, log4j, IDE, gitlab, junit, jacoco...
- Languages & artefacts: Java, scripts, grammars, architecture diagrams, tests...
- Management methods: Agile, gantt planners, reporting...
- Working in a team, adapting to peoples’ strengths and weaknesses

Ensimag Future Engineers

What you may start to discover (and learn further at Ensimag)

- Floating point computation
- Ecological impact of digital world
- Testing methodologies (more advanced than project)
- “Bowels” of computing: bytecode, binary (FP), link editing...
- ...

Quality Criteria for Software

- Criteria for the user
  - Reliable: Gives the expected result,
  - Robust: Doesn’t crash, behaves reasonably in unexpected conditions,
  - Effective: Gives the result quickly,
  - Efficient: Uses a minimum of resources
  - User-friendly: Easy to use.
- Main focus for us: **Reliable**
- Secondary focus: Efficient (w.r.t. energy)

Quality Criteria for Software

- Criteria for the developer
  - Readable: Easy to read, to understand. Well documented,
  - Maintainable: Easy to modify, to fix,
  - Portable: Runs on various systems,
  - Extensible: Easy to improve,
  - Reusable: Can be adapted to other applications.
- Third focus for you: Readable

Software Lifecycle Stages

- Requirement analysis and definition
- Analysis and design
- Coding/Debugging
- Validation
- Evolution and Maintenance

Software Stages: Requirements

- Requirement analysis and definition
  - high level specifications
  - feasibility study

Projet GL:

- Decac compiler: specifications are ready (just read them)
- Extension: specs. are negociated with teachers

In real life, discussing requirements with customers is an important task (time consuming and critical).

Software Stages: Design

- Analysis and design
  - Detailed specification
    (for us, this is booklet part II)
  - Architecture
    (for us, 3 stages, Java packages, ...)
  - Detailed design (algorithms, data-structures)

Software Stages: Coding

- Coding: translating algorithms into programming language
- Debugging: compiling and exercising the code to check it

Beware: testing is NOT debugging

- Debugging done by developer to check whether the lines of code are actually written as he/she meant.
- Testing done by testing team to check whether program behaves as specified.

Software Stages: Validation

- Validation: make sure the program “works”
  - Static analysis and proof
  - Code review (very efficient)
  - Tests (essential)

Software Stages: Maintenance

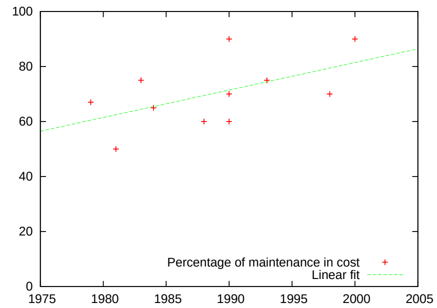
- Evolution and maintenance:
  - Corrective maintenance (Bug fixing)
  - Adaptive maintenance (Porting, ...)
  - Evolutionary maintenance (New features, ...)

“Always code as if the guy who
ends up maintaining your code
will be a violent psychopath
who knows where you live.”

Effort distribution

http://users.jyu.fi/~koskinen/smcosts.htm

- Part of Maintenance in Total Cost:



$\Rightarrow$ better optimize for maintainability than for initial development

Effort distribution in *Initial* Development

As a rule of thumb ...

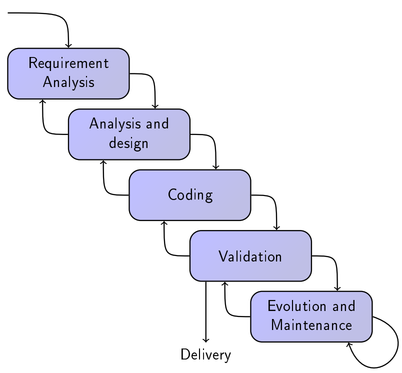
- Initial development:
  - Requirement analysis, architectural design: 40%
  - Coding, debugging: 20%
    - /! debugging is not part of validation.
    - Validation starts when the code looks correct.
  - Validation: 40%

And for our project

- Analysis, architectural design: 15% (reading, splitting into packages, ...)
- Detailed design, coding, debugging: 20%
- Validation: 40% (including scripting)
- Extension: 25%, of which 40% on analysis

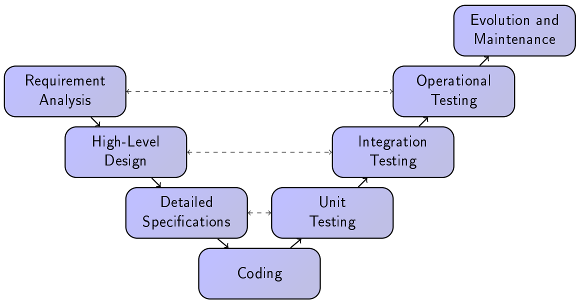
And time will also be used by management, synchronizing with team and with professors.

Waterfall Lifecycle - Historic



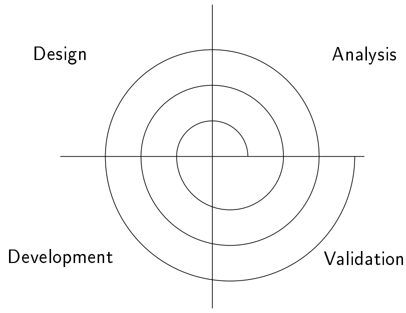
V Lifecycle - Large critical systems

Stresses Validation



Incremental (Spiral) Lifecycle

Typically in Agile development



Incremental Lifecycle

- Guiding principle: divide the program in small amounts of analyzed, coded, and tested features.
- Advantages:
  - Early discovery of problems,
  - Early availability of prototypes (essential to get feedback from the client),
  - Helps continuous validation,
  - Allows time-based releases, as opposed to feature-based releases.

Specifying the increment

- Informally
- With a set of rules in Deca's grammar
- With a set of tests
  ⇒ Test Driven Development
  while true loop
    write tests
    make sure they don't pass
    implement feature
    debug until test pass
    commit and push
  end loop

Examples of increment

- First goals:
  - Compile the empty program
  - Compile a hello-world
- Without objects:
  - Simple expressions (2+2, 2-2, ...)
  - Variables (int, float)
  - Control-structures (if/while)
- Objects:
  - Objects without methods
  - Methods (definitions and calls)

Planning should be driven by language subsets,
not by stage/passes (B1, B2, B3, C1, C2)

Incremental Lifecycle in our Project

- Hardly applicable to stage A (too short)
- Mandatory for stages B and C (type-checking and code generation).
- Avoids big-bang validation right before the final deadline
- Avoids half-done or untested features at the final deadline
- Necessary to get the intermediate delivery on time

⚠ prefer complete and well-tested compiler
on a subset of the language
to a buggy feature-complete compiler.

Validation

- Validation means making sure the program is
  - Correct
  - Robust
  - Efficient
  - Readable
  - Usable
  - Documented

Reminder: focus in our project is on Correctness (reliability).

Validation Techniques

- Use of static analysis tools
  (typing, coding style, absence of overflows, ...)
- Formal proof: costly, rarely used except for critical systems.
  Example: "meteor" subway in Paris, developed with "Atelier B",
  CompCERT C compiler proved in coq.
- Code review: one person reviews the code written by another, and checks the readability and correctness of the code.
- Test: run the program with different test-cases, and check that the results correspond to the expected results.

Testing

- Testing is the main validation technique.
- Objective: “show” that the program is correct, or find defects.
- Cannot “prove” the correctness, can indeed only exhibit defects.

Phases

- Test objective: select the feature to test
- Write test-cases
- Execute tests
- Observing, assessing and recording the result (oracle)
- Fix defects
- Evaluation: was the test sufficient?

Test objective and test cases

- Test objective: select the feature to test
- Examples:
  - Test stage A, test stage B (imprecise),
  - Test passe 2 of stage B,
  - Test type-checking of declarations,
  - Test rule 2.9.
- Select relevant data to accomplish the test objective.
- Exhaustive test usually impossible (infinite)

Execute tests and observe the result

- We execute the program with inputs and get outputs,
- Oracle: Verify that the output matches the expected output,
- Fix defects if some are found.

Evaluation: was the test sufficient?

- Is the test-suite sufficient? ...
- ... or shall we continue testing?
- How can we “measure” the effectiveness of a test-suite?
- ⇒ one answer is the notion of coverage (details follow).

Types of Tests: Overview

Unit tests Test small parts of the system,

Integration tests Check that the components work well together,

System tests Test the system under real conditions,

Acceptance tests Tests to run before any release (useful when the test-suite is not 100% automated),

Black-box tests Tests for an objective based on the *specification* of the program,

Glass-box tests Tests for an objective based on the *implementation* of the program,

(Non-)Regression tests Check that what *used to* work *still* works.

Example of program to test: factorial

```java
public class Util {
    public static int fact(int n) {
        if (n == 0) return 1;
        else return n * fact(n - 1);
    }
}

import java.io.*;
public class FactMain {
    public static void main(String[] args) {
        BufferedReader stdin = new BufferedReader(
                new InputStreamReader(System.in));
        System.out.print("Enter a value: ");
        try {
            int v = Integer.parseInt(stdin.readLine());
            System.out.println("fact(v) = " + Util.fact(v));
        } catch (Exception e) {
            System.out.println("Input error");
        }
} }
```


Unit tests

« Tests unitaires »

- Test a small portion of code (one method, one class, ...)
- Example: test for the class `EnvironmentExp`
- Advantages:
  - Can be executed before building the whole system,
  - Finds errors more easily than testing the whole system,
  - Can test conditions hard to reach in normal executions,
  - Debugging unit-test is easy.
- Drawbacks:
  - Requires drivers to call the code under test (example: class `TestEnvironmentExp`),
  - May require stubs to replace the portions needed by the code under test.

Unit test for factorial

The manual way

```java
class FactUnit {
    static void assertTrue(boolean c) {
        if (c) {
            System.out.println("ok");
        } else {
            throw new RuntimeException();
        }
    }
    public static void main(String[] args) {
        assertTrue(Util.fact(0) == 1);
        assertTrue(Util.fact(1) == 1);
        assertTrue(Util.fact(3) == 6);
    }
}
```


Unit test for factorial

Using JUnit (cf. III-[Tests])

```java
import static org.junit.Assert.*;
import org.junit.Test;

public class FactTest {
    @Test
    public void testFact() {
        assertEquals(Util.fact(0), 1);
        assertEquals(Util.fact(1), 1);
        assertEquals(Util.fact(3), 6);
    }
}
```

- JUnit provides:
  - A library of assertions (`assertTrue`, `assertFalse`, `assertEquals`...),
  - A launcher that runs all methods decorated with `@Test` in classes named `Test...` or `...Test`,
  - Integration with Maven (`mvn test`), IDE (Right-click → Test file with Netbeans)...

Integration tests

« Tests d'intégration »

- Test for a set of methods, classes, or packages
- Examples: `test_synt`, `test_context`

Example system test for FactMain

```sh
#! /bin/sh

echo "Enter a value: fact(v) = 24" > expected
# we test both input/output and computation of fact(4).
echo 4 | java FactMain > actual

if ! diff expected actual; then
    # exit with error if expected and actual differ.
    exit 1
fi

# we should try "echo -1 | java FactMain" too ...
```


Black-box Tests

« Tests boîte noire »

- Black-box test = functional tests,
- Based on specifications of the program,
- Can, and should be written before coding,
- Preferably not written by the implementer of the code under test, otherwise
  - Ambiguities in the specifications are interpreted the same way,
  - Missing functionality will hardly be detected.
- Example: from the attribute grammar of Deca, one can
  - Identify the possible errors,
  - Write the list of error messages,
  - Prepare black-box tests for stage B,
  - Write part of the user manual.
  - before writing a single line of code!

Glass-box Tests

« Tests boîte transparente (ou blanche) »

- Glass-box test = structural tests
- Based on the implementation of the program.
- Goal: cover as much as possible of the program source code.
- Example:
  Dictionary implemented with a hash-table ⇒ test the colliding cases and the non-colliding ones.

Regression Tests

« Tests de non-regression »

- Re-execute the tests after each modification of the program,
- Check that the new result matches the old ones,
- Example: use "`diff old new`"

Code Coverage

« Couverture de code »

- Goal: "everything in the code must have been tested"
- What does it mean?
  - Each instruction has been executed?
  - Each variable took all the possible values?
  - ...?
- No perfect coverage metric in a finite world.

Statement coverage

« Couverture des instructions »

- Definition: a statement is covered when at least one test-case triggers its execution.
- Coverage ratio: number of statements covered/number of statements.
- Goal: cover 100% of the code
- (except dead code, as a result of defensive programming)

Branch Coverage

« Couverture des arcs »

- Definition: Branch = path from an instruction to the next.
- Example:

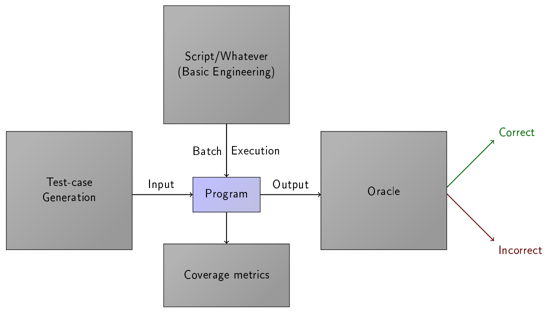
```
I1 ;
if (C1) {
  I2 ;
}
I3 ;
```

⇒ Instruction coverage achieved by one execution if C1 is true. Does not cover I1 → I3.

Jacoco: Statement Coverage Measure

- Compile the program with the right options (see III-[Jacoco]),
- Execute the test-suite,
- Jacoco tells which line of code has been executed, which hasn't.
- ⇒ essential to finish the validation
  or some lines of code have not even been tried!
- Add extra tests to increase coverage,
- However 100% usually not reachable (dead code, esp. with defensive programming)

General Considerations on Testing



Execution automation

- Minimal launcher:

```
#!/bin/sh
for i in *.deca
do
    echo "$i"
    # replace <executable> with test_synt or
    # test_lex or test_context or decac
    <executable> "$i"
done
```


Oracle: Checking the Result

- Automatic oracle essential:
  - Manual checking of output is boring and error-prone
  - Regression testing almost impossible without automatic oracle.
- Many ways to manage oracles:
  - Manual validation the first time, diff the next times,
  - Comparison of two implementations,
  - Assertions, defensive programming,
  - Approximation (example: casting out 9).

Regression and Efficiency

Regression testing is heavily used in s/w industry, esp. with Continuous Integration (every commit triggers tests to avoid a regression).
BUT automated execution of large test suites takes a lot of CPU and energy.

- Automated regression testing is necessary to ensure Reliability
- Requires smart scripts to focus on impacted parts.

⇒ You will have to manage conflicting goals:

- Ensure highest reliability (primary goal)
- While being conservative about energy (scondary goal)

Your approach to solving this conflict will be reported (and graded) in your report on energy.

Mandatory Conventions for our Project

- Directories:
  - Deca tests must be in sub-directories of `src/test/deca/syntax`, `src/test/deca/context` and `src/test/deca/codegen`.
  - Each directory must have
    - `valid/`: Deca program correct with respect to the current stage.
    - `invalid/`: Deca program triggering a compiler error in the current stage.
  - `src/test/deca/codegen` has in addition:
    - `interactive/`: all interactive tests.
      `valid/` and `invalid/` must not contain any `read` instruction.
    - `perf/`: performance tests, to assess the number of ima cycles used executing them. They should all be valid programs.

Mandatory Conventions for our Project

cf. III-[Tests]

- File name extensions:
  - .deca: Deca source files,
  - .ass: Generated (archived) assembly files.

Mandatory Conventions for our Project

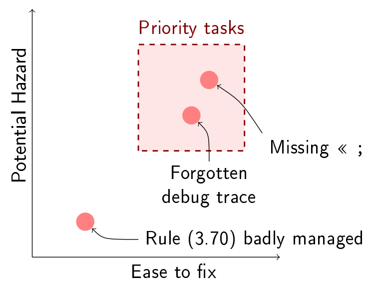
- Automation: `mvn test`
- Test-suite must be automated as much as possible (scripts).
  - Scripts must exit with 0 if the test succeeds, with another value (exit 1) if the test fails.
  - Add test scripts in pom.xml file (cf III-[Tests], section 1.6).
  - Example scripts are provided, but are minimalistic.
- Must be non-interactive by default (both for success and failures)
- (for info: the teacher's test infrastructure is >2000 lines of shell-script).
- `/bin/sh` is the suggested language for test automation (perl, python are other good candidates).
- Resources for shell-scripts available on EnsiWiki.

Test Suite in the Software Engineering Project

- Test suite is an important part of the grade.
  - It weighs almost the same as the compiler
  - If your compiler is perfect, but tests are absent, you get half the points.
  - And you will get the same if you do not write a single line of code for decac but have excellent tests
  - ⇒ share your efforts accordingly.
  - You can and should write tests before writing a single line of code.
- Grading takes into account:
  - Coverage of the test-suite
  - Test-case layout (conventions above)
  - Automation

See `III-[Tests]`

Risks management: cost-benefit



Risks management & release process

- Risk assessment and control:

Document	Danger	Action
`I-[Introduction]`	Miss a deadline	Use an agenda
`IV-[Example]`	Fail on provided example	Test it!
`II-[Decac]`	...	...
...		

- Release Process
  - Checklist of actions to perform before a release
  - Should prevent all major risks (i.e. compiler unusable with respect to the teachers' testsuite, grossly mis-classified testsuite...)

See `III-[Tests]`, section 2.

Roles

- Designer
- Developer
- Reviewer
- Tester
- Documentation writer
- Scrum master etc.

Tips (see resources on Project Management on Chamilo):

- Ideally, try all the possible roles.
- Practically, in this project, more efficient to choose depending on your individual skills.
- However, a big task should never be assigned to a single person, as this single person can fail (lack of skills, health problem...)
- At any time, the team should be able to re-assign tasks quickly.

Provisional Schedule

« Planning prévisionnel »

- Make a provisional schedule at the beginning of the project.
- Use "`planner Planning.planner`"[1] in `Projet_GL/planning` to modify your schedule
- Specify your increments and distribute the tasks between the members of the team.
- (You may use an alternative to Gantt charts, e.g. burndown chart, for day-to-day planning)

[1] or your favorite alternative, as long as it can create PDF files

Actual Schedule

« Planning effectif »

- Make the actual schedule of your daily work.
- You must explain the differences between your estimated and effective schedules (evaluation takes into account your explanations, not the differences themselves)
- Use "`planner Realisation.planner`" in `Projet_GL/planning` to modify your schedule.

Typical Efforts for Projet GL

According to parts of project

- Stage A lex+synt: 10%
- Stage B ctx verif: 20%
- Stage C gencode: 45%
- Extension: 25%

According to type of activity (see Rule of thumb, adapted for Projet GL)

- Analysis & Design: 25% (mostly for stage C and extension)
- Coding & debugging: 20%
- Validation (reviews & tests): 35%
- Documentation & Management (incl. lectures) : 20%

Activity Report

You are expected to make an activity report for each "progress meeting". Specify:

- what has been done since the last "progress meeting",
- the current differences between your effective and estimated schedules.

We advise you to keep a detailed count of how many hours were spent on each task (including tasks such as meetings, preparations etc): this will help you for the final report ("bilan"), and also for your own feedback and planning.

Progress Meetings in our Project

Reminders

- `I-[Suivis]`
- 3 meetings, 30 minutes each
- 20 minutes "progress report"
  - You convince the teacher that the progress is good,
  - Must be prepared.
- 10 minutes "technical support"
  - ⇒ The teacher can help you.
- first two meetings with a "SHEME" teacher.

First Progress Meeting

- See `I-[Suivi-SHEME1]`
- Prepare a short document presenting your team and your organization,
- Prepare a provisional schedule (See `III-[GuidePlanner]`).
- Present a proposition of an extension (2 pages)
  - analysis
  - draft specification of the extension

Execution Traces

- Traces can be useful to debug a program
- *must* be easy to remove
  ⇒ **never** use `println` for debugging.
- Implementation (the manual way - prefer log4j):

```
class TraceDebug {
    private static final int LEVEL = 5;
    public static void trace(int level,
                             String message) {
        if (level <= LEVEL) {
            System.out.println("trace: " + message);
        }
    }
}
```

Usage: `TraceDebug.trace(4, "Message");`

Log4j library

cf. III-[ConventionsCodage]

- ```
  import org.apache.log4j.Logger;
  public class LogClass {
      // Instantiation of logger, done once for each class.
      private static final Logger LOG =
          Logger.getLogger(LogClass.class);
      // ...
      LOG.trace("Trace Message!");
      LOG.debug("Debug Message!");
      LOG.info("Info Message!");
      LOG.warn("Warn Message!");
      LOG.error("Error Message!");
      LOG.fatal("Fatal Message!");
  ```
- To choose the level:
  - method `setLevel` of each logger,
  - configuration file `log4j.properties`
    (in `src/test/resources/` and `src/main/resources/`).
- `warn` level ⇒ messages corresp. to `warn`, `error` and `fatal` displayed.

Good Practices and Coding Style

- Keep methods short (≈ 1 screen)
- Do not write long lines (80 characters max)
- Indent consistently with 4 spaces (if using tabs, 1 tab = 8 spaces)
  ⚠ Not the default with Eclipse :-(
- Class names start with an uppercase letter, method and variable names start with a lowercase letter
- Comment your code to explain *why* the code is how it is, not *what* it does
- Comment your method headers (javadoc) to explain what methods are doing (pre/post conditions, ...)
- cf. III-[ConventionsCodage], section 3

Defensive Programming

- See `III-[ProgrammationDefensive]`
- Method preconditions: conditions that the method arguments must satisfy:
  - partial functions,
  - conditions that the arguments must satisfied, so that the algorithm works correctly.
    Example: dichotomic search in a sorted array.
- Method postconditions: conditions that must be satisfied after a method call.
- Invariant: condition that is always satisfied
  (loop invariant, class invariant)
  ```

Defensive Programming

- Defensive programming: explicit check of preconditions, postconditions and invariants.
- Allows the programmer to detect and correct bugs at a lower cost.
- When an assertion is violated, the program is stopped by raising an exception.

Checking Preconditions

- Use of the class `Validate` from apache commons
- Example:

```
import org.apache.commons.lang.Validate;
// ...
/**
 * precondition : x >= 0
 */
float sqrt(float x) {
    Validate.isTrue(x >= 0 ,
                    "x should be positive");
    // ...
}
```

- Methods: `isTrue`, `isFalse`, `notNull`, `notEmpty`.

Checking postconditions and invariants

- Use of assertions
- Assertions are enabled during development, and disabled during final testing and release.
- In Java: assertions are disabled by default, enable with `java -enableassertions`
- Syntax:
  `assert` *`condition`*`;`
- Violating an assertion raises the `AssertionError` exception (deriving from `Error`).

Checked and unchecked exceptions

Two types of exceptions in Java:

- unchecked exceptions
  - derive from `RuntimeException` or `Error`;
  - are the result of a programming problem (e.g. `NullPointerException`), or other unrecoverable error (e.g. `OutOfMemoryError`);
  - should not be caught.
  - `Validate` and `assert` raise unchecked exceptions.
- checked exceptions
  - are part of the specification of the method (`throws` clause);
  - must be caught by the caller.