Software Engineering

CS305, Autumn 2020

Week 10

Class Progress…

- Last Week
  - RUP phases,
  - Software Construction
    - Inspections/Reviews
- This week
  - Software Construction
    - Coding
    - Refactoring
    - Introduction to testing and unit testing (if time permits)

Coding

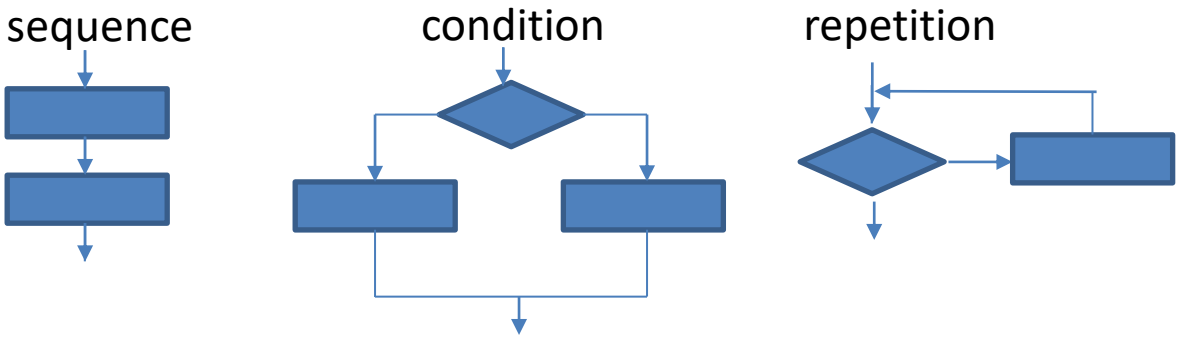
Coding

- Could involve:
  - Writing source code / programming in a chosen language
  - Automatic generation of source code using a design representation of the component to be constructed
  - Automatic generation of executable code using a *fourth-generation* language – program generating language

Human understanding is facilitated by linear sequence of logical statements

Programming Paradigms

- Unstructured Programming
  - Writing a sequence of commands or statements that access 'Global' data. E.g. Assembly lang. programming.
- Structured Programming (sometimes used interchangeably with procedural programming)
  - Dijkstra's advice on using simple logical constructs of:



  - Focus on writing 'modular' programs. Have single-entry and single-exit for a procedure / function (control construct). E.g. C, Assembly lang. programming

Programming Paradigms

- Object Oriented Programming
  - Modeling real-world objects. Data is the centerpiece. Combine data and functions, allow code reuse, incremental dev. maintainability, modularity. *(more in Week3 lectures).* E.g. C++, Java
- Functional Programming
  - Focus on what to do and not how to do. Don't create state that is changeable. E.g. Lisp, Racket
- Concurrent Programming
  - Focus on concurrent execution of a sequence of statements.
  - Parallel programming is a type.
  - E.g. Threads programming (Java threads), Open MP, MPI, CUDA-C.

Coding Principles

- Ensure that the problem is well-understood before coding (i.e. design is clear, programming language is clear)
- Follow Dijkstra's advice and create modular code that is highly cohesive and loosely coupled
- Select data structures that meet the design objectives
- Create readable code (have indentation, blank lines, and comments)
- Select meaningful names for variables, functions, and follow coding standards and best practices
  - `tmp, temp, data` are "symptoms of programmer laziness".
  - (for GCC) https://gcc.gnu.org/wiki/CppConventions
- Get code reviewed by peers

Code Review – class exercise

- Review the following Fortran code

```
 1 DOUBLE PRECISION FUNCTION SIN(X, E)
 2 C     THIS DECLARATION COMPUTES SIN(X)TO ACCURACY E
 3         DOUBLE PRECISION E,TERM,SUM
 4         REAL X
 5         TERM=X
 6         DO 20 I=3,100,2
 7         TERM=TERM*X**2/(I*(I-1))
 8         IF(TERM.LT.E)GO TO 30
 9         SUM=SUM+(-1**(I/2))*TERM
10      20 CONTINUE
11      30 SIN=SUM
12         RETURN
13         END
```

Code Review – class exercise

- Review the following Fortran code

- `C` is comment to end of line
- The `CONTINUE` statement is often used as a place to hang a statement label, usually it is the end of a `DO` loop. If the `CONTINUE` statement is used as the terminal statement of a `DO` loop, the next statement executed depends on the `DO` loop exit condition.
- `.LT.` is less than
- `**` is exponentiation (has higher priority than *)

- `DO` *`label var = expr1, expr2, expr3`*
  `statements`
  `Label CONTINUE`

`var` is the loop variable (often called the *loop index*) which must be integer. *`expr1`* specifies the initial value of *`var`*, *`expr2`* is the terminating bound, and *`expr3`* is the increment (step).

```
1  DOUBLE PRECISION FUNCTION SIN(X, E)
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Code Inspection Checklist (excerpt)

1. Data (DA)

- Is each variable correctly typed?
- Is each variable initialized before use?
- Is the initialization appropriate for the type?
- Can global variables be made local?
- Are buffer overflows checked?
- Is dynamically allocated memory freed?

2. Interface (IF)

- Are appropriate values returned from functions?
- Do function calls have correct parameter types/values?
- Are return values tested?

3. Functionality (FN)

- Do loops terminate?
- Do all loops iterate the correct number of times (no off-by-one errors)?
- Is behavior correct if a loop is never entered?
- Is there dead (unreachable) code?
- Do all switch statements have a default case?
- Do all switch arms have break statements? If not, is the ``fall through'' correct?

4. Input/Output (IO)

- Are files opened before use?
- Are files closed after use?
- Are error conditions checked?

5. Other (OT)

- Any defect discovered that does not fall into one of the above categories.

Slide courtesy: Alex Orso, CS3300

Further Reading

- Code Reviews:

http://web.mit.edu/6.005/www/fa16/classes/04-code-review/

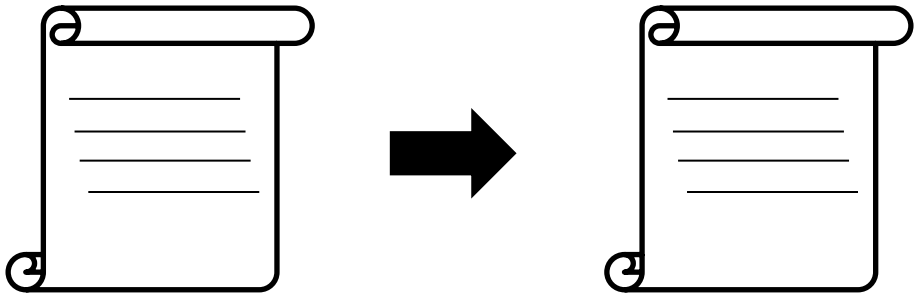
Misc: "The Mess We're In" – Joe Armstrong
https://youtu.be/lKXe3HUG2l4

Pay special attention to the slide on "7 deadly sins" at around 8:00

Software Refactoring

Refactoring

- **Objective:** transform code to make it easier to read, maintain, and improve the design

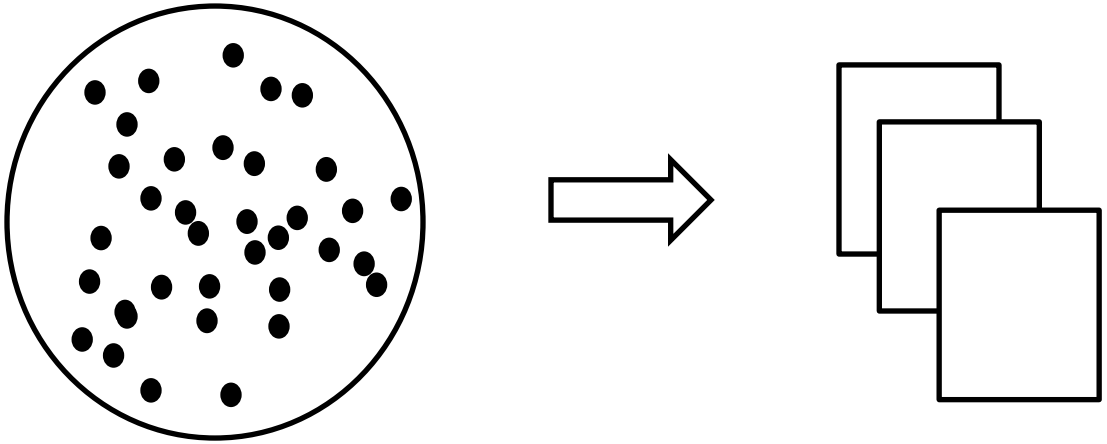


program behavior doesn't change after refactoring – "behavior preserving"

You would have probably done it without actually referring to it by the name

Refactoring

- How can we “guarantee” that the transformed program is behavior preserving?
  - No guarantees. Simply test it.
    - Testing is inherently incomplete.



Why Refactoring?

- To accommodate design changes
  - Requirements Change
- To improve design
  - Add new feature
  - Make code more maintainable etc.
  - To adapt (may not have the best design in the first attempt)
- To improve “cut-paste” code

Refactoring History

- Well suited to OO languages but not limited to those languages only
  - Because of the ability of OO languages to create flexible code/design
  - William F. Opdyke's 1990 PhD thesis on refactoring for Smalltalk
- Increasingly popular (because making changes is less costly) in Agile Environments
- Martin Fowler's Book - "Refactoring – Improving the Design of Existing Code"

Refactoring Types

- Many types listed in Fowler's book
- E.g.
  - Extract Method
  - Collapse Hierarchy
  - Decompose Conditionals
  - Consolidate Conditionals
  - Extract Class
  - Inline Class

Refactoring Type – Collapse Hierarchy

Applied when:

- Class hierarchy (superclass and subclass chain) may grow over time
- Methods and attributes may move from one class to another

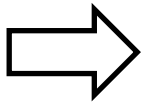
Consequence: superclass and subclass may become too similar

Fix: Merge superclass and subclass into one

Refactoring Type – Consolidate Conditionals

- **Applied when:** a set of conditional expressions with different conditional check and same result

```
double disabilityAmount() {
if( seniority < 2)
        return 0
if (monthsDisabled > 12)
        return 0
if (isParttime)
        return  0;
// compute disability amount
}
```



```
bool notEligibleForDisability() {
return (seniority < 2) ||
        (monthsDisabled > 12) ||
        isParttime ;
}

double disabilityAmount() {
if( notEligibleForDisability())
        return 0
// compute disability amount
}
```

Fix: Combine conditionals to have single check and single result (combine and extract)

Refactoring Type – Decompose Conditionals

- **Applied when:** a complex conditional check obscures what happens and why it happens

```
if( date.before (SUMMER_START) || date.after(SUMMER_END))
        charge = quantity * winterRate + winterServiceCharge;
else
        charge = quantity * summerRate;
```

```
if(notSummer(date))
        charge = winterCharge(quantity);
else
        charge = summerCharge(quantity);
```

Fix: Extract methods from conditionals, modify if-else body

Refactoring Type – Extract Method

- Large method with cohesive code snippet

`Demo in Eclipse IDE`

- **Fix:** create a method extracting the code snippet

More refactoring types..

- Extract Class
  - When a class is doing the work of two classes, create new class and move relevant methods and attributes.
- Inline Class
  - When a class is not doing much, move its features into another class and delete this class.

Refactoring when not to do?

- Refactoring is powerful but may introduce regression errors
- So, do not do it when:
  - Code is broken
  - Deadlines are close
  - When there is no need
  - When there is no budget (manpower, money) for manual change, test development, and maintenance

When to do refactoring?

- Bad smells – symptoms of unhygienic code
  - Duplicated code
  - Long method
  - Large class
  - Long parameter list
  - Shotgun surgery
  - Feature envy
  - . . .

When to do refactoring?

- Bad smells – symptoms of unhygienic code
  - Duplicated code: extract method
  - Long method: extract method, decompose conditionals
  - Large class: extract class (or subclass)
  - Long parameter list: **?**
  - Shotgun surgery: move method/field, inline class
  - Feature envy: extract method, move method
  - . . .

Software Verification

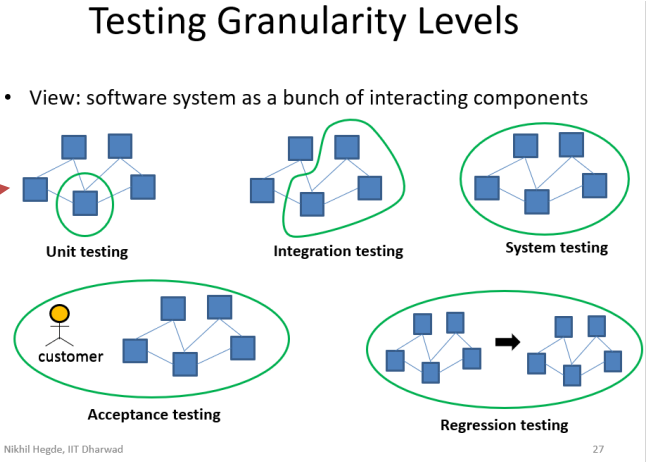
- Checking the software for bugs
- Approaches:
  - Testing
    - Most commonly used method in the industry. Refer slides 25-36 from Week4 for testing overview.
  - Inspection
    - Human intensive method (refer to Week9 slides)
  - Static Verification
    - E.g. check for null pointer dereferences
    - Considers all possible inputs unlike testing
  - Formal proofs of correctness
    - Based on formal specifications provided, proves that a program is implemented correctly.

Detour: IEEE Terminology

- Failure: observable incorrect behavior of the system
- Fault / Bug: related to code. Presence of a fault doesn't mean failure - necessary but not sufficient condition for failure.
- Error: Cause of a fault (usually a human error)

Unit Testing

- Recall testing granularity from week4
- Focus: Unit Testing -
  Testing of individual modules in isolation
- Recall white-box testing. Unit testing is an example of white-box testing. Other examples:
  - Integration testing
  - Static code analysis (for detecting errors)
    - Using code patterns and machine learning



White-box Testing Example

- Note: test without a specification (don't know how `fun` is called in a bigger picture)

```
1. int fun(int param)  {
2.   int result;
3.   result = param / 2;
4.   return result;
5. }
```

  - Execute all statements in the function
  - Cons: miss catching an obvious error for a specification: `input an integer and return half the value if even. Unchanged otherwise.`

Nikhil Hegde, IIT Dharwad 36

JUnit (http://junit.org)

- Open-source framework to write and run tests for Java programs
- You can write Unit tests
  - E.g. test individual methods of a class
- Erich Gamma and Kent Beck wrote it initially

JUnit – how to use?

- Provides annotations
  - E.g. annotations:
    - `@Test` – identifies a test method
    - `@Before` – identifies a method that is executed before a test is run
    - `@After` – identifies a method that is executed after a test is run

behaving as expected / did we get it right?

- Provides assertions for *verifying* methods
  - E.g. `assertEquals(3,MyClass.GetMinWordLen());`
- Provides Test runners for running the tests
- Provides features for automated running of tests and progress indicators

JUnit Demo

Demo in Eclipse IDE