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

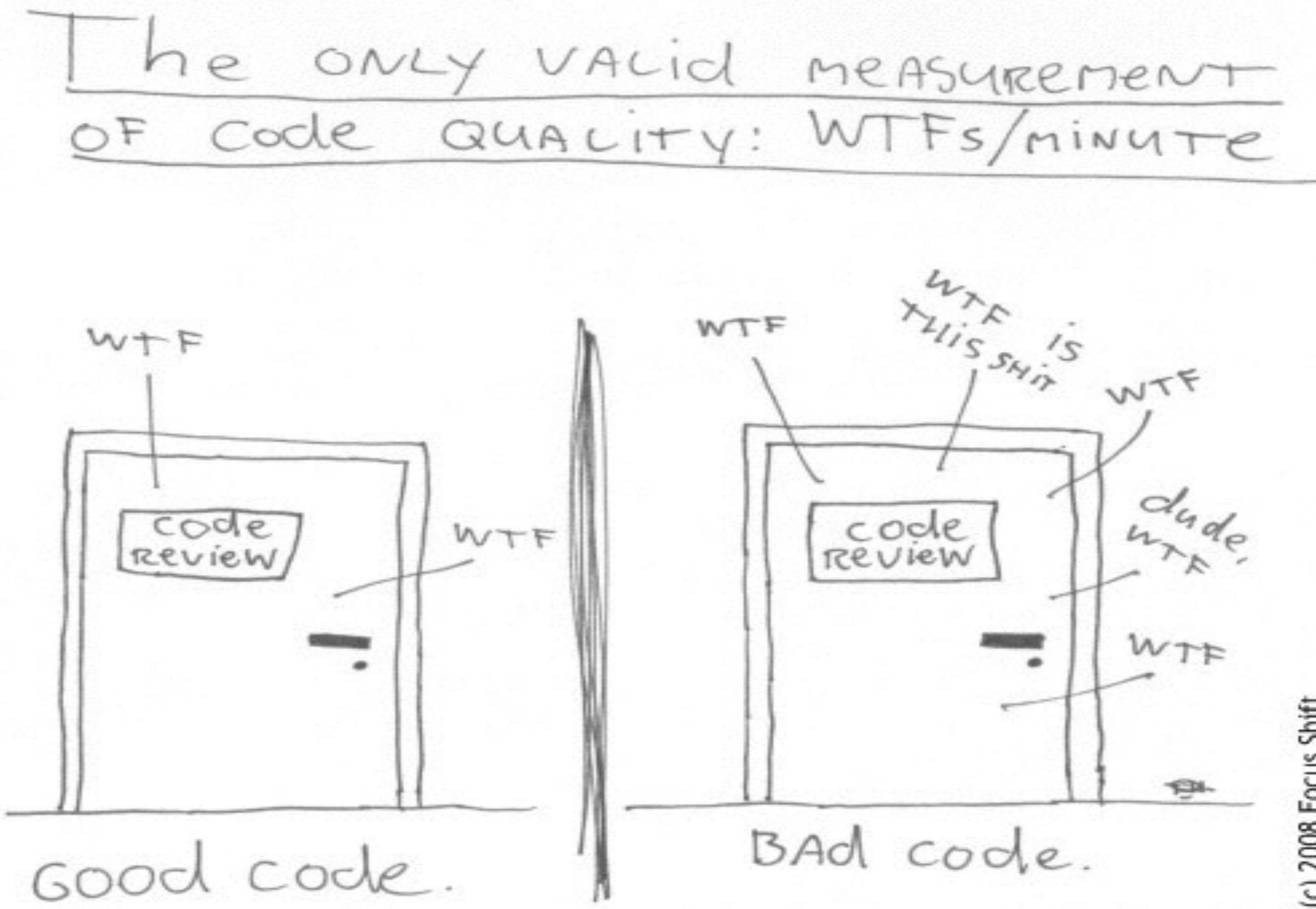
- Evolution is important from the start
  - Software is read much more than it is written
  - Understanding is a crucial component
  - Programming is an act of communication
- We can generalize this:
  - As soon as the first line of code is written, programming becomes maintenance
- Quality code is
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


The only valid measurement of code quality: WTFs/minute
WTF
code review
WTF
Good code.
WTF
WTF is this shit
WTF
dude, WTF
code review
WTF
BAd code.
(c) 2008 Focus Shift

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

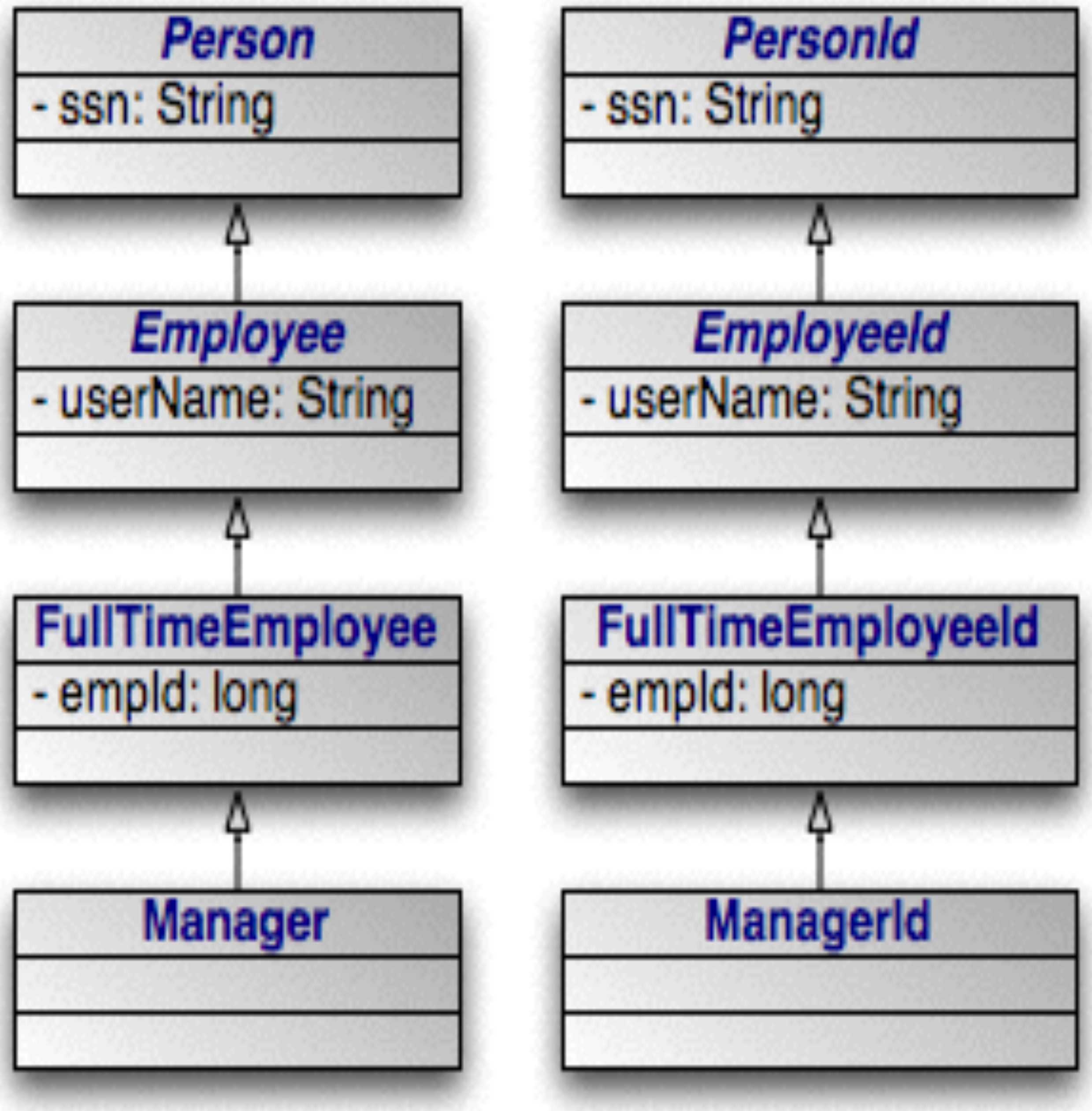
- copy-pasted code (clones)
- parallel inheritance hierarchies
- Implicit coupling
- sequence of calls where order matters
- similar parameter lists
- conventions
- idioms

Copy-pasted code

```
String error = "";
if (!containsNode(source)) {
    if (source == null) {
        error += "source is null";
    } else {
        error += "source : " + source.getId() + " ," + source
    }
    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
```

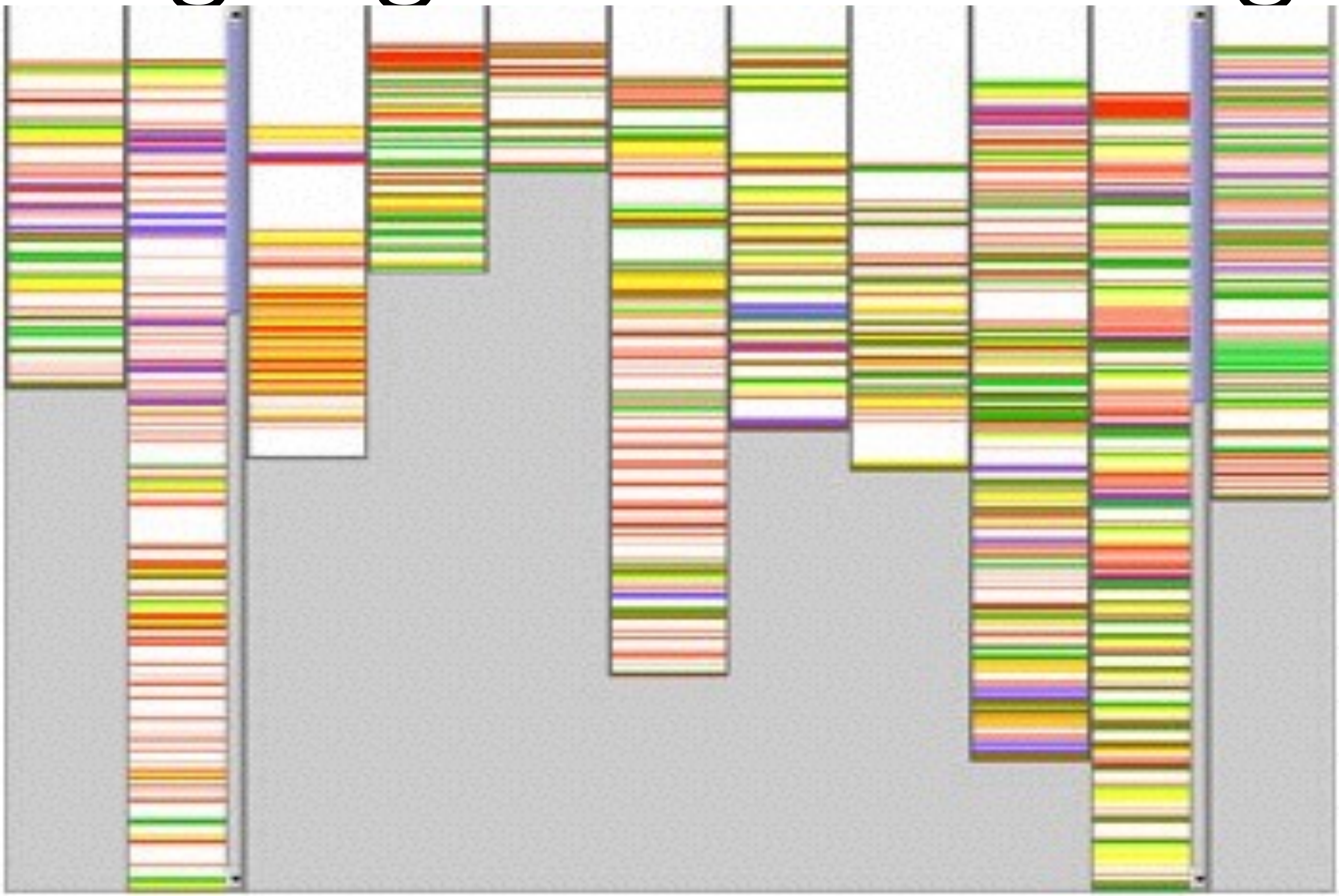
Tangling

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 illustrate the topics of duplication and tangling

m_lineNumbers is dependent on m_sourceLines yet they are maintained separately

```java
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...

```
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

Another example of tangling

```
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:

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

  - join contains the loop complexity just for joining

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?

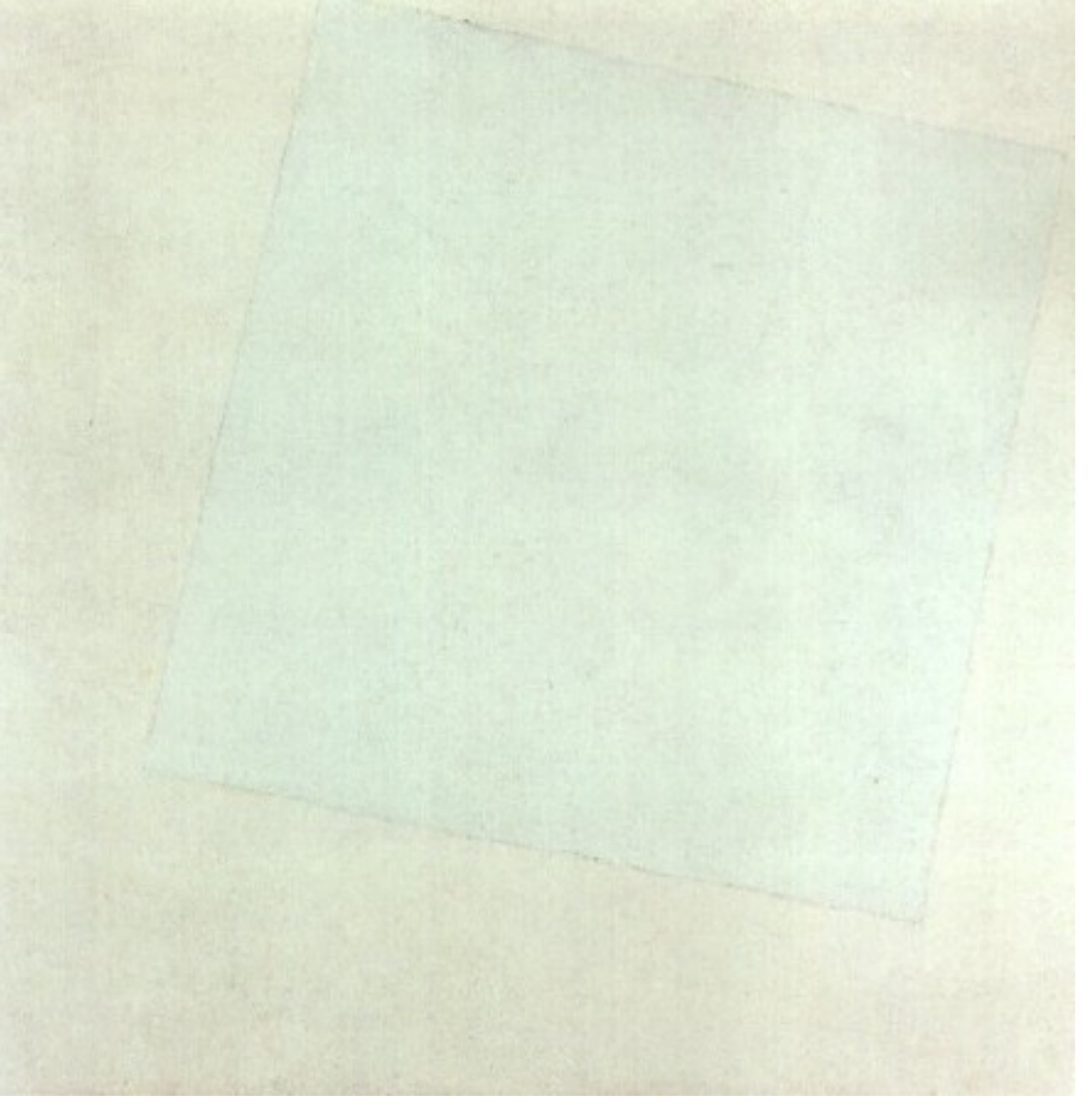
Problems duplication & tangling

- 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:

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

  - (From Richard P. Gabriel, ”Patterns of Software”)

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

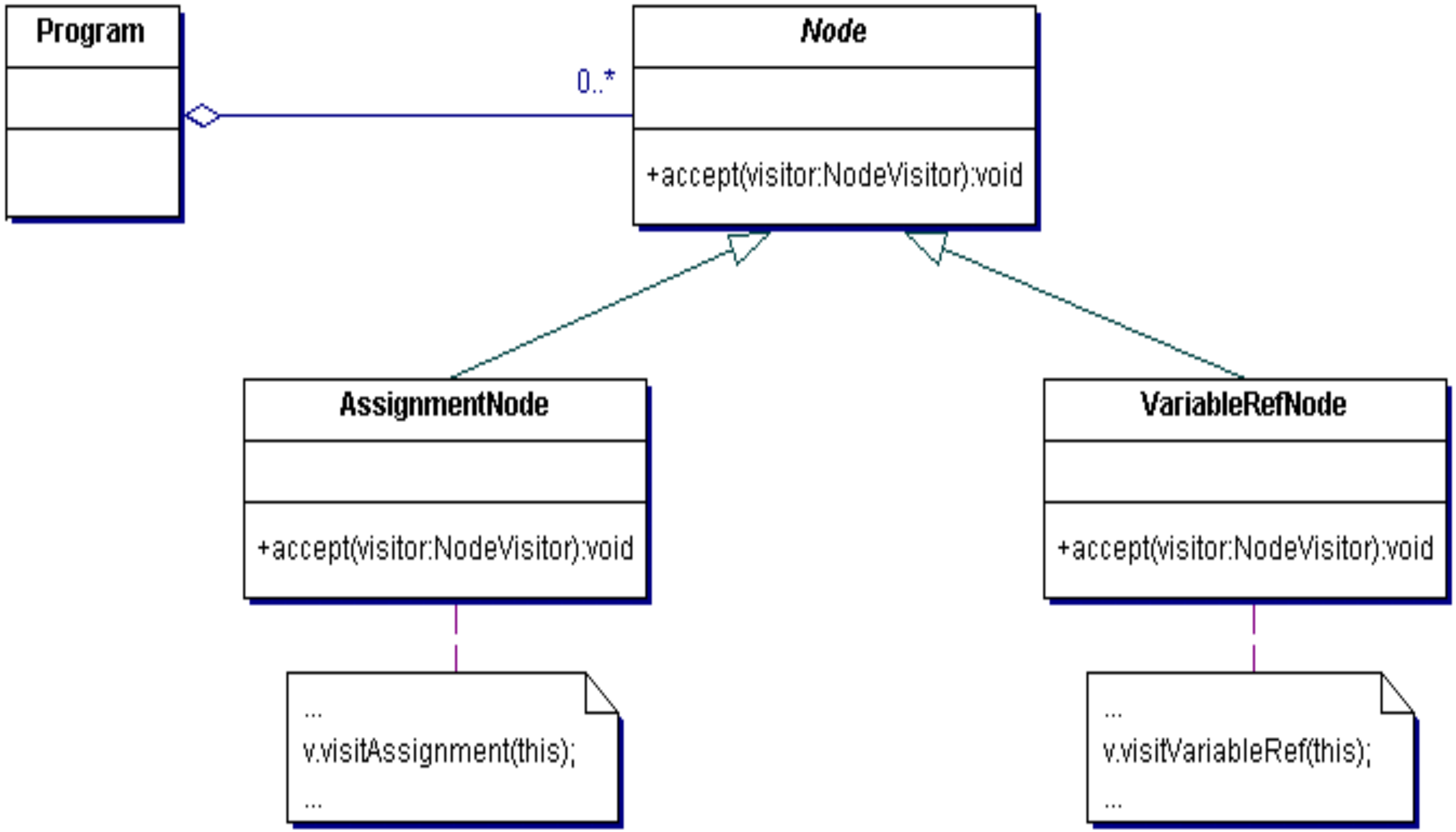
Example of refactoring trade-off

- 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()));
      }
```

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

```
        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()));
        }
```

```
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.

Kent Beck
@KentBeck

Following

first you learn the value of abstraction, then you learn the cost of abstraction, then you're ready to engineer

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