CS 635 Advanced Object-Oriented Design & Programming
Spring Semester, 2009
Doc 12 Object Coupling & Metrics
March 3, 2010

References

Object Coupling and Object Cohesion, chapter 7 of Essays on Object-Oriented Software Engineering, Vol. 1, Berard, Prentice-Hall, 1993, pp 92-111

Cyclomatic complexity, http://en.wikipedia.org/wiki/Cyclomatic_complexity

Lines of Code, http://en.wikipedia.org/wiki/Source_lines_of_code

Eclipse Metrics, http://metrics.sourceforge.net/

Specialization Index, http://semmle.com/documentation/semmlecode-glossary/specialization-index-of-a-type/

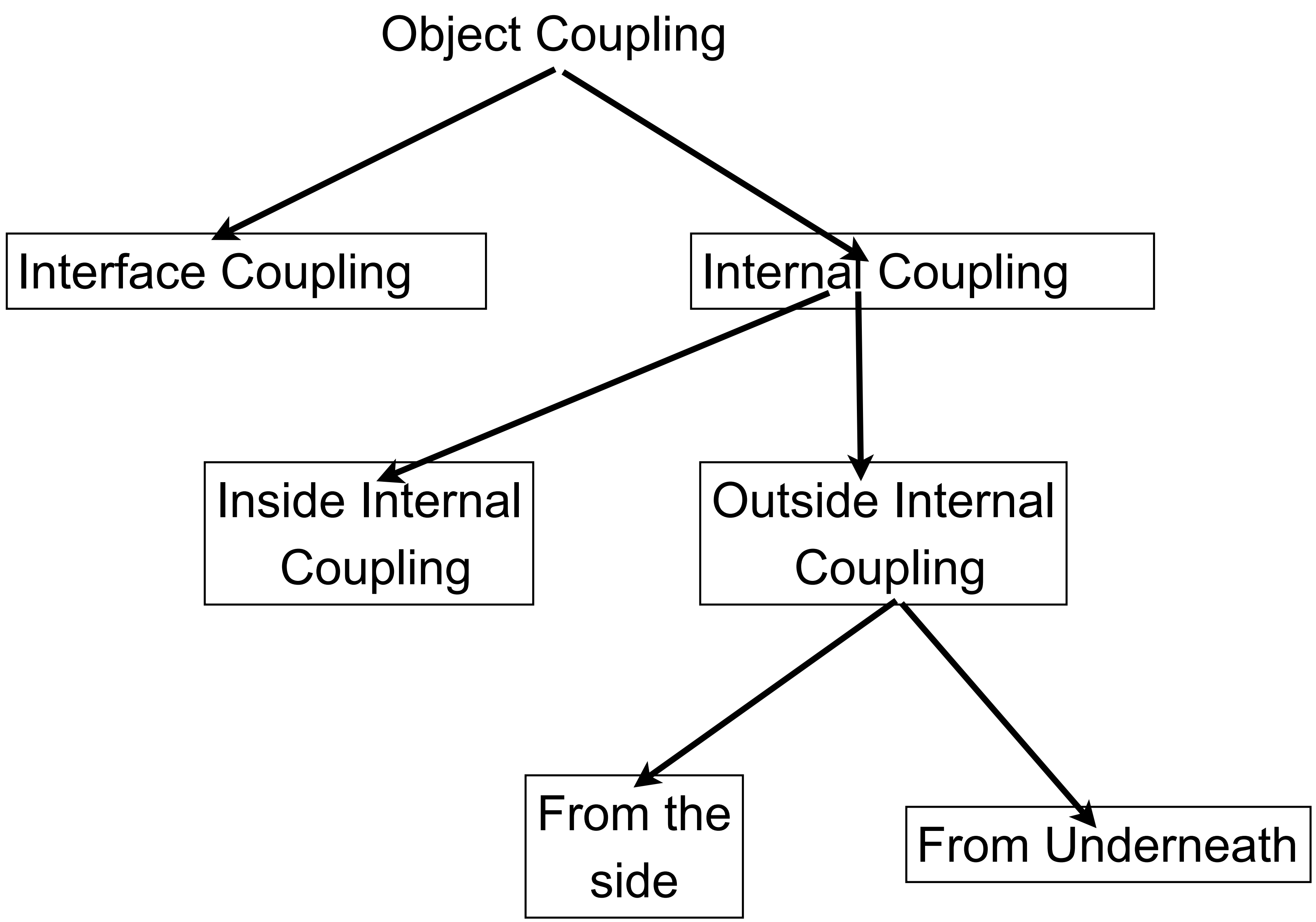
OO Design Quality Metrics: An Analysis of Dependencies, Robert Martin, http://www.objectmentor.com/resources/articles/oodmetrc.pdf

Source code for twitter4j, http://yusuke.homeip.net/twitter4j/en/index.html

Eclipse Metrics Plugin, http://eclipse-metrics.sourceforge.net/

Object-Oriented Metrics: Measures of Complexity, Brian Henderson-Sellers, Prentice Hall, 1996

Object Coupling


Object Coupling
Interface Coupling
Internal Coupling
Inside Internal Coupling
Outside Internal Coupling
From the side
From Underneath

Internal Coupling & Cohesion

Internal Coupling

Physical relationships among the items that comprise an object

Cohesion

Logical relationships among the items that comprise an object

Interface Coupling

One object refers to another specific object, and the original object makes direct references to one or more items in the specific object's public interface

Includes module coupling already covered

Weakest form of object coupling, but has wide variation

Issues

- Object abstraction decoupling
- Selector decoupling
- Constructor decoupling
- Iterator decoupling

Object Abstraction Decoupling

Assumptions that one object makes about a category of other objects are isolated and used as parameters to instantiate the original object.

C++/Java 1.5 Example

```
class LinkedListCell {
        int cellItem;
        LinkedListCell* next;

        // code can now use fact that cellItem is an int
        if ( cellItem == 5 ) print( "We Win" );
}

template <class type>
class LinkedListCell#2 {
        type cellItem;
        LinkedListCell* next;

        // code does not know the type, it is just a cell item,
        // it becomes an abstraction
}
```

Selector Decoupling

Counter Example

```
class Counter{
	int count = 0;

	public void increment()	{  count++; }
	public void reset()		{ count = 0; }
	public void display() {
		Java Swing code to display the counter
		in a slider bar
}
```

Counter

Selector Decoupled

```
class Counter{
	int count = 0;

	public void increment()	{  count++; }
	public void reset()		{ count = 0; }
	public int count()		{return count;}
	public String toString()	{return String.valueOf( count );}
}
```

Primitive Methods

Any method that cannot be implemented simply, efficiently, and reliably without knowledge of the underlying implementation of the object

Functionally cohesive, they perform a single specific function

Small, seldom exceed five "lines of code"

Types

Selectors (get operations)
Constructors (not the same as class constructors)
Iterators

Composite method

Any method constructed from two or more primitive methods

sometimes from different objects

Selectors

Return state information about their encapsulated object and
Do not alter the state of their encapsulated object

```
public void display()   {
        Swing GUI code to display the counter
}
```

Selector
decoupling

```
public String toString() {return String.valueOf( count );}
```

Primitive Objects

Primitive objects are objects that are both:

- Defined in the standard for the implementation language
- Globally known

Primitive objects don't count in coupling with other objects

Why not?

Constructors

Operations that construct a new, or altered version of an object

```
class Calendar {
	public void getMonth( from where, or what) { blah }
}

class Calendar {
	public static Calendar fromString( String date ) { blah}
}
```

Composite Object

Object **conceptually** composed of two or more objects

Heterogeneous Composite Object

Object **conceptually** composed from objects which are not all **conceptually** the same

```
class Date{
    int year;
    int month;
    int day;
}
```

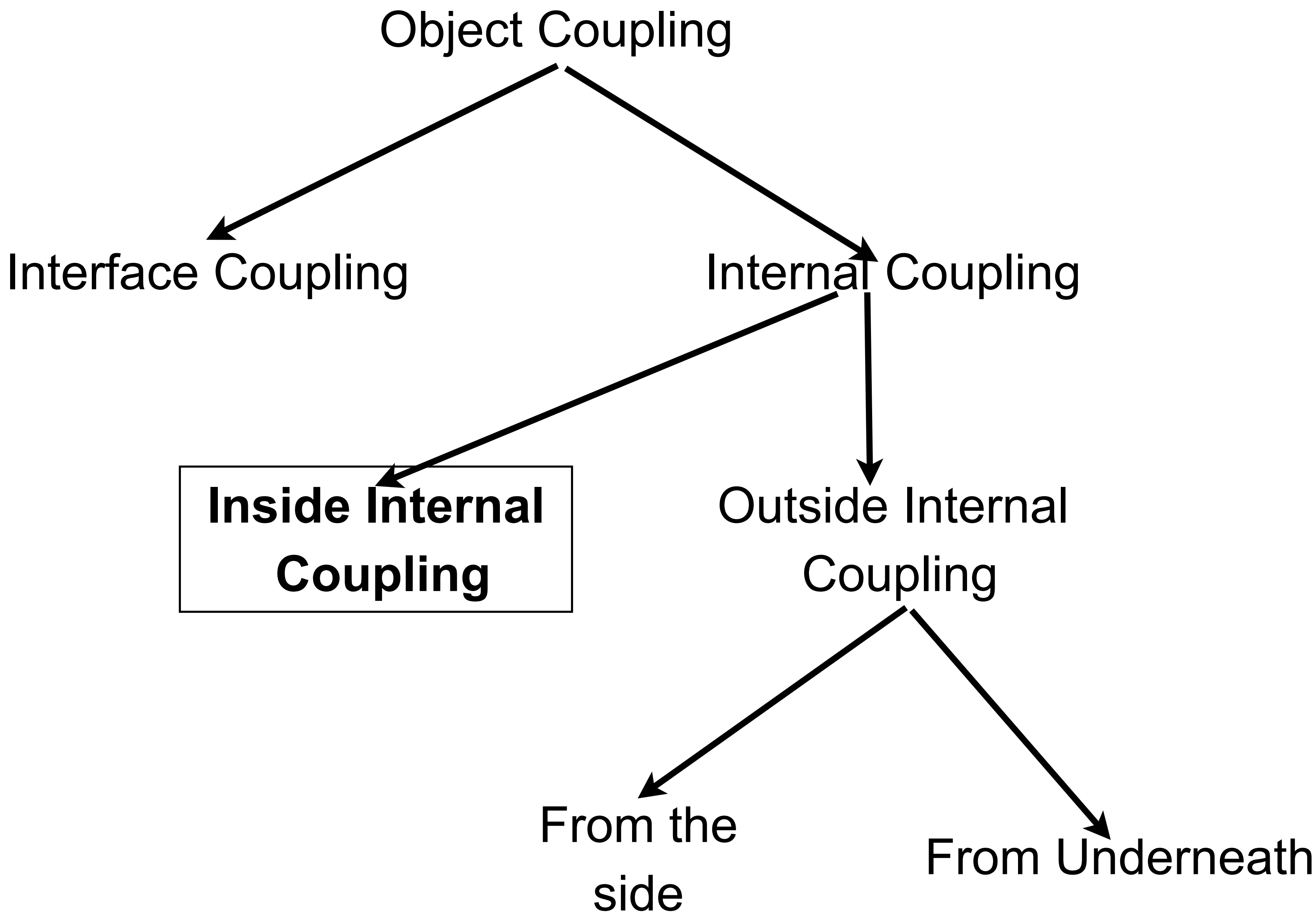
Homogeneous Composite Object

Object **conceptually** composed from objects which are all **conceptually** the same

list of names - each item is a member of the same general category of object – a name

Iterator

Allows the user to visit all the nodes in a homogeneous composite object and to perform some user-supplied operation at each node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From Underneath

Inside Internal Object Coupling

Coupling between state and operations of an object

The big issue: Accessing state

Changing the structure of the state of an object requires changing all operations that access the state including operations in subclasses

Solution: Access state via access operations

C++ implementation

Provide private functions to access and change each data member

Outside Internal Coupling from Underneath

Coupling between a class and subclass involving private state and private operations

Major Issues

Access to inherited state

- Direct access to inherited state
- Access via operations

Unwanted Inheritance

- Parent class may have operations and state not needed by subclass

Outside Internal Coupling from the Side

Class A accesses private state or private operations of class B

Class A and B are not related via inheritance

Main causes

Using non-object-oriented languages
Special language "features"
C++ friends

Metrics

Metrics

DeMarco's Principle

Effort moves toward whatever is measured

The Swedish Army Dictum

When the map and the territory don't agree, always believe the territory.

Eclipse Metrics 1.3.6

Eclipse plugin

Docs

http://metrics.sourceforge.net/

Source Forge Site

http://sourceforge.net/projects/metrics

Generates about 20 metrics
Displays result in tables in Eclipse
Generates dependency graphs

Eclipse Metrics Plugin

http://eclipse-metrics.sourceforge.net/

Author: Lance Walton

Generates about same metrics as Metrics 1.3.6
Exports results to html or csv
Generates table and graphs

Lines Of Code

SLOC

Rough measure of size

Effort is highly correlated with SLOC

Physical SLOC

- Code + comments + blank lines
- Not count blank lines over 25% of a section
- Eclipse Metrics - calls this Total Lines of Code (TLOC)

Logical SLOC

- Just lines of actual code
- Eclipse Metrics
  - calls this Method Lines of Code (MLOC)
  - But only code inside method bodies

Basic COCOMO

Software Cost Estimation Model

Effort Applied = $a(KLOC)^b$ [man-months]

Type	a	b
Organic	2.4	1.05
Semi-detached	3.0	1.12
Embedded	3.6	1.20

Organic

Small team, less than rigid requirements

Semi-detached

Medium teams,

Embedded

Tight constraints

Example - 2 KLOC Embedded

Effort Applied = $a(KLOC)^b$ [man-months]

Effort Applied = $3.6*(2)^{1.20}$ = 8.3 man-months

Problems with LOC

Language differences

Hand written code verses autogenerated code

Programmer variation

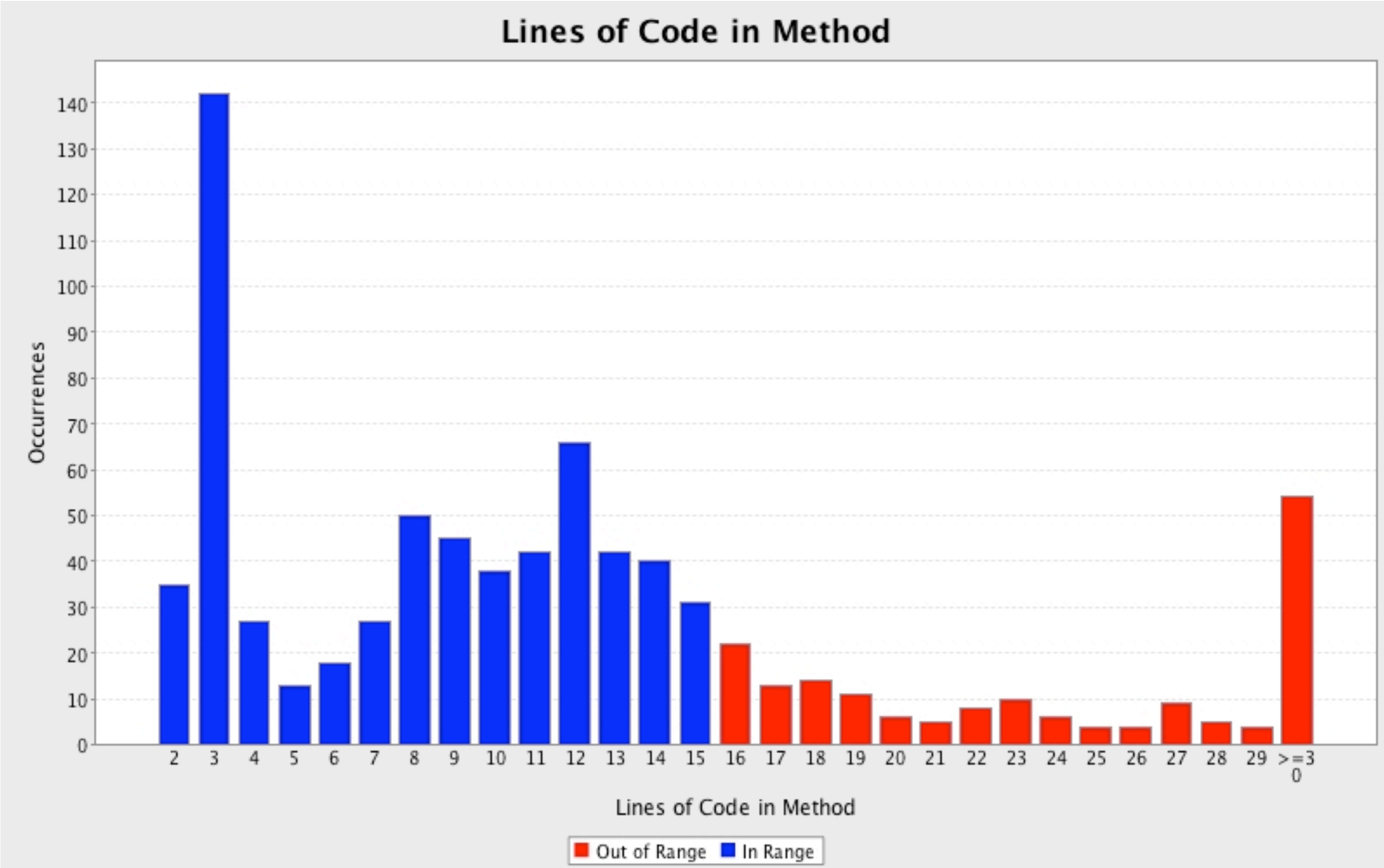
Defining and counting LOC

Coding accounts for about 35% of overall effort

Twitter4j Example

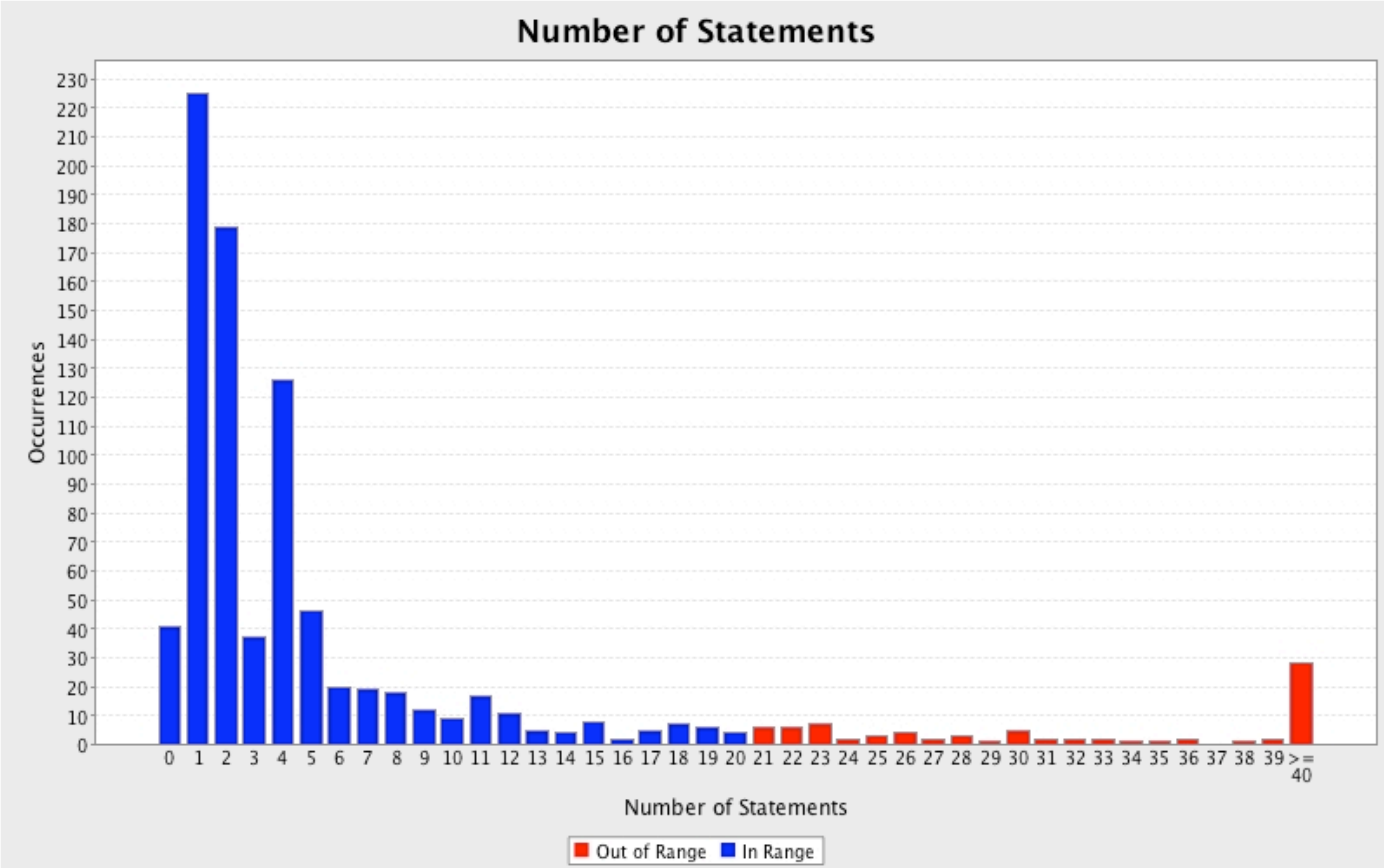
Metric	Total	Mean	Std. Dev.	Maximum
▼ Total Lines of Code	8161			
▼ java	6908			
▶ twitter4j.org.json	3193			
▶ twitter4j	2489			
▶ twitter4j.http	894			
▶ twitter4j.examples	332			
▼ java	1253			
▶ twitter4j	1115			
▶ twitter4j.http	138			
▼ Method Lines of Code (avg/max per method)	5854	7.254	22.032	518
▼ java	4899	6.949	22.726	518
▶ twitter4j.org.json	2759	14.295	41.037	518
▶ twitter4j.http	557	5.626	10.117	76
▶ twitter4j.examples	240	26.667	14.877	57
▶ twitter4j	1343	3.324	4.324	29
▼ java	955	9.363	16.298	123
▶ twitter4j	853	9.374	16.949	123
▶ twitter4j.http	102	9.273	9.304	33

Eclipse Metrics Plugin



Metrics 1.3.6 finds 8161 total lines of code. Eclipse Metrics Plugin finds 11113 total lines of code as it does not remove large segments of white space

Eclipse Metrics Plugin



Number of statements = Logical LOC. Not the difference from the graph on the previous slide.

More Size Metrics

Number of Packages

Number of Interfaces

Number of classes per Package

Metric	Total	Mean	Std. Dev.	Maximum
▼ Number of Classes (avg/max per packageFragment	58	9.667	5.558	18
▶ java	49	12.25	4.815	18
▶ java	9	4.5	2.5	7

The number of interfaces might be considered a metric related to abstraction. Although (number of interfaces / number of class) per package might be a better metric. At least in Java. Abstraction is a better metric for this.

McCabe Cyclomatic Complexity

Number of linearly independent paths through a program

From graph theory

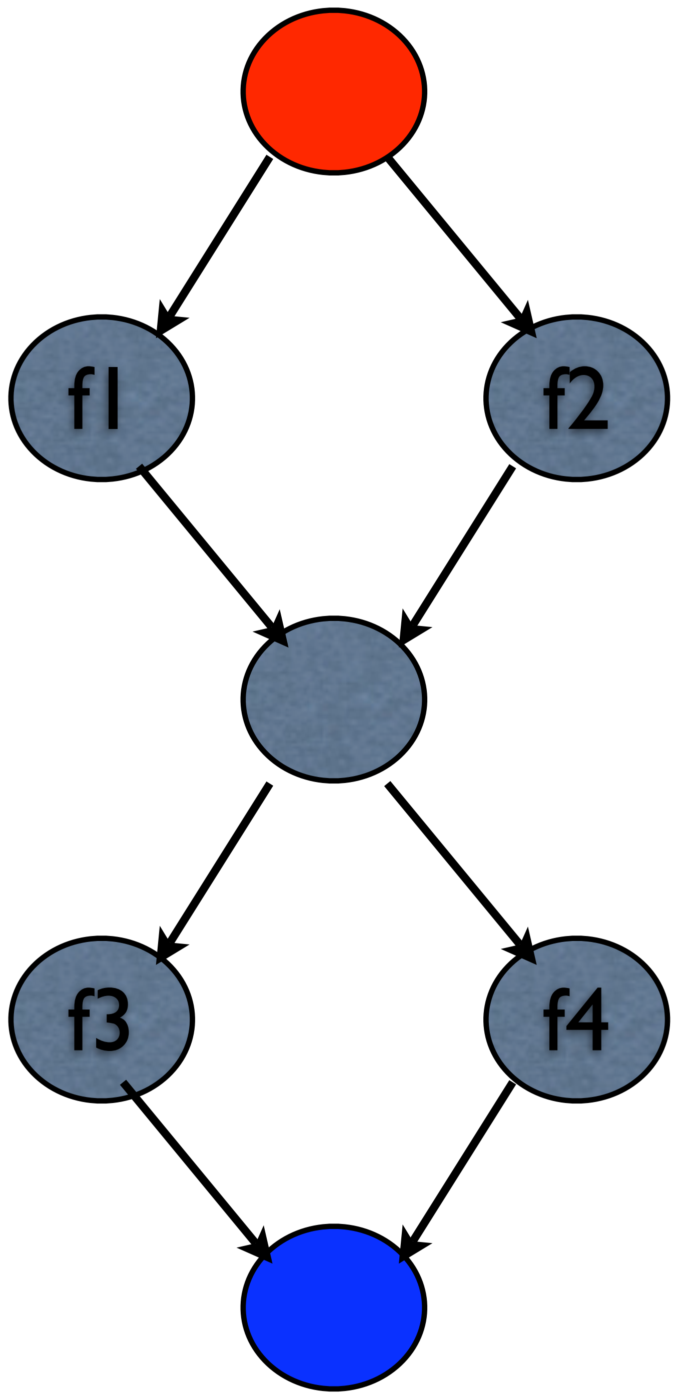
$$M = E - N + 2P$$

M = cyclomatic complexity
E = the number of edges of the graph
N = the number of nodes of the graph
P = the number of connected components.

Example

```
if( c1() )
  f1();
else
  f2();

if( c2() )
  f3();
else
  f4();
```



N = 7
E = 8
M = 8 - 7 + 2*1 = 3

Example From http://en.wikipedia.org/wiki/Cyclomatic_complexity

What does it tell us?

branch coverage ≤ cyclomatic complexity ≤ number of paths

Cyclomatic Complexity

Is an upper bound for the number of test cases that are necessary to achieve a complete branch coverage

Is a lower bound for the number of paths through the code

Cyclomatic Complexity & Quality

Higher Cyclomatic Complexity might indicate lower cohesion

- One study indicated it is better indicator than metrics designed for cohesion

Some evidence that higher Cyclomatic Complexity implies more bugs

NIST Structured Testing methodology

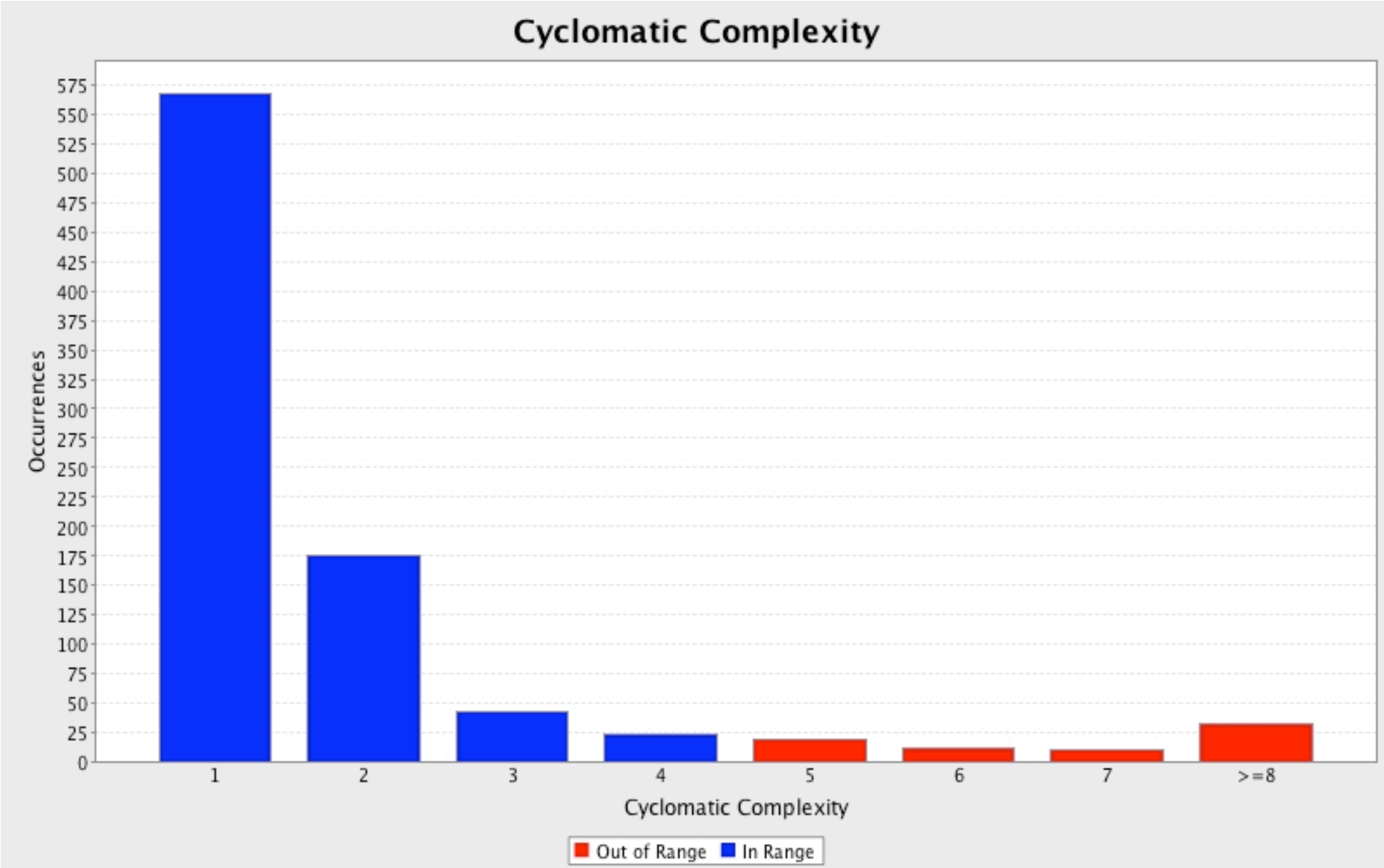
Split modules with cyclomatic complexity greater than 10

It may be appropriate in some circumstances to permit modules with a complexity as high as 15

Eclipse Metrics 1.3.6

Metric	Total	Mean	Std. Dev.	Maximum
▼ McCabe Cyclomatic Complexity (avg/max per method)		2.15	3.569	46
▼ java		2.288	3.787	46
▼ twitter4j.org.json		4.212	5.9	46
▶ JSONML.java		10.286	15.229	46
▶ XML.java		11.5	12.42	36
▶ XMLTokener.java		12.143	9.463	28
▶ Test.java		21	0	21
▶ JSONObject.java		3.552	4.306	19
▶ JSONTokener.java		4.688	3.531	14
▶ HTTP.java		7.5	4.5	12
▶ JSONArray.java		2.2	2.04	12
▶ CDL.java		4.3	3.132	11
▶ HTTPTokener.java		5.5	4.5	10
▶ JSONWriter.java		2.786	2.042	8
▶ Cookie.java		5.75	1.299	7
▶ CookieList.java		3	1	4
▶ JSONStringer.java		1.5	0.5	2
▶ JSONException.java		1	0	1
JSONString.java		0	0	
▶ twitter4j		1.408	2.099	29
▶ twitter4j.http		2.03	2.359	16
▶ twitter4j.examples		3.333	1.333	6
▶ java		1.196	0.805	7

Eclipse Metrics Plugin



Weighted Methods per Class (WMC)

Sum of the McCabe Cyclomatic Complexity for all methods in a class

Metric	Total	Mean	Std. Dev.	Maximum
▼ Weighted methods per Class (avg/max per type)	1735	29.914	41.206	235
▼ java	1613	32.918	43.423	235
▶ twitter4j.org.json	813	50.812	57.857	235
▶ twitter4j	569	31.611	33.705	140
▶ twitter4j.http	201	25.125	29.464	100
▶ twitter4j.examples	30	4.286	3.01	11
▼ java	122	13.556	18.963	56
▶ twitter4j	110	15.714	20.899	56
▶ twitter4j.http	12	6	4	10

Basic Class Metrics

Number of methods per class
Number of static methods per class
Number of attributes(fields) per class
Number of static attributes per class

Number of parameters per method

Twitter4j Example

Metric	Total	Mean	Std. Dev.	Maximum
▼ Number of Methods (avg/max per type)	742	12.793	21.461	111
▼ java	641	13.082	22.274	111
▶ twitter4j	398	22.111	29.04	111
▶ twitter4j.org.json	151	9.438	16.948	55
▶ twitter4j.http	90	11.25	14.481	49
▶ twitter4j.examples	2	0.286	0.7	2
▶ java	101	11.222	16.253	52
▼ Number of Parameters (avg/max per method)		0.954	0.901	6
▼ java		1.033	0.918	6
▶ twitter4j		1.017	0.999	6
▶ twitter4j.http		0.97	1.039	6
▶ twitter4j.org.json		1.104	0.652	3
▶ twitter4j.examples		0.889	0.314	1
▶ java		0.412	0.512	2

Nested Block Depth

The depth of nested blocks of code

Depth = 2

```
public static JSONObject toJSONObject(String string) throws JSONException {
    JSONObject o = new JSONObject();
    JSONTokener x = new JSONTokener(string);
    while (x.more()) {
        String name = Cookie.unescape(x.nextTo('='));
        x.next('=');
        o.put(name, Cookie.unescape(x.nextTo(';')));
        x.next();
    }
    return o;
}
```

Twitter4j Example

Metric	Total	Mean	Std. Dev.	Maximum
Nested Block Depth (avg/max per method)		1.489	0.938	8
java		1.549	0.984	8
twitter4j.org.json		2.047	1.348	8
JSONML.java		3.143	2.642	8
XML.java		3.833	2.672	8
JSONObject.java		1.881	1.153	6
CDL.java		2.5	1.5	5
Cookie.java		3.25	0.829	4
JSONTokener.java		2.375	1.053	4
CookieList.java		3	1	4
HTTPTokener.java		2.5	1.5	4
XMLTokener.java		2.857	0.833	4
JSONArray.java		1.58	0.851	4
JSONWriter.java		1.786	1.013	4
Test.java		3	0	3
HTTP.java		2.5	0.5	3
JSONException.java		1	0	1
JSONStringer.java		1	0	1
JSONString.java		0	0	
twitter4j.examples		3	1.054	5
twitter4j.http		1.465	0.868	5
twitter4j		1.3	0.619	4
java		1.078	0.269	2

Some Inheritance Metrics

Depth of Inheritance Tree (DIT)

Distance from class Object in the inheritance hierarchy

Number of Children

Total number of direct subclasses of a class

Number of Overridden Methods (NORM)

Specialization Index

NORM * DIT / number of methods

If greater than 5 likely that superclass abstraction has a problem

Lack of Cohesion in Methods (LCOM)

$$\frac{\langle r \rangle - |M|}{1 - |M|}$$

M be the set of methods defined by the class

F be the set of fields defined by the class

r(f) be the number of methods that access field f, where f is a member of F

<r> be the mean of r(f) over F.

High Cohesion

When each method accesses all fields

$\langle r \rangle = |M|$

LCOM = 0

Low Cohesion

When each method accesses one fields

$\langle r \rangle = 1$

LCOM = 1

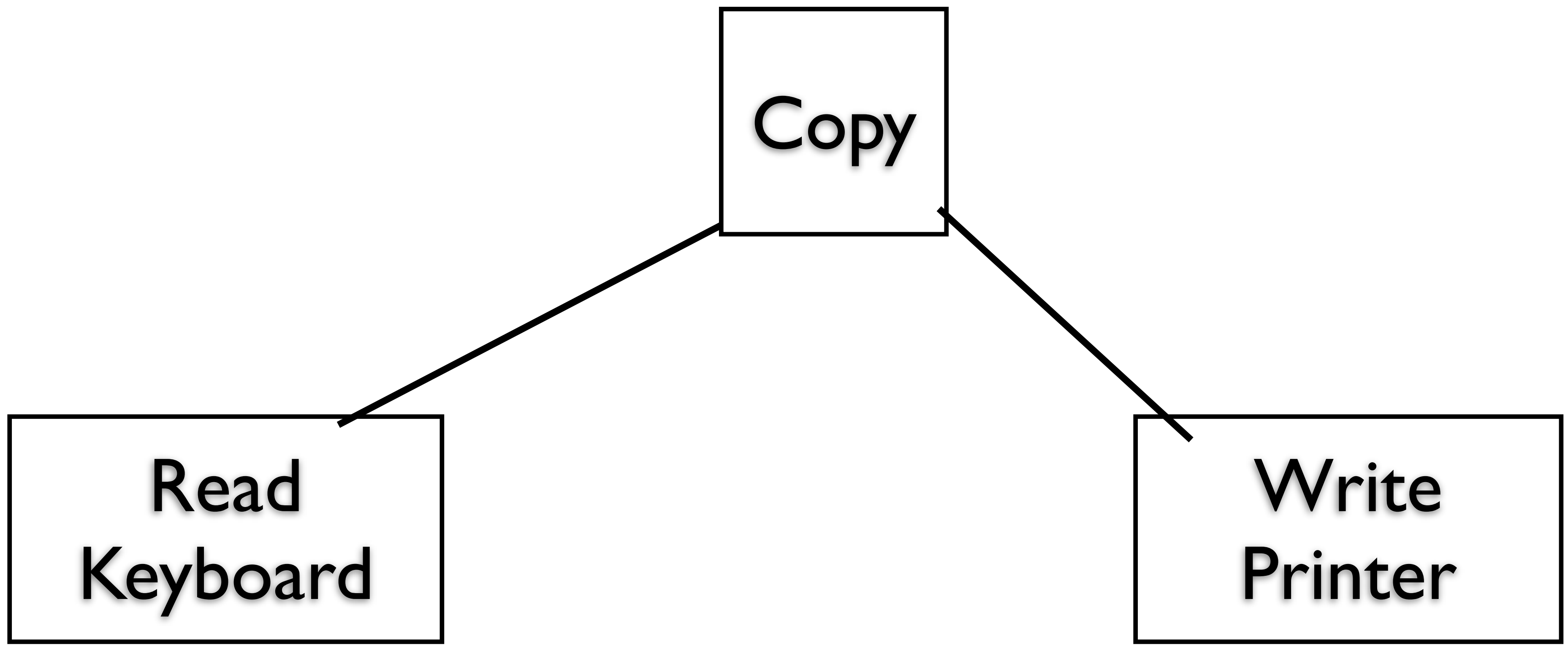
Some people recommend that you create an accessor for each field. When you need to access the field in the class you use the accessor, rather than access the field directly. This will give you a LCOM of 1. One has to be careful with metrics.

Lack of Cohesion of Methods

Metric	Total	Mean	Std. Dev.	Maximum
▼ Lack of Cohesion of Methods (avg/max per type)		0.26	0.342	0.938
▼ java		0.25	0.336	0.938
▶ twitter4j.http		0.358	0.348	0.938
▶ twitter4j		0.461	0.359	0.902
▶ twitter4j.org.json		0.056	0.15	0.5
▶ twitter4j.examples		0.024	0.058	0.167
▶ java		0.319	0.37	0.905

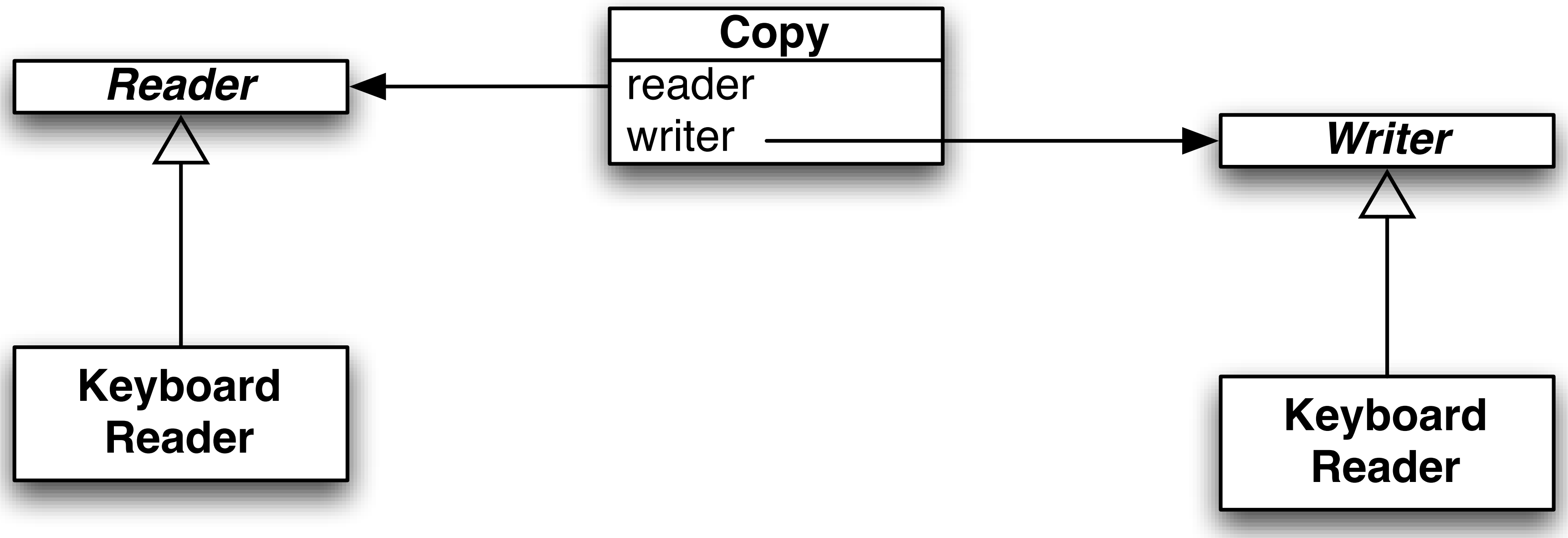
Metrics for Stable Code

Dependencies make code rigid, fragile and difficult to reuse



Consider a program that copies characters typed on a keyboard to a printer. Rest of lecture is from OO Design Quality Metrics: An Analysis of Dependencies, Robert Martin, http://www.objectmentor.com/resources/articles/oodmetrc.pdf

Flexible version



Have dependencies on Reader/Writer classes
But these classes are stable

Main Idea

When code depends on other classes, changes to those classes can force the code to change

The fewer classes code depends on the stabler the code is

Class Categories

Group of highly cohesive classes that

1. The classes within a category are closed together against any force of change

   If one class must change, all classes are likely to change

2. The classes within a category are reused together

3. The classes within a category share some common function or achieve some common goal

Dependency Metrics

Afferent Couplings (Ca)

The number of classes outside this category that depend upon classes within this category

Efferent Couplings (Ce)

The number of classes inside this category that depend upon classes outside this category

Instability (I)

$$\frac{Ce}{Ca+Ce}$$

I = 0 means a category is maximally stable

I = 1 means a category is maximally instable

Instabilty Twitter4j Example

Metric	Total	Mean	Std. Dev.	Maximum
▼ Instability (avg/max per packageFragment)		0.645	0.35	1
▼ java		0.51	0.354	1
twitter4j.examples	1			
twitter4j	0.538			
twitter4j.http	0.5			
twitter4j.org.json	0			
▼ java		0.917	0.083	1
twitter4j.http	1			
twitter4j	0.833			

How to be flexible and stable?

Use abstract classes

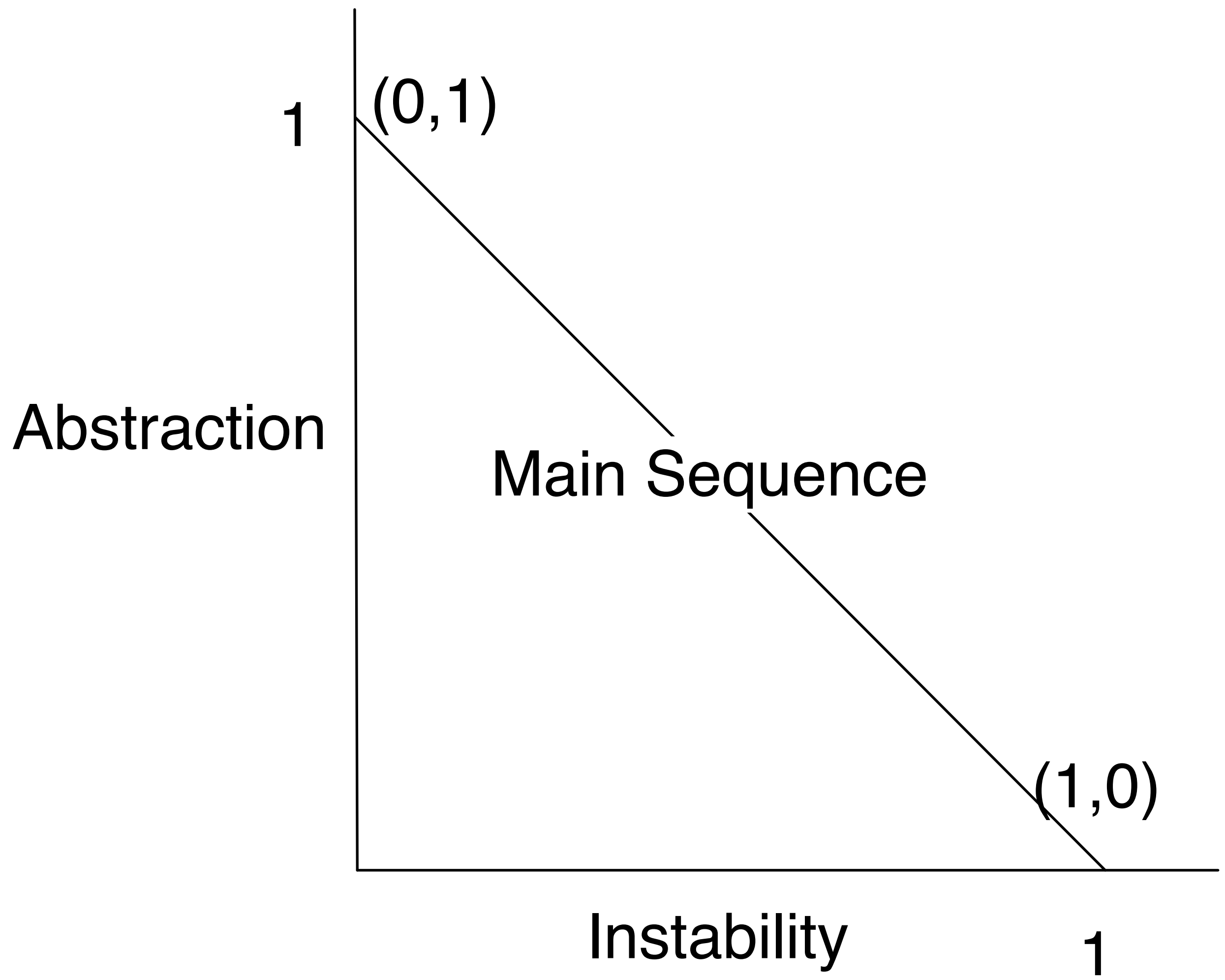
Abstractness (A)

$$\frac{\text{\# of abstract classes in category}}{\text{total \# of classes in category}}$$

A = 1, all classes are abstract

A = 0, all classes are concrete

Main Sequence



Distance From Main Sequence

$$Dn = | A + I - 1 |$$

Dn = 0 , category is on the main sequence

Dn = 1, category is far from main sequence

Values not near zero suggest restructuring the category

Twitter4j Example

Metric	Total	Mean	Std. Dev.	Maximum
▼ Normalized Distance (avg/max per packageFragment)		0.327	0.329	0.941
▼ java		0.449	0.337	0.941
twitter4j.org.json	0.941			
twitter4j.http	0.5			
twitter4j	0.356			
twitter4j.examples	0			
▼ java		0.083	0.083	0.167
twitter4j	0.167			
twitter4j.http	0			