Aspects of code quality

Introduction

- Let's talk about
  - quality code
  - and how to achieve it
- Learning goals:
  - How to recognize good/bad code
  - Knowledge of key problems/solutions
  - Awareness of the trade-offs involved

Topics of today

- Code quality
- Duplication
- Tangling & scattering
- Bad code example (Dancing Bears)
- Abstraction
- Design Patterns
- Trade-off example Rascal code (CWI)
- Conclusion

Code quality

Code quality

Background

- Fact 41: Maintenance typically consumes 40 to 80 percent of software costs. It is probably the most important life cycle phase of software.
- Fact 44: Understanding the existing product is the most difficult task of maintenance.

Source: Facts and Fallacies of Software Engineering (Robert L. Glass)

It's all about change

- Evolution is important from the start
  - Software is read much more than it is written
  - Understanding is a crucial component
  - Programming is an act of communication
- We can generalize this:
  - As soon as the first line of code is written, programming becomes maintenance
- Quality code is
  - **easy to understand and change**

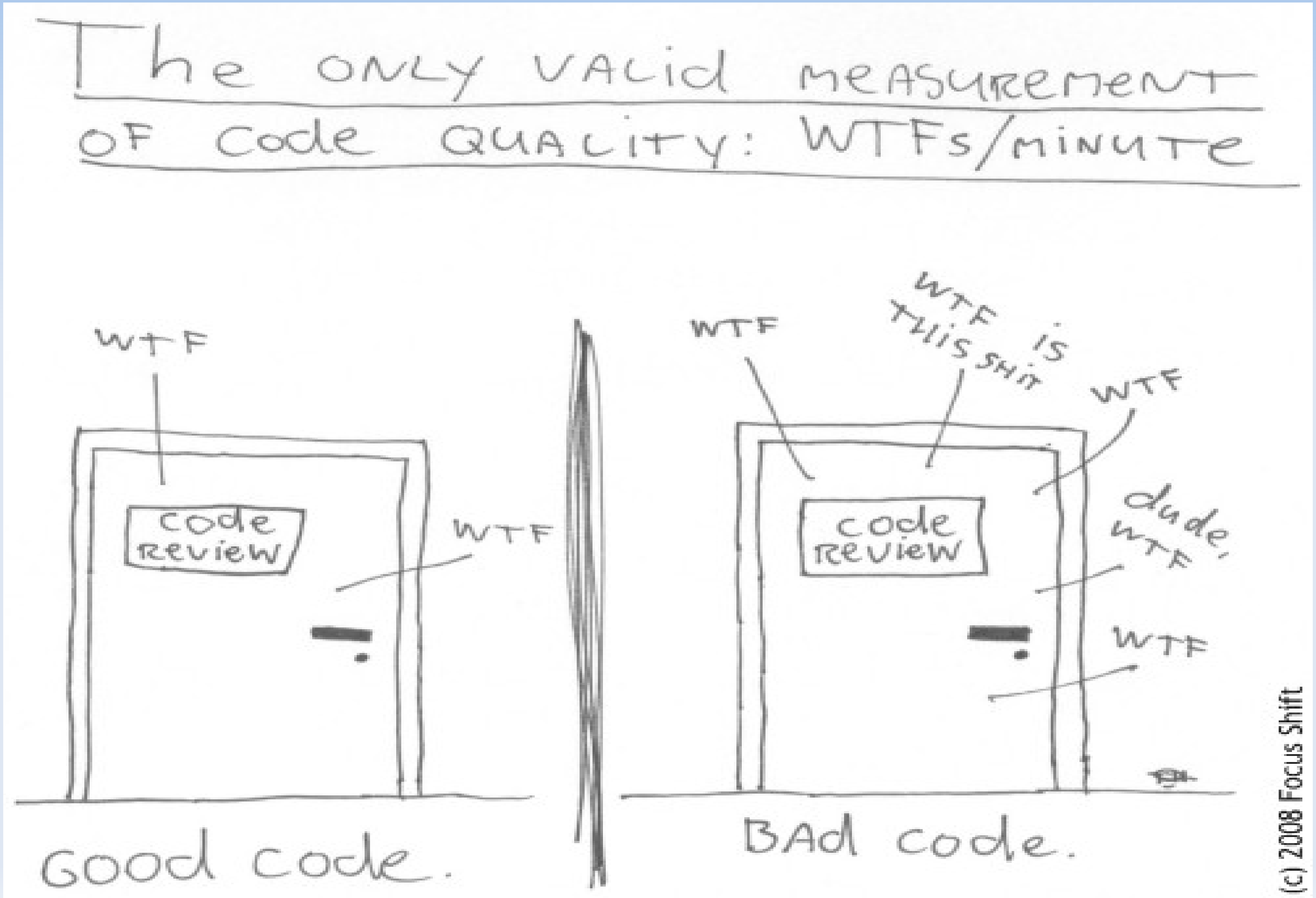
How to characterize quality code?

- DRY, OAOO, KISS, QWON

How to characterize quality code?

- DRY, OAOO, KISS, QWON
- DRY: Don't Repeat Yourself
- OAOO: Once And Only Once
- KISS: Keep It Simple Stupid
- QWON: Quality Without a Name

Quality is hard to define



Some suggestions

- No duplication
- Well-factored
- Conceptual integrity
- Intentional naming
- Low complexity
- Strong cohesion
- Weak coupling
- Lean and mean
- Simple
- Testable
- Readable
- Not too smart
- Consistent
- Uniform
- Imperfect
- Flat
- ...

Duplication

Duplication

Duplication

- Two program elements or structures that are similar in a certain way
- Creates multiple sources of knowledge
- One change requires other changes
  - duplicate maintenance obligation
  - fault prone

Duplication ctd.

- Duplication related to coupling
  - implicit dependencies between distant elements
  - worse than normal coupling (which is explicit)
- Also counts for data
  - normal forms in databases
  - example later

Examples of duplication

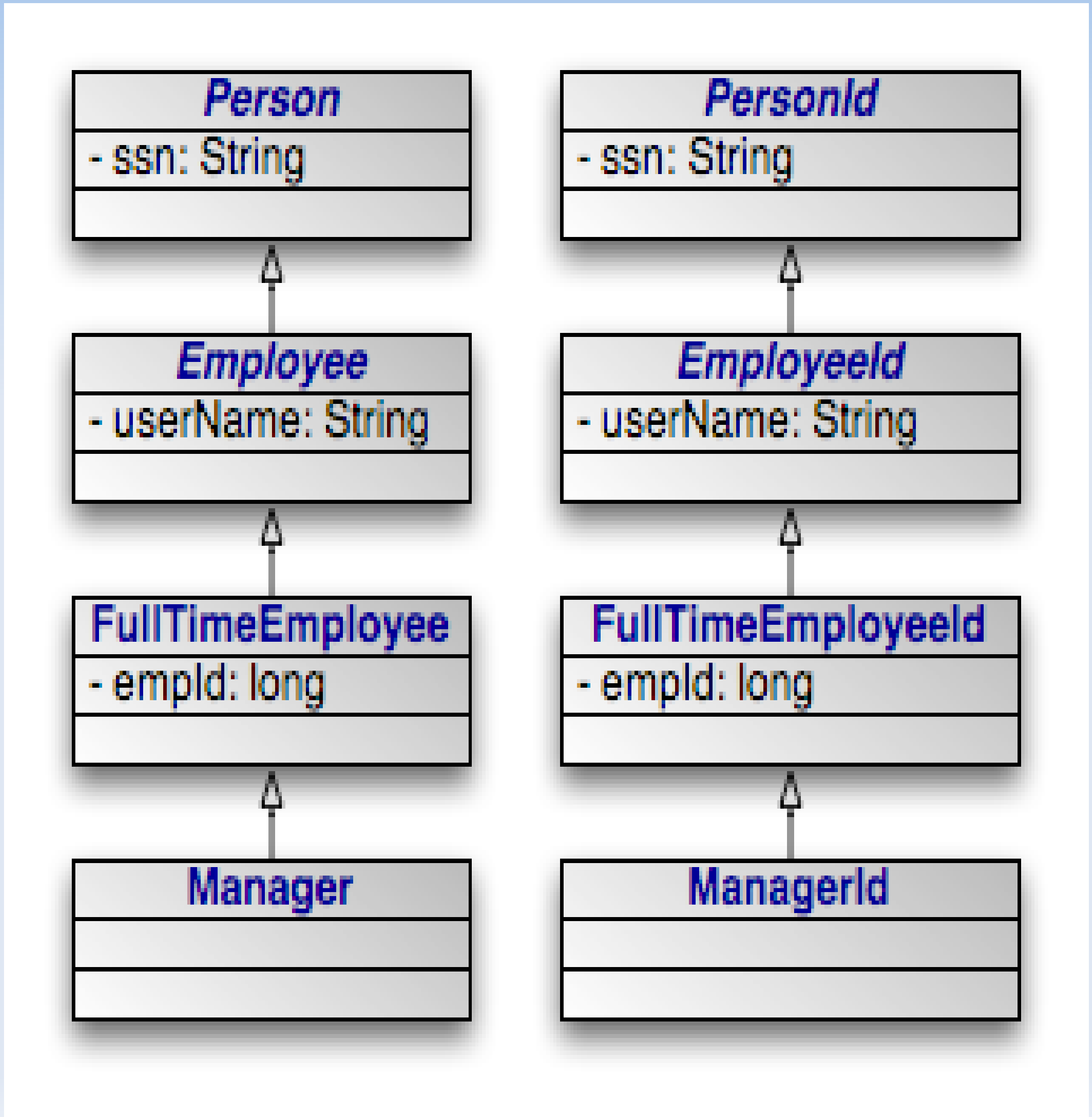
- copy-pasted code (clones)
- parallel inheritance hierarchies
- Implicit coupling
- sequence of calls where order matters
- similar parameter lists
- conventions
- idioms

Copy-pasted code

```
String error = "";
 if (!containsNode(source)) {
      if (source == null) {
           error += "source is null";
      } else {
           error += "source : " + source.getId() + " ," + source.getName();
      }
      error += "\n";
 }
 if (!containsNode(target)) {
      if (source == null) {
           error += "target is null";
      } else {
           error += "target : " + target.getId() + " ," + target.getName();
      }
      error += "\n";
 }
 if (!error.equals("")) {
      throw new NoSuchElementException(error);
 }
```

DIRECT CONSEQUENCE OF COPY PASTING!!!

Parallel inheritance hierarchies



Implicit coupling and Order dependence

- Implicit coupling

```
edge.getSource().firePropertyChange(...);
edge.getTarget().firePropertyChange(...);
```

- Order dependence:

```
class Circle {
  public void setRadius(double r) { ... }
  public double getCircumference() { ... } }
Circle c = new Circle();
print(c.getCircumference());
```

- Also for parameter lists

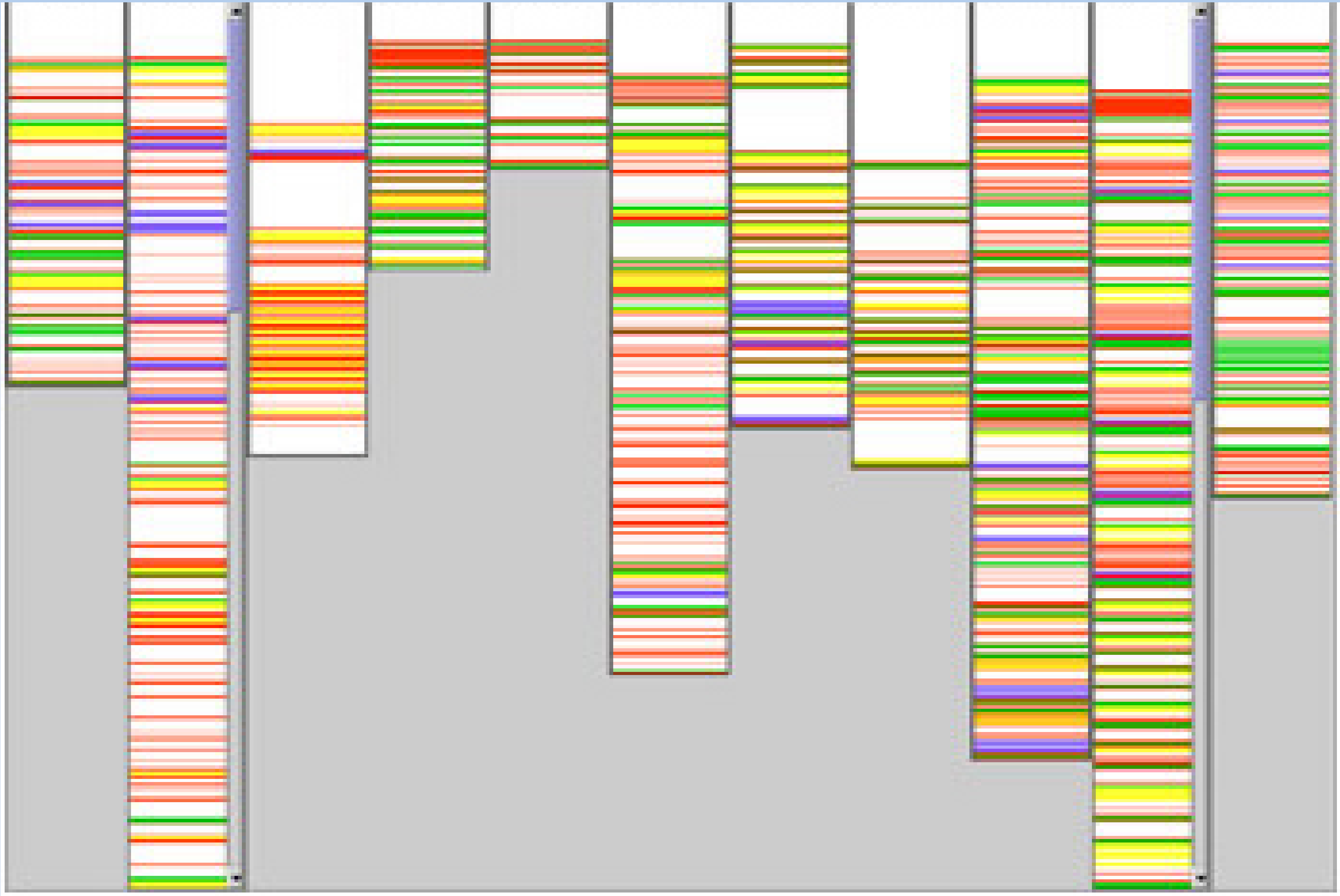
Tangling

Tangling

Tangling and scattering

- Tangling: one piece of code has multiple responsibilities
- Scattering: one responsibility is distributed over different pieces of code
- Common with *cross cutting concerns*
- Problems:
  - Scattering is duplication
  - Tangling makes code hard to understand
  - Change is error-prone

Tangling and scattering



Problems duplication & tangling

- Duplication: ”the same in different places”
  - duplicate maintenance
  - change is fault-prone
- Tangling: ”different things in one place”
  - complicates understanding
  - fault-prone

Show me some (bad) code!

Introduction

- Code from project some years ago
- Debugger for Toolbus Middleware
- Some examples to illustate the topics of duplication and tangling

SourceFileTableMod

m_lineNumbers is dependent on m_sourceLines yet they are maintained separately

```
public SourceFileTableModel(String source) {
        String sourceFile = source;
        m_lineNumbers = getTextLineNumbers(sourceFile);
        m_sourceLines = new Object [m_lineNumbers][COLUMN_COUNT];
        int index = 0;
        final int breakPointPosition = 0;
        final int sourceCodeLineNumber = 1;
        final int text = 2;
        int firstEndLine = 0;
        int nextLine = 0;
        while (sourceFile.length() != 0) {
            if (sourceFile.contains("\n")) {
                firstEndLine = sourceFile.indexOf("\n");
                nextLine = firstEndLine + 1;
            } else {
                firstEndLine = sourceFile.length();
                nextLine = firstEndLine;
            }
            String firstLine = sourceFile.substring(0, firstEndLine);
            m_sourceLines[index][breakPointPosition] = false;
            m_sourceLines[index][sourceCodeLineNumber] = index + 1;
            firstLine = firstLine.replaceAll("\t", "    ");
            m_sourceLines[index][text] = firstLine;
            sourceFile = sourceFile.substring(nextLine, sourceFile.length());
            index++;
        }
    }
```

One loop that serves multiple purposes:
- initialization
- line counting
- splitting
- normalization

By the way...

```java
public int getTextLineNumbers(String source) {

        String sourceFile = source;
        int lineNumbers = 0;
        int firstEndLine = 0;
        int nextLine = 0;
        while (sourceFile.length() != 0) {
            if (sourceFile.contains("\n")) {
                firstEndLine = sourceFile.indexOf("\n");
                nextLine = firstEndLine + 1;
            } else {
                firstEndLine = sourceFile.length();
                nextLine = firstEndLine;
            }
            sourceFile = sourceFile.substring(nextLine, sourceFile.length());
            lineNumbers++;
        }
        return lineNumbers;
    }
```

This loop looks familiar...

Only here it's just counting lines, not storing them

other example of tangling

What this method does may be clear from the name, but can you spot errors?

```
protected String createMultilineString(String text) {
    if (text.length() <= CHARACTERS_PER_LINE) {
        return text;
    }

    StringBuilder multilineText = new StringBuilder();
    int linesCount = text.length() / CHARACTERS_PER_LINE;
    for (int i = 0; i < linesCount; i++) {
        int beginIndex = i * CHARACTERS_PER_LINE;
        int endIndex = beginIndex + CHARACTERS_PER_LINE;

        String line = text.substring(beginIndex, endIndex);
        multilineText.append(line);
        multilineText.append("<br>");
    }

    int beginIndex = CHARACTERS_PER_LINE * linesCount;
    int endIndex = text.length();
    String lastLine = text.substring(beginIndex, endIndex);
    multilineText.append(lastLine);

    return multilineText.toString();
}
```

Loop with complex logic and two special cases: tangling of concerns. What are they?

Refactoring opportunities

- The two responsibilities:
  - splitting and joining
- Separate the two concerns
  - using helper method and/or library class
- Result could be:
  - join contains the loop complexity just for joining

```
protected String createMultilineHTMLString(String text) {
    return join(split(text, CHARACTERS_PER_LINE), "<br>");
}
```

Summary

- Duplication: similar loops for splitting, counting, joining
- Tangling: joining and splitting in one loop
- Coevolving state: m_lineNumbers vs m_sourceLines (implicit coupling)
- Logic encoded using (local!) literals: 0, 1, 2 in table
  - missing abstraction?

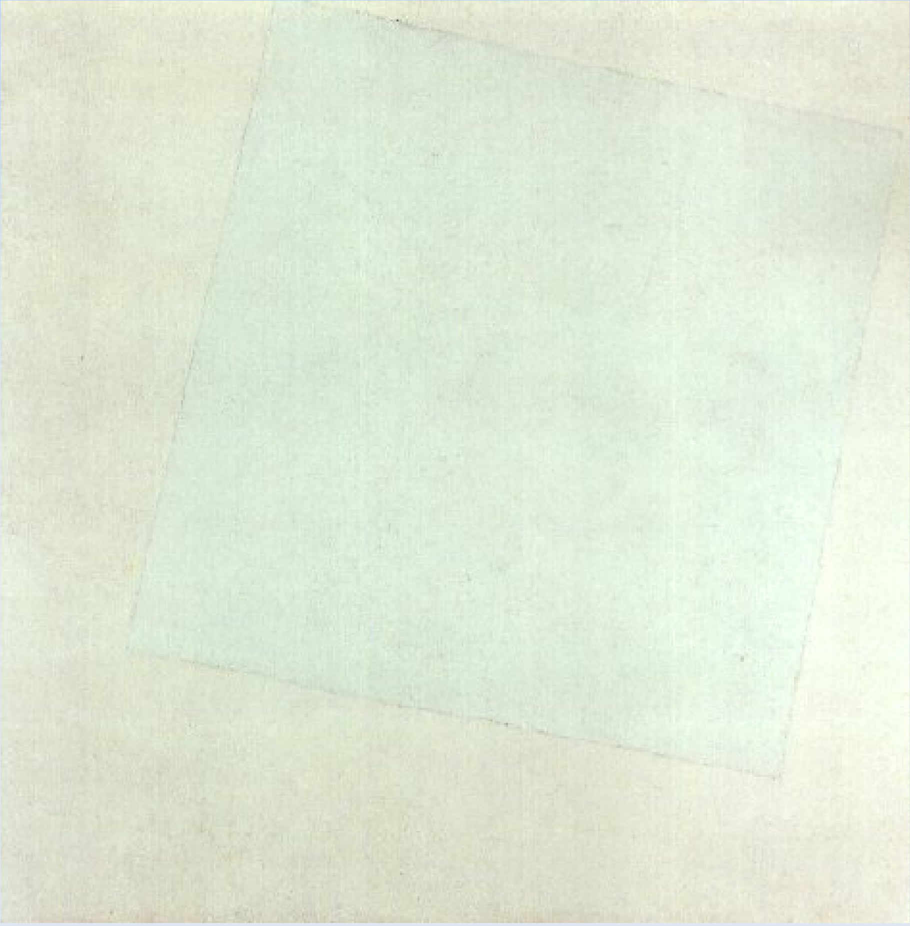
Problems duplication & tangling

- Duplication: ”the same in different places”
  - duplicate maintenance
  - change is fault-prone
- Tangling: ”different things in one place”
  - complicates understanding
  - fault-prone
- *How to avoid these problems*?

Abstraction

Abstraction

Abstraction



Malevich: ”White on White” , 1918

Abstraction

- Leaving out details
  - information hiding (implementation and data)
- Allowing systematic variation
  - parameterization
- Giving a name to something
  - use the name of something instead of the thing itself
- Decreasing degrees of freedom
  - freedom also means freedom to make mistakes

Benefits of abstraction

- Benefits
  - single point of change
  - understanding through intention revealing names
  - reuse
  - variation
  - lower complexity through factoring
  - compression (i.e. less code)

Exercise: Abstraction in action

- Simple program
- Spot the duplication/coupling/degrees of freedom
- Resolve using abstraction

Abstraction in action

```
print 1
print 4
print 9
print 16
print 25
```

Abstraction in action

```
i = 0;
next:
  i++;
  print i*i
  if i <= 5
    goto next;
```

Abstraction in action

```
i = 1;
while i <= 5 do
    print i*i
    i++;
end
```

Abstraction in action

```
for i = 1 to 5 do
  print i*i
end
```

Abstraction in action

```
def squares
  for i = 1 to 5 do
    print i*i
  end
end
```

Abstraction in action

```
def squares(n)
  for i = 1 to n do
    print i*i
  end
end
```

Abstraction in action

- Fewer degrees of freedom with the first steps
  - sequence to gotos to while loop to for loop
  - less risk of error
- Last two steps allow reuse and enable single point of change
  - naming
  - parameterization

```
def squares(n)
  for i = 1 to n do
    print i*i
  end
end
```

Abstraction in short

- Abstraction enables
  - well-factored code
  - problem decomposition
  - separation of concerns
  - reuse
  - variation
  - single point of change (DRY, OAOO)
- But there are problems of abstraction as well...

Abstraction trade-offs

- Dependencies create distance
  - use site vs definition site
- Condensed/compressed code can be harder to understand
  - Good naming is essential

Trade-offs ctd.

- May introduce performance penalty
  - method call overhead
  - object allocation
- Law of leaky abstractions
  - the hidden implementation seeps through
  - client code must have knowledge of the implementation
- Risk of overdesign: making things too generic
  - YAGNI: You Ain't Gonna Need It

Abstraction and understanding

- Understanding crucial during maintenance
- Using abstraction: you need more context
  - Context can be far away
- Copy-pasted code: you can see what is happening
  - Distance is zero, as it were

Understanding compressed code

- Try to understand the following (Lisp) code:
  - (From Richard P. Gabriel, ”Patterns of Software”)

```
(mismatch sequence list :from-end t
    :start1 20 :start2 40
    :end1 120 :end2 140 :test #'baz)
```

Why is this hard to understand?

- Meaning of ”mismatch”
- Meaning of ”baz”
- Meaning of the keyword parameters
- Mismatch is a control abstraction

Now try to understand this:

```
(let ((subseq1 (reverse (subseq sequence 20 120)))
    (subseq2 (reverse (subseq list 40 140))))
  (flet ((the-same (x y) (baz x y)))
    (loop for index upfrom 0
        as item1 in subseq1
        as item2 in subseq2
        finally (return t) do
        (unless (the-same item1 item2)
            (return index)))))
```

Patterns

Patterns

Contra extreme abstraction

- Alternative viewpoint:
  - extreme abstraction makes programs hard to read
  - patterns, conventions, idioms achieve better quality
- Patterns of program design:
  - documented, recognizable ways of solving certain problem
- Examples:
  - Design patterns (Gang of Four, GOF, book)
  - Implementation patterns (new book by Kent Beck)

Patterns

- Patterns are not abstractions
- Descriptions of solutions to common problems that can be tailored to certain context
- Examples:
  - Abstract factory: Provide an interface for creating families of related or dependent objects without specifying their concrete classes.
  - Visitor: Represent an operation to be performed on the elements of an object structure. Visitor lets you define a new operation without changing the classes of the elements on which it operates.

Patterns and code literacy

- Patterns can be
  - learned
  - recognized
  - discussed
  - taught
- Use of patterns thus can help understanding
- Programming as an act of communication but not though abstraction

Refactoring trade-off example

Refactoring trade-off example

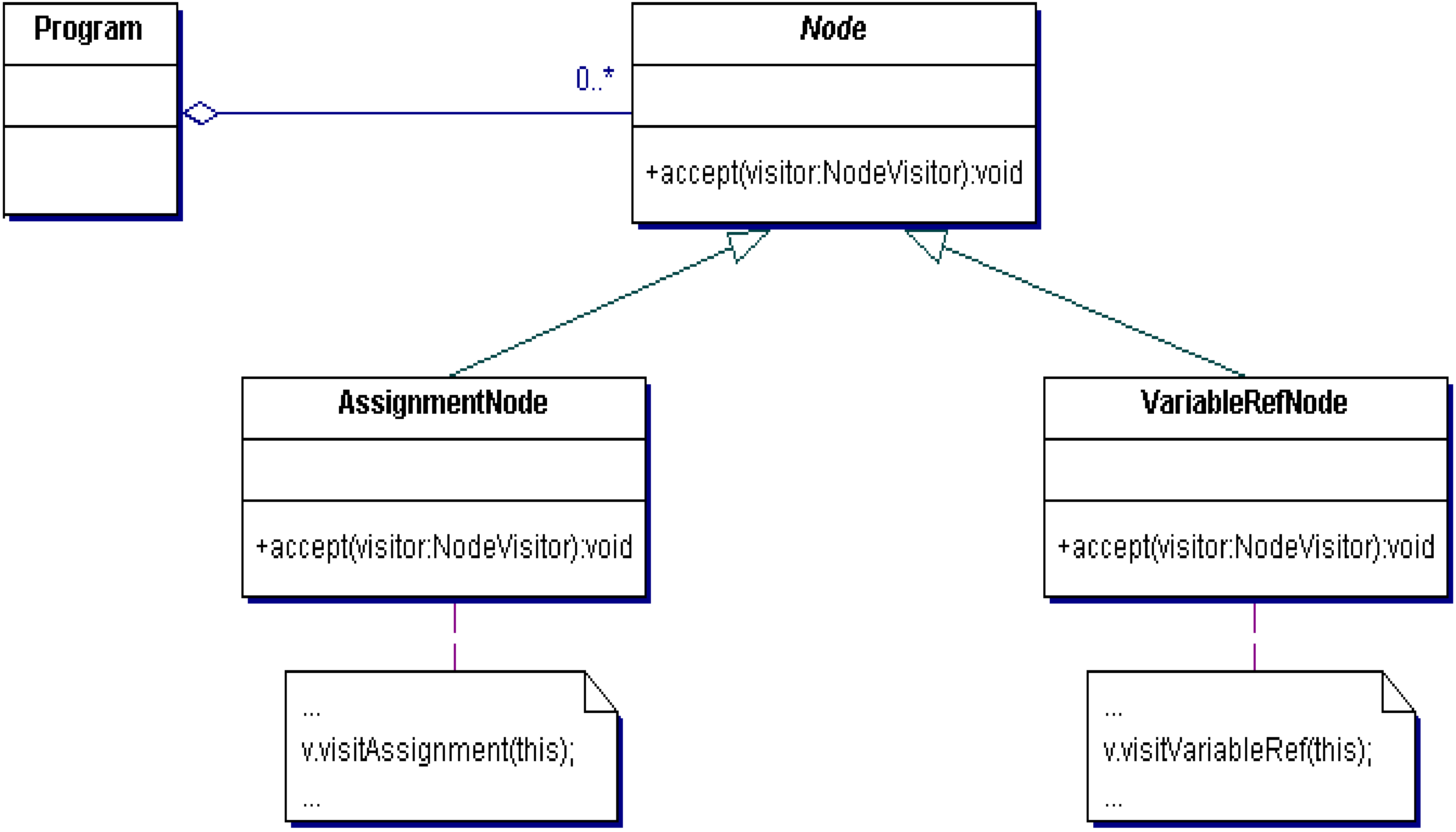
Example of refactoring trade-off

- Duplication vs factoring
- Use of design patterns
  - Visitor
  - Double dispatch
- Real case in Rascal implementation
  - By Paul, Jurgen and me
- Interpreter of Rascal contained ”bad” code

Rascal

- Rascal is a typed functional languages for software analysis and transformation
- Many operators are overloaded
- Interpreter checks whether operations are allowed:
  - 1 + 2: 3
  - [1] + [2]: [1, 2]
  - ”1” + ”2”: ”12”
  - 1 + ”x”: error
- How to implement this?

Visitor pattern



Visitor pattern ctd.

- Can be used for implementing interpreters
- Abstract Syntax Trees have accept()
- Interpreter has visitExp, visitStat, visitDecl etc.
- During visiting
  - Expressions get evaluated
  - Variables get assigned
  - Etc. Etc.
- If statements do the typechecking on overloading.

Addition...
(integers, doubles, strings)

```
@Override
public Result visitExpressionAddition(Addition x) {
    Result left = x.getLhs().accept(this);
    Result right = x.getRhs().accept(this);
    widenArgs(left, right);
    Type resultType = left.getType().lub(right.getType());
    if (left.getType().isIntegerType() && right.getType().isIntegerType()) {
        return result(((IInteger) left.getValue()).add((IInteger) right.getValue()));
    }
    if (left.getType().isDoubleType() && right.getType().isDoubleType()) {
        return result(((IDouble) left.getValue()).add((IDouble) right.getValue()));
    }
    if (left.getType().isStringType() && right.getType().isStringType()) {
        return result(vf.string(((IString) left.getValue()).getValue()
                + ((IString) right.getValue()).getValue()));
    }
```

Lists and relations... (ctd)

```
        if (left.getType().isListType()){
                if(right.getType().isListType()) {
                    return result(resultType, ((IList) left.getValue())
                    .concat((IList) right.getValue()));
                }
                if(right.getType().isSubtypeOf(left.getType().getElementType())){
                    return result(left.getType(),
((IList)left.getValue()).append(right.getValue()));
                }
        }
        if (right.getType().isListType()){
            if(left.getType().isSubtypeOf(right.getType().getElementType())){
                return result(right.getType(),
((IList)right.getValue()).insert(left.getValue()));
            }
        }
        if (left.getType().isRelationType() && right.getType().isRelationType()) {
                return result(resultType, ((ISet) left.getValue())
                        .union((ISet) right.getValue()));
        }
```

Sets and maps... (ctd)

```
        if (left.getType().isSetType()){
            if(right.getType().isSetType()) {
                return result(resultType, ((ISet) left.getValue())
                .union((ISet) right.getValue()));
            }
            if(right.getType().isSubtypeOf(left.getType().getElementType())){
                return result(left.getType(),
((ISet)left.getValue()).insert(right.getValue()));
            }
        }
        if (right.getType().isSetType()){
            if(left.getType().isSubtypeOf(right.getType().getElementType())){
                return result(right.getType(),
((ISet)right.getValue()).insert(left.getValue()));
            }
        }
        if (left.getType().isMapType() && right.getType().isMapType()) {
            return result(resultType, ((IMap) left.getValue())
                    .join((IMap) right.getValue()));
        }
```

Tuples... (ctd)

```
if(left.getType().isTupleType() && right.getType().isTupleType()) {
        Type leftType = left.getType();
        Type rightType = right.getType();
        int leftArity = leftType.getArity();
        int rightArity = rightType.getArity();
        int newArity = leftArity + rightArity;
        Type fieldTypes[] = new Type[newArity];
        String fieldNames[] = new String[newArity];
        IValue fieldValues[] = new IValue[newArity];
        for(int i = 0; i < leftArity; i++){
            fieldTypes[i] = leftType.getFieldType(i);
            fieldNames[i] = leftType.getFieldName(i);
            fieldValues[i] = ((ITuple) left.getValue()).get(i);
        }
        for(int i = 0; i < rightArity; i++){
            fieldTypes[leftArity + i] = rightType.getFieldType(i);
            fieldNames[leftArity + i] = rightType.getFieldName(i);
            fieldValues[leftArity + i] = ((ITuple) right.getValue()).get(i);
        }
        for(int i = 0; i < newArity; i++){
            if(fieldNames[i] == null){
                fieldNames[i] = "f" + String.valueOf(i);
            }
        }
        Type newTupleType = tf.tupleType(fieldTypes, fieldNames);
        return result(newTupleType, vf.tuple(fieldValues));
    }
```

Otherwise: error

```
   throw new TypeError(
      "Operands of + have illegal types: "
      + left.getType() + ", "
      + right.getType(), x);
}
```

Not so nice

- A lot of duplication:
  - Similar if statements
- Hard to understand
  - Control flow sometimes depends on earlier side-effects
- This was just +;
  - -, *, /, >, <, >=, <=, ., o, join
  - ....

Double dispatch to the rescue

- Take inspiration from numbers in Smalltalk
- 1 + 2 is method call: 1.+(2)
- In Integer class
  - + x
    - x addInt: self
  - addInt: x
    - // do the addition

In Java

```
public interface Value {
  public Value add(Value arg);
  public Value addInt(Int arg);
  public Value addReal(Real arg);
}
```

```
public class Int implements Value {
 int n;
 public Int(int n) { this.n = n; }
 public Value add(Value arg) {
  return arg.addInt(this);
 }
 public Value addInt(Int arg) {
  return new Int(arg.n + n);
 }
 public Value addReal(Real arg) {
  return new Real(arg.f + n);
 }
}
```

```
public class Real implements Value {
 float f;
 public Real(float f) { this.f = f; }
 public Value add(Value arg) {
  return arg.addReal(this);
 }
 public Value addInt(Int arg) {
  return new Real(arg.n + f);
 }
 public Value addReal(Real arg) {
  return new Real(arg.f + f);
 }
}
```

Example

- (1).add(2) → (2).addInt(1) → 3
- (1).add(2.0) → (2.0).addInt(1) → 3.0
- (1.0).add(2.0) → (2.0).addReal(1.0) → 3.0

Result in Rascal

```
public Result<IValue> visitExpressionAddition(Addition x)
{
  Result<IValue> left = x.getLhs().accept(this);
  Result<IValue> right = x.getRhs().accept(this);

  return left.add(right,
      new EvaluatorContext(this, x));
}
```

Typechecking is dispatch

- ”Correspondence”
  - If and case statements
  - Dynamic dispatch of Java
- Complex logic has disappeared
- Dispatch handles typechecking
  - Default ”add” method in superclass Value throws TypeError

But...

- Pros
  - Adding a new overloaded implementation is as easy as adding the necessary methods
  - For each data type all relevant operator implementations are in a single class
- Cons
  - First all typechecking related to a single operator was at one place
  - Now it's scattered over each data class
- Trade-off!

Multiple perspectives

- First
  - Tangling from the perspective of data class
  - To understand how + works on integers you have to understand complex control-flow
- Now
  - Scattering from the perspective of the operations
  - To understand the evaluation of an operation you have to look at many classes

Conclusion

Conclusion

Concluding

- Duplication and tangling detrimental to quality
- Abstraction is the key mechanism
- Overuse of abstraction has its own problems
- Patterns may provide a useful middle ground
- However, trade-offs remain.