CS 635 Advanced Object-Oriented Design & Programming
Fall Semester, 2021
Doc 13 Cohesion, Metrics
Oct 15, 2020

Reference

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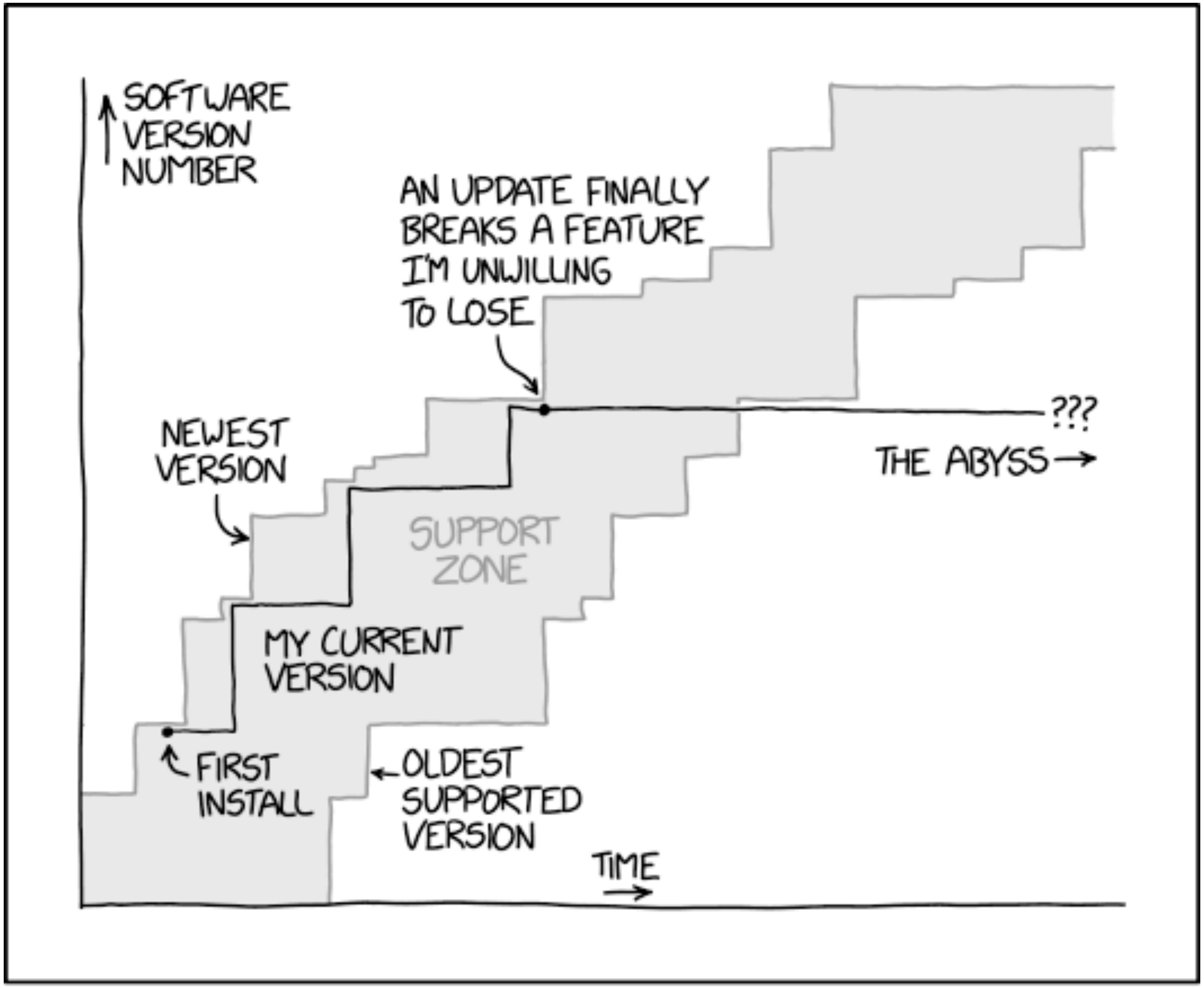


ALL SOFTWARE IS SOFTWARE AS A SERVICE.

Cohesion

Cohesion

"Cohesion is the degree to which the tasks performed by a single module are functionally related."

IEEE, 1983

"Cohesion is the "glue" that holds a module together. It can be thought of as the type of association among the component elements of a module. Generally, one wants the highest level of cohesion possible."

Bergland, 1981

"A software component is said to exhibit a high degree of cohesion if the elements in that unit exhibit a high degree of functional relatedness. This means that each element in the program unit should be essential for that unit to achieve its purpose."

Sommerville, 1989

Types of Module Cohesion

Coincidental (worst)

Logical

Temporal

Procedural

Communication

Sequential

Functional (best)

Coincidental Cohesion

Little or no constructive relationship among the elements of the module

Common Object Occurrence

Object does not represent any single object-oriented concept

Collection of commonly used source code as a class inherited via multiple inheritance

```
class Rous{
   public static int findPattern( String text, String pattern) { // blah}

   public static int average( Vector numbers ) { // blah}

   public static OutputStream openFile( String fileName ){ // blah}
   }
```

Logical Cohesion

Module performs a set of related functions, one of which is selected via function parameter when calling the module

Cure – Isolate each function into separate operations

```
public void sample( int flag ){
   switch ( flag ){
      case ON:
         // bunch of on stuff
         break;
      case OFF:
         // bunch of off stuff
         break;
      case CLOSE:
         // bunch of close stuff
         break;
      case COLOR:
         // bunch of color stuff
         break;
   }
```

Temporal Cohesion

Elements are grouped into a module because they are all processed within the same limited time period

Common example

"Initialization" modules that provide default values for objects
"End of Job" modules that clean up

```
procedure initializeData() {
   font = "times";
   windowSize = "200,400";
   foo.name = "Not Set";
   foo.size = 12;
   foo.location = "/usr/local/lib/java";
   }
```

Temporal Cohesion

Cure
Each object should have a constructor and destructor

How is this better?

Procedural Cohesion

Groups processing elements based on procedural or algorithmic relationships

Procedural modules are application specific

In context the module seems reasonable

Outside the context modules seem strange and very hard to understand

Can not understand module without understanding the program and the conditions existing when module is called

Makes module hard to modify, understand

Procedural Cohesion

```
class LinkedList {

  public boolean add(String item ) { blah }

  public Object get(int index) { blah }

  public Iterator iterator() { blah}

  public Object[] studentsOnProbabation() { blah }
}
```

Class Builder verse Program writer

Communication Cohesion

Operations of a module all operate upon the same input data set and/or produce the same output data

Cure - Isolate each element into separate modules

Rarely occurs in object-oriented systems due to polymorphism (overloading)

Sequential Cohesion

Sequential association the type in which the output data from one processing element serve as input data for the next processing element

A module that performs multiple sequential functions where the sequential relationship among all of the functions is implied by the problems or application statement and where there is a data relationship among all of the functions

Cure – Decompose into smaller modules

Functional Cohesion

If the operations of a module can be collectively described as a single specific function in a coherent way, the module has functional cohesion

If not, the module has lower type of cohesion

In an object-oriented system:

- Each operation in public interface of an object should be functional cohesive
- Each object should represent a single cohesive concept

Informational Strength Cohesion

Myers states:

"The purpose of an informational-strength module is to hide some concept, data structure, or resource within a single module.

An informational-strength module has the following definition:

It contains multiple entry points

Each entry point performs a single specific function

All of the functions are related by a concept, data structure, or resource that is hidden within the module"

Object Cohesion

Object Cohesion

The degree to which components of a class are tied together

Evaluating cohesion requires:

- Technical knowledge of the application domain
- Some experience in building, modifying, maintaining, testing and managing applications in the appropriate domain
- Technical background in and experience with reusability

Questions to probe cohesiveness of an object

Does the object represent a complete and coherent concept or does it more closely resemble a partial concept, or a random collection of information?

Does the object directly correspond to a "real world entity," physical or logical?

Is the object characterized in very non-specific terms?
  Collection of data, statistics, etc.

Do each of the methods in the public interface for the object perform a single coherent function?

If the object (or system of objects) is removed from the context of the immediate application, does it still represent a coherent and complete object-oriented concept?

Questions to probe cohesiveness of system of

Does the system represent an object-oriented concept?

Do all the objects directly support, or directly contribute to the support of, the object-oriented concept that the system represents?

Are there missing objects?

Objects in Isolation

Isolation means without considering any hierarchy that may contain the object or class

Individual Objects

A **primitive method** is any method that cannot be implemented simply, efficiently, and reliably without knowledge of the underlying implementation of the object

A **composite method** is any method constructed from two or more primitive methods – sometimes from different objects

A **sufficient set of primitive methods** for an object is a minimum set of primitive methods to accomplish all necessary work with on the object

A sufficient set of primitive methods has two major problems:

> Some tasks may be awkward and/or difficult with just a sufficient set of primitive methods
>
> A sufficient set of primitive methods may not allow us to fully capture the abstraction represented by the object

A **complete set of primitive methods** is a set of primitive methods that both allows us to easily work with the object, and fully captures the abstraction represented by the object.

To implement Java Collection

Subclass java.util.AbstractList and implement

- add(int index, Object element)
- get(int index)
- remove(int index)
- size()
- set(int index, Object element)

Subclass java.util.AbstractCollection and implement

- add(int index, Object element)
- iterator()
- size()

Iterator implements

- hasNext()
- next()
- remove()

Is either of these a sufficient set of primitive methods?

Java's ArrayList

add(int index, Object element)	add(Object o)	addAll(Collection c)
addAll(int index, Collection c)	clear()	clone()
contains(Object elem)	containsAll	**ensureCapacity**(int minCapacity)
equals	get(int index)	hashCode
indexOf(Object elem)	isEmpty()	iterator
lastIndexOf(Object elem)	listIterator	remove(int index)
removeAll	retainAll	set(int index, Object element)
size()	subList	toArray()
toArray(Object[] a)	toString	trimToSize()

Is this a complete set of primitive methods?

Ruby Array

-	&	*	[]	[]=	|
+	<<	<=>	==	abbrev	all?
any?	assoc	at	clear	collect	collect!
compact	compact!	concat	delete	delete_at	delete_if
detect	each	each_index	each_with_index	empty?	entries
eql?	fetch	fill	find	find_all	first
flatten	flatten!	frozen?	grep	hash	include?
index	indexes	indices	initialize_copy	inject	insert
inspect	join	last	length	map	map!
max	member?	min	nitems	pack	partition
pop	push	rassoc	reject	reject!	replace
reverse	reverse!	reverse_each	rindex	select	shift
size	slice	slice!	sort	sort!	sort_by
to_a	to_ary	to_s	to_set	transpose	uniq
uniq!	unshift	values_at	zip		

Smalltalk OrderedCollection 1

,	=	add:	add:after:	add:before:
add:beforeIndex:	addAll:	addAllFirst:	addAllLast:	addFirst:
addLast:	addLastNoCheck:	after:	allButFirst:	allButLast:
allSatisfy:	anySatisfy:	asArray	asBag	asFixedArgument
asList	asOrderedCollection	asSet	asSortedCollection	asSortedCollection:
asSortedStrings	asSortedStrings:	asSortedStrings:with:	asSortedStringsWith:	at:
at:put:	atAll:put:	atAllPut:	before:	capacity
changeCapacityTo:	changeSizeTo:	collect:	contains:	copyEmpty
copyEmpty:	copyFrom:to:	copyReplaceAll:with:	copyReplaceFrom:to:with:	copyUpTo:
copyWith:	copyWithout:	detect:	detect:ifNone:	do:
do:separatedBy:	doWithIndex:	emptyCheck	emptyCollectionError	errorOutOfBounds
find:	findFirst:	findFirst:startingAt:	findLast:	first
first:	firstObjectError	fold:	forStackDumpPrintUsing:	groupedBy:
grow	growSize	growToAtLeast:	hash	identityIndexOf:
includes:	identityIndexOf:ifAbsent:		identityIndexOf:from:to: ifAbsent:	

Smalltalk OrderedCollection 2

increaseCapacity	indexOf:	indexOf:ifAbsent:	inject:into:	insert:before:
inspectorClass	inspectorClasses	isEmpty	isNotEmpty	isSameSequenceAs:
isSequenceable	isWeakContainer	isWeakContainer:	keysAndValuesDo:	last
last:	lastIndexOf:	lastIndexOf:ifAbsent:	lastObjectError	literalArrayEncoding
makeRoomAtFirst	makeRoomAtLast	maxPrint	newReadWriteStream	nextIndexOf:from:to:
noMatchError	noSuchElementError	notEmpty	notEnoughElementsError	notFoundError
notKeyedError	occurrencesOf:	piecesCutWhere:	piecesCutWhere:do:	prevIndexOf:from:to:
writeStream	printOn:	readStream	readWriteStream	reject:
remove:	remove:ifAbsent:	removeAll:	removeAllSuchThat:	removeAtIndex:
removeFirst	removeFirst:	removeIndex:	removeLast	removeLast:
replaceAll:with:	replaceAll:with:from:to:	replaceFrom:to:with:	replaceFrom:to:with:startingAt:	representBinaryOn:
reverse	reverseDo:	runsFailing:	runsFailing:do:	runsSatisfying:
runsSatisfying:do:	select:	setIndices	setIndicesFrom:	size
storeOn:	swap:with:	tokensBasedOn:	trim	with:do:
			printBriefInspectorTextOn:	

Smalltalk OrderedCollection 3

decrementBy:boundedBy:highValue:wrapAround:
startingAt:replaceElementsIn:from:to:
replaceElementsFrom:to:withArray:startingAt:
replaceElementsFrom:to:withByteArray:startingAt:
replaceElementsFrom:to:withByteEncodedString:startingAt:
replaceElementsFrom:to:withCharacterArray:startingAt:
replaceElementsFrom:to:withIntegerArray:startingAt:
replaceElementsFrom:to:withLinkedList:startingAt:
replaceElementsFrom:to:withSequenceableCollection:startingAt:
replaceElementsFrom:to:withTwoByteString:startingAt:
replaceElementsFrom:to:withWordArray:startingAt:
indexOfSubCollection:startingAt:
indexOfSubCollection:startingAt:ifAbsent:
incrementBy:boundedBy:lowValue:wrapAround:

Levels of Cohesion

An object is not as cohesive as it could be if the public interface contains:

- Only primitive methods, but does not fully capture the abstraction represented by the object
- Primitive and composite methods, but does not fully capture the abstraction represented by the object
- A sufficient set of primitive methods with composite methods
- No primitive methods, just composite methods

Note

- Objects with a sufficient set of primitive methods with composite methods is more cohesive than objects with out a sufficient set of primitive methods
- All public methods must directly support the abstraction represented by the object. The methods must make sense when object is removed from the application

Composite Objects

A **composite object** is an object that is conceptually composed of two, or more, other objects, which are externally discernible.

Component objects are those that make up the composite object.

Component objects are **externally discernible** if

- The externally discernible state of the object is directly affected by the presence or absence of one or more component objects

- Component objects can be directly queried or changed via methods in the public interface of the composite object and/or

Ranking of Cohesion of Composite Objects

Externally discernible component objects not related

Some externally discernible component objects are related, the group component objects does not make sense

The group component objects does not represent a single stable object-oriented concept, but are all bound together some how in an application

A majority of the externally discernible component objects support a single, coherent, object-oriented concept, but at least one does not

All of the externally discernible component objects support a single, coherent, object-oriented concept, but at least one needed is missing

All of the externally discernible component objects support a single, coherent, object-oriented concept, and none are missing

Accessing Cohesion of an Individual Object

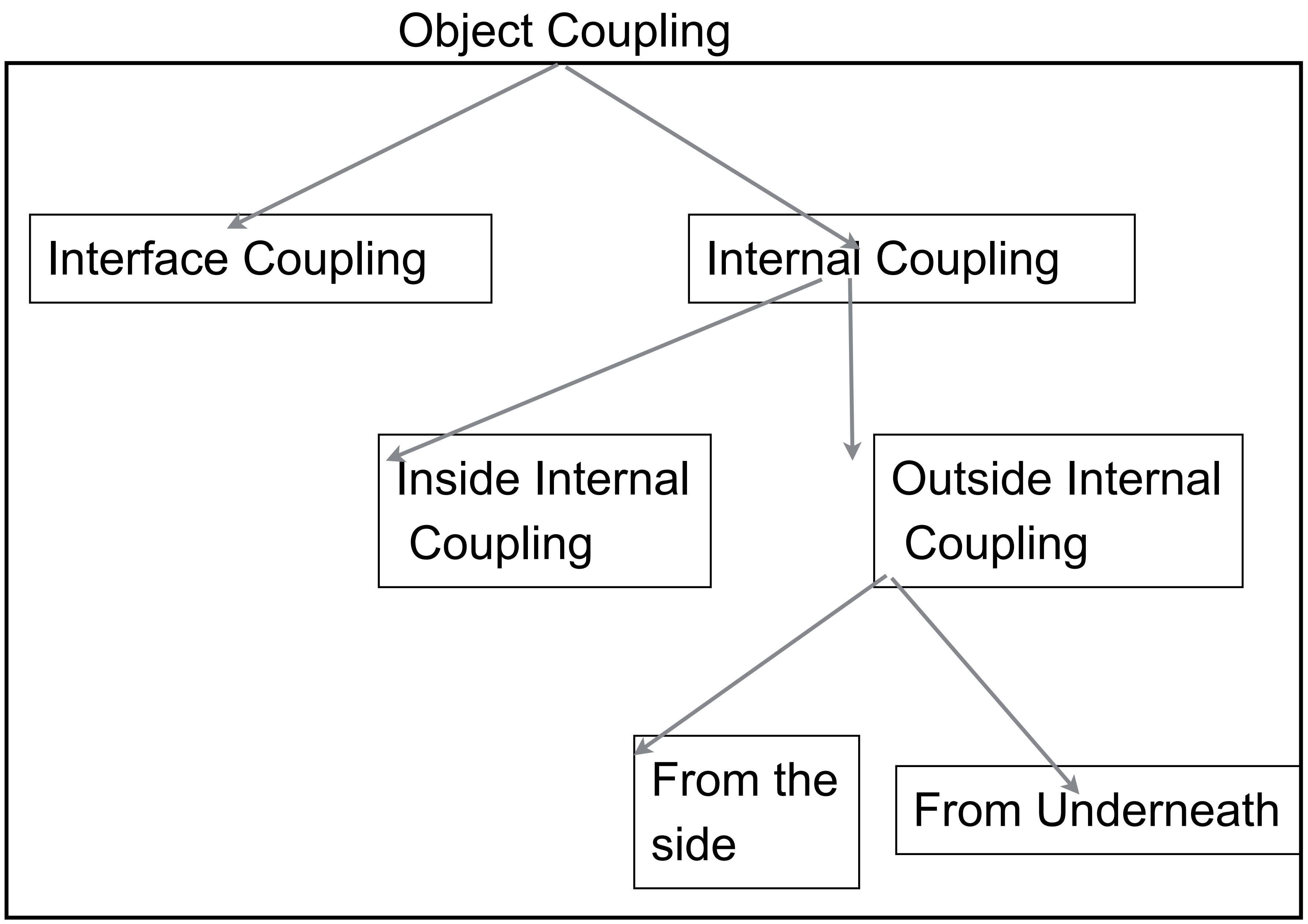
Assessment of the public methods/public non-methods/component objects

Are all the items appropriate for the given object?

Do we have at least a minimally sufficient set of items?

Do we have extra or application-specific items?

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
}
```

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

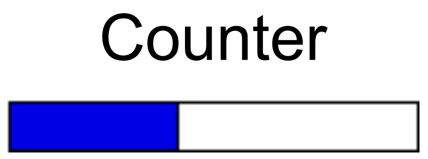
```
public String toString() {return String.valueOf( count );}
```

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
}
```



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 );}
}
```

Iterator

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

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

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}
}
```

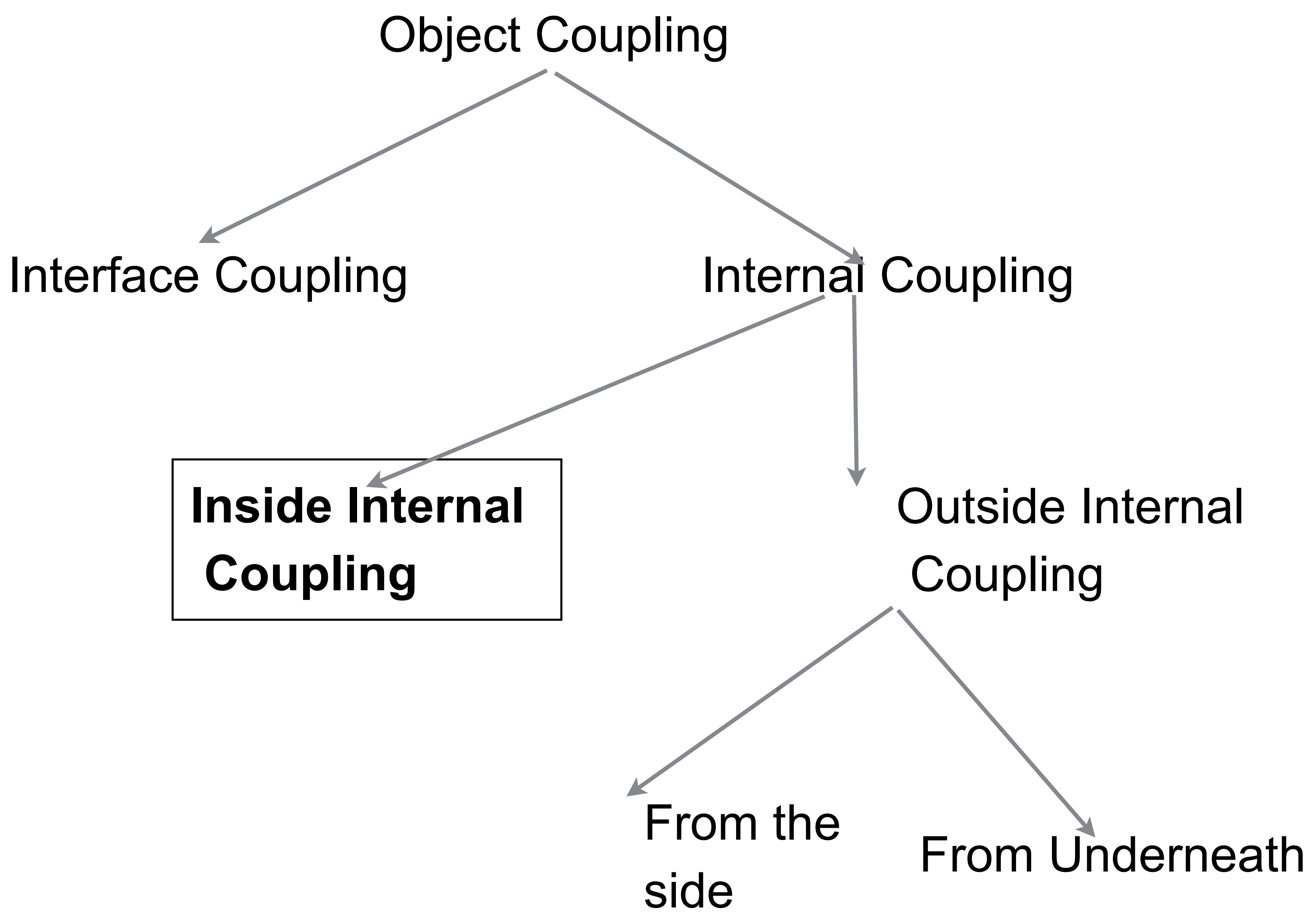
Primitive Objects

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?


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

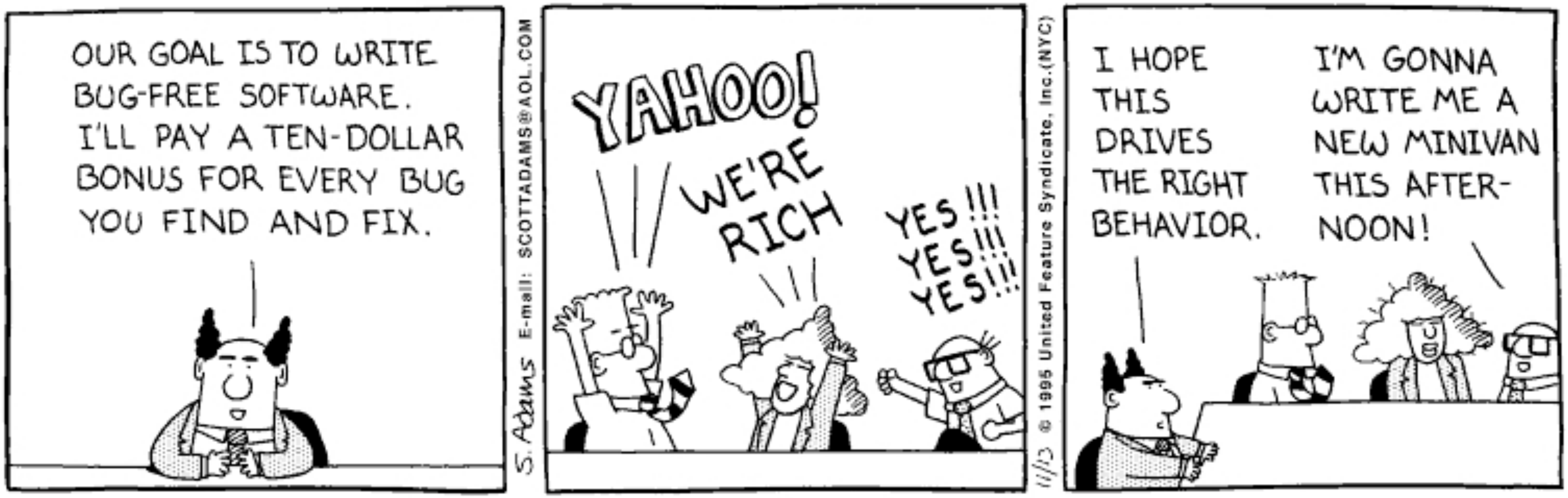
- Using non-object-oriented languages
- Special language "features"
- C++ friends

Metrics

Metrics

DeMarco's Principle

Effort moves toward whatever is measured


OUR GOAL IS TO WRITE BUG-FREE SOFTWARE. I'LL PAY A TEN-DOLLAR BONUS FOR EVERY BUG YOU FIND AND FIX.
YAHOO!
WE'RE RICH
YES!!! YES!!! YES!!!
I HOPE THIS DRIVES THE RIGHT BEHAVIOR.
I'M GONNA WRITE ME A NEW MINIVAN THIS AFTERNOON!
S. Adams E-mail: SCOTTADAMS@AOL.COM
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11/13

The Swedish Army Dictum

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

Eclipse Metrics 1.3.6

Docs	Source Forge Site
http://metrics.sourceforge.net/	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

- 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 = $a(\text{KLOC})^b$ [man-months]

Type	a	b
Organic	2.4	1.05
Semi-detached	3	1.12
Embedded	3.6	1.2

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

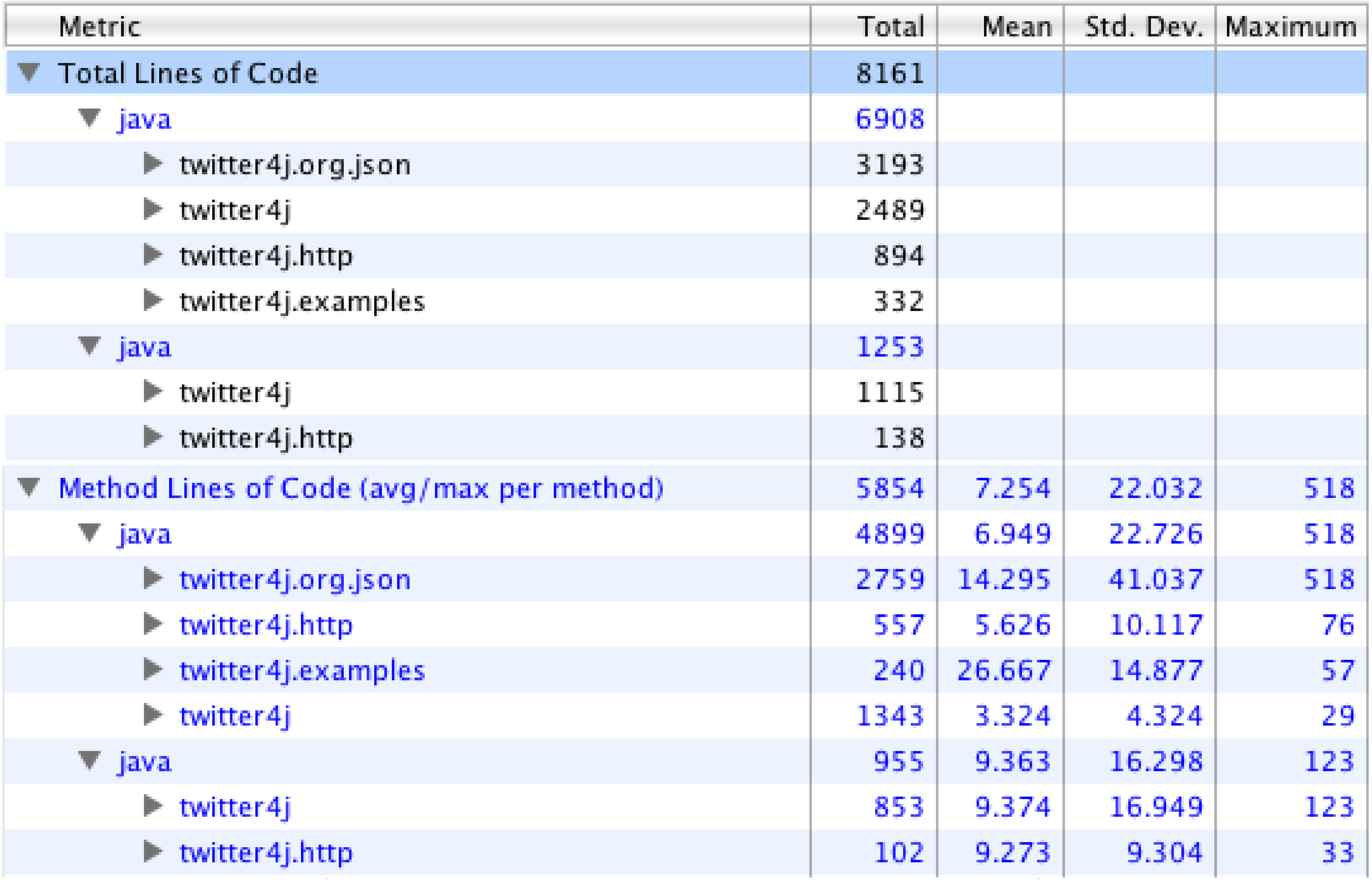
Hand written code verses autogenerated code

Programmer variation

Defining and counting LOC

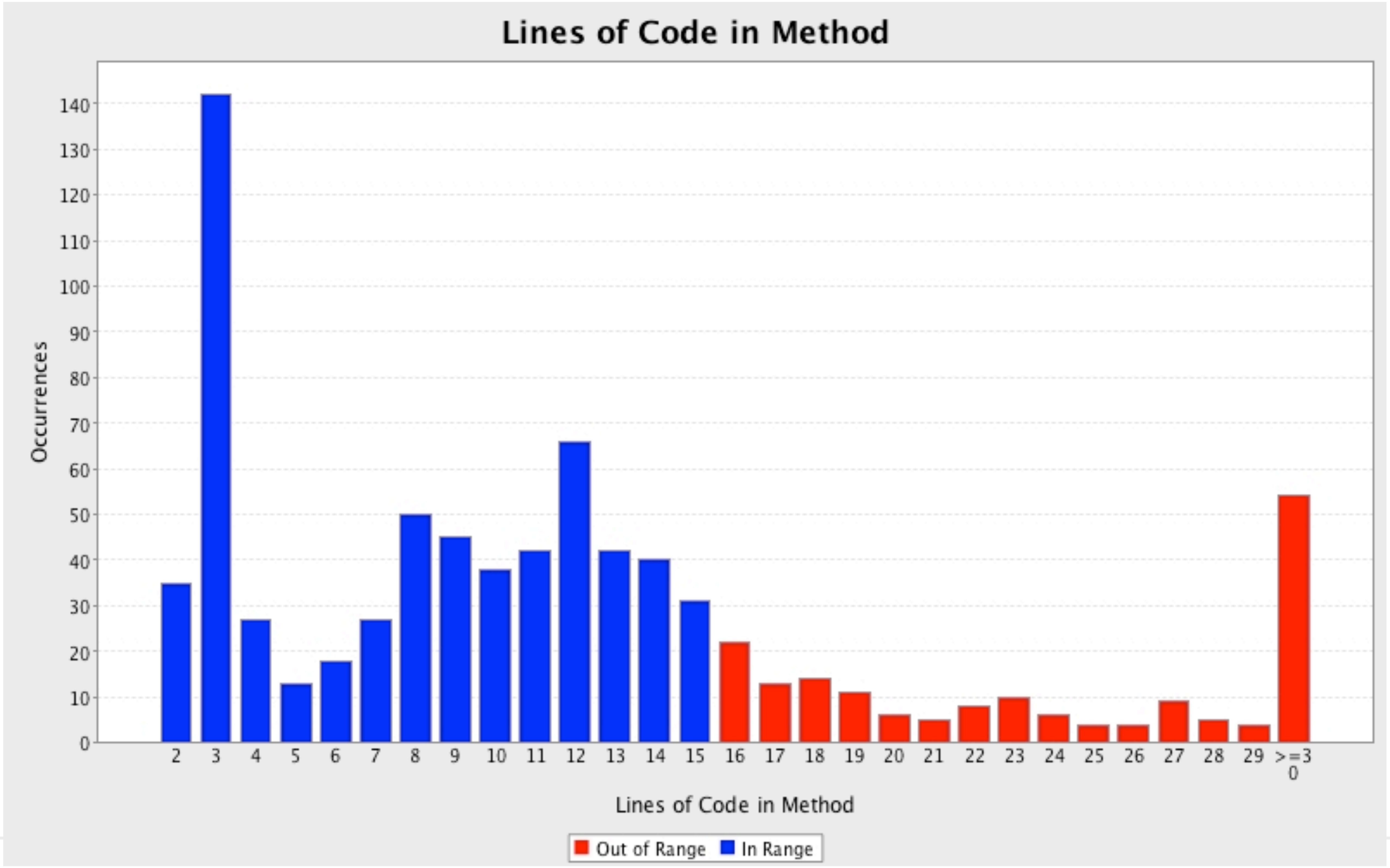
Coding accounts for about 35% of overall effort

Twitter4j Example

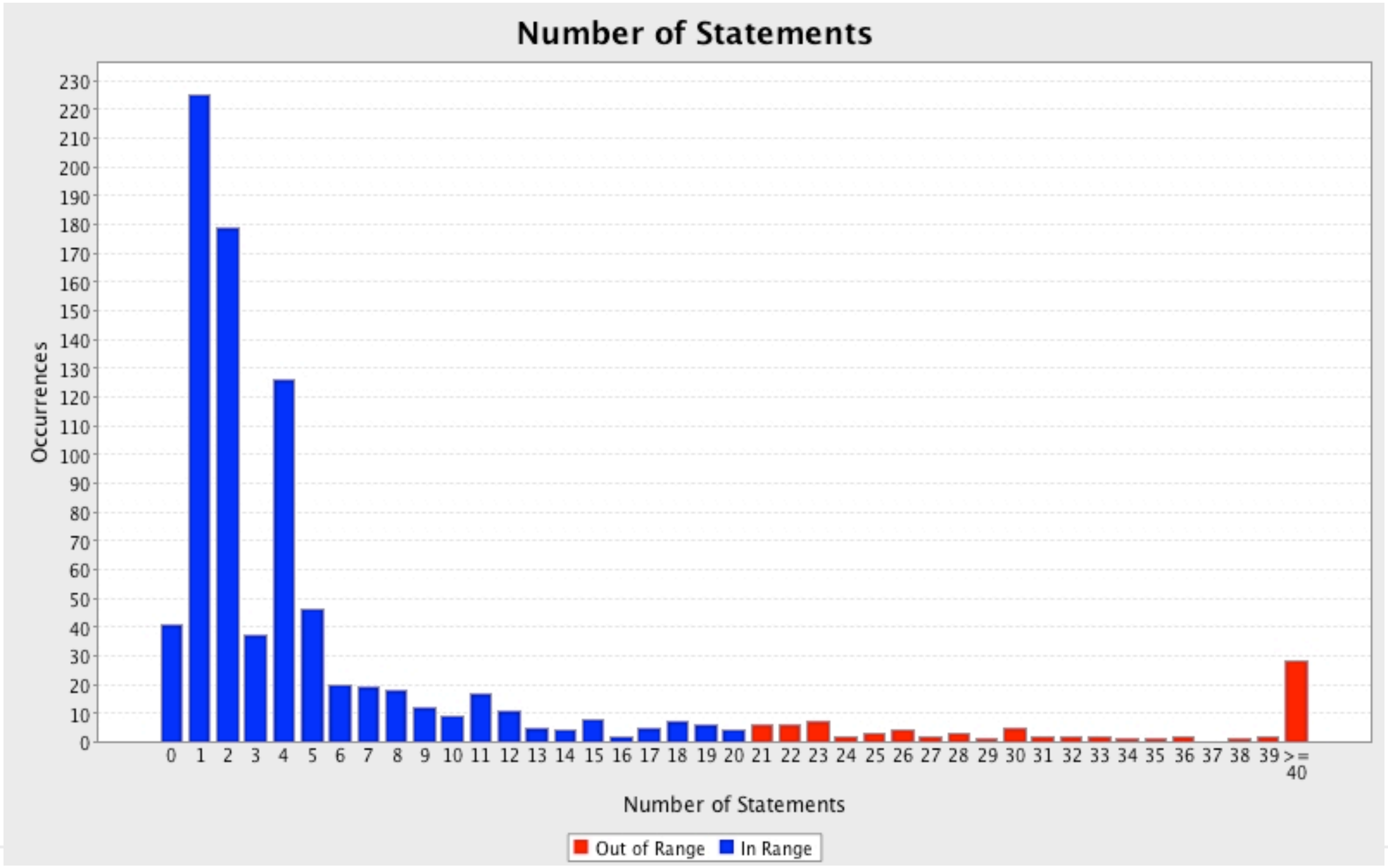


Metric	Total	Mean	Std. Dev.	Maximum
▼ Total Lines of Code	8161			
▼ java	6908			
▶ twitter4j.org.json	3193			
▶ twitter4j	2489			
▶ twitter4j.http	894			
▶ twitter4j.examples	332			
▼ java	1253			
▶ twitter4j	1115			
▶ twitter4j.http	138			
▼ Method Lines of Code (avg/max per method)	5854	7.254	22.032	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



Eclipse Metrics Plugin

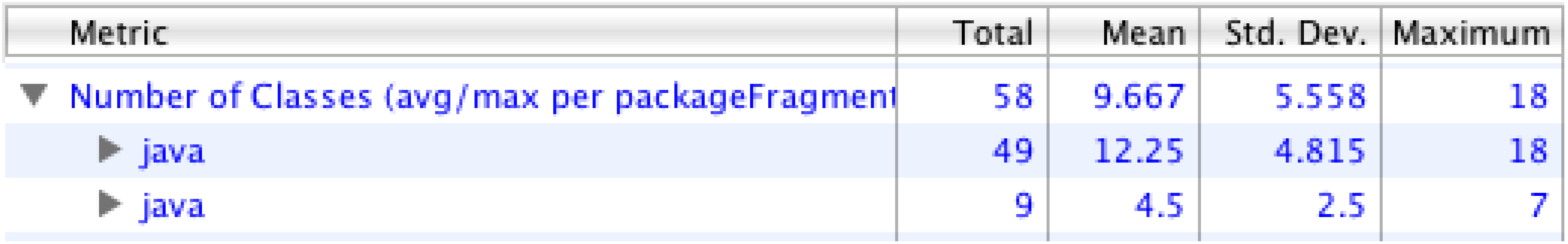


More Size Metrics

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

McCabe Cyclomatic Complexity

Number of linearly independent paths through a program

From graph theory

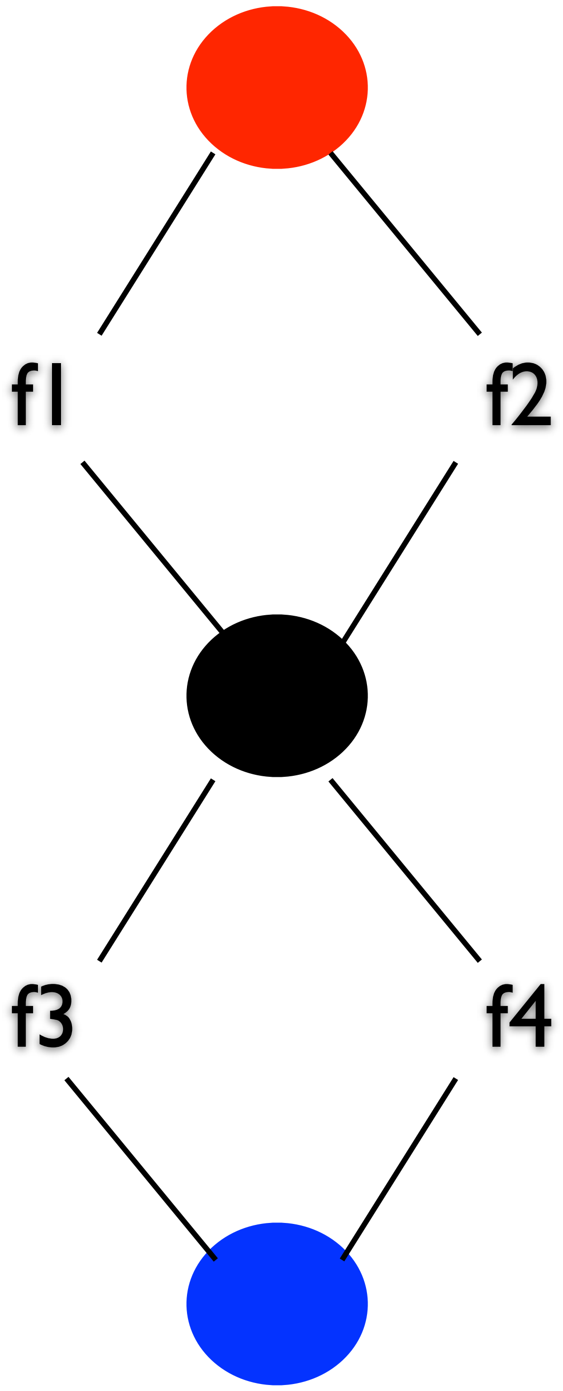
$M = E - N + 2P$

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

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

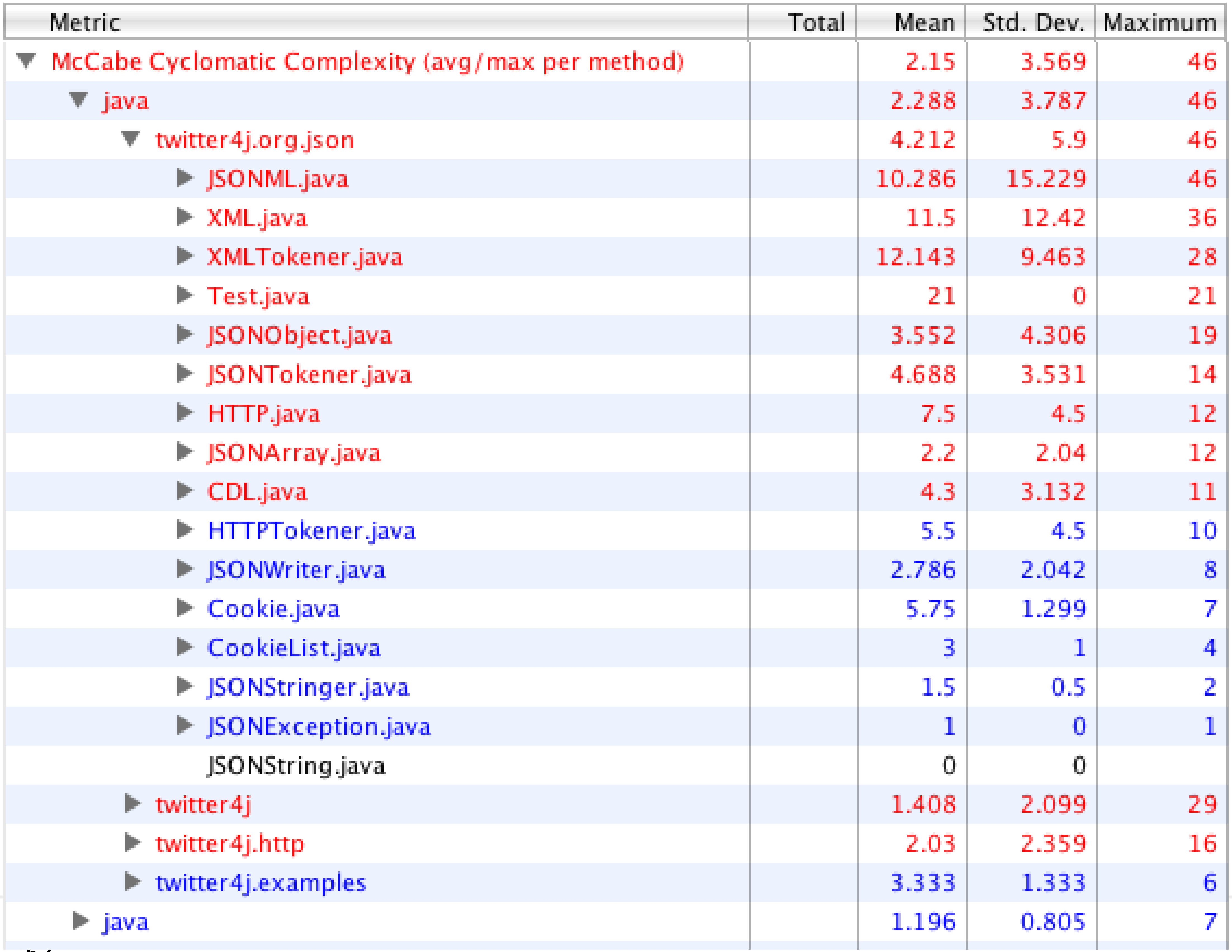
Some evidence that higher Cyclomatic Complexity implies more bugs

NIST Structured Testing methodology

Split modules with cyclomatic complexity greater than 10

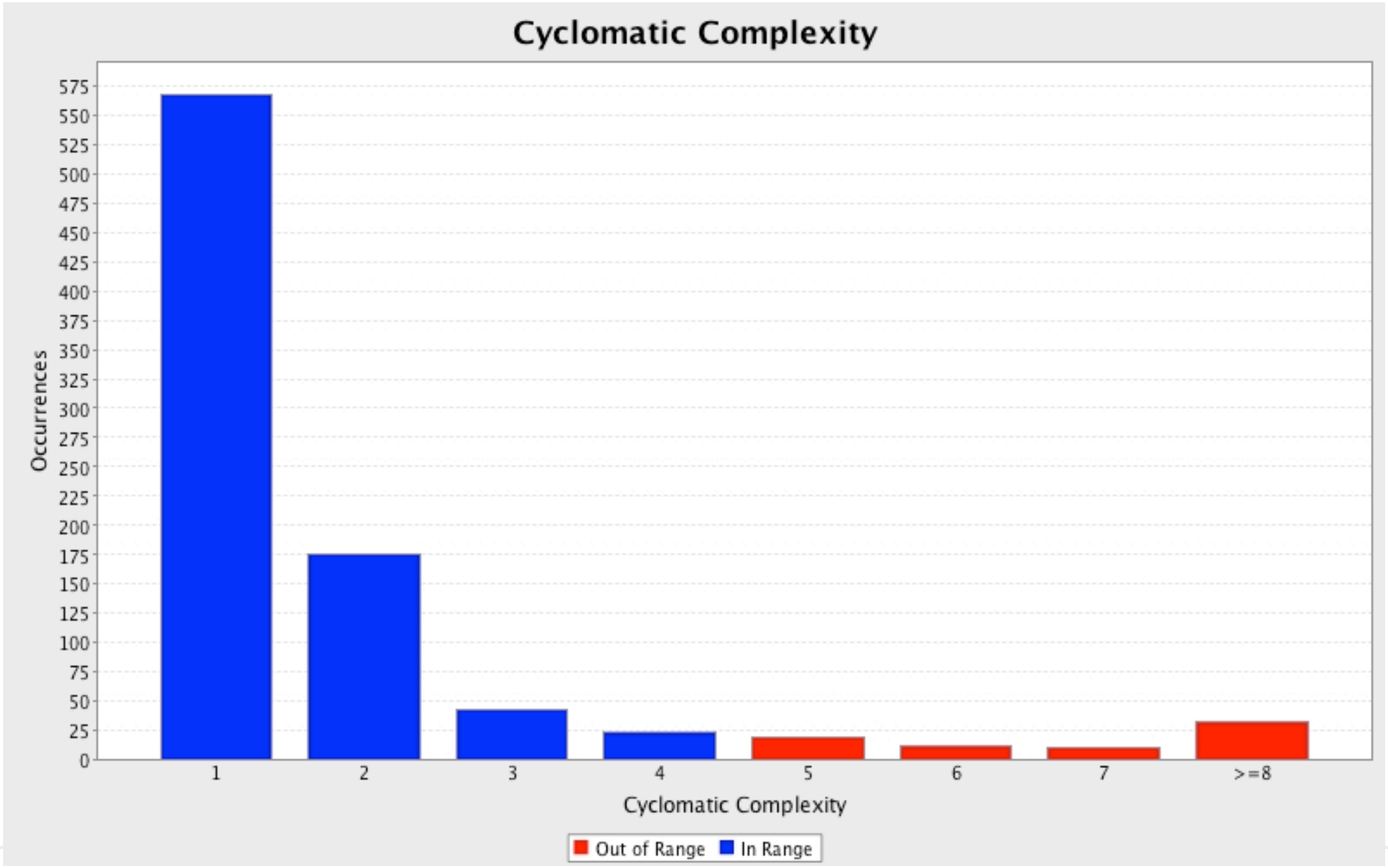
It may be appropriate in some circumstances to permit modules with a complexity as high as 15

Eclipse Metrics 1.3.6

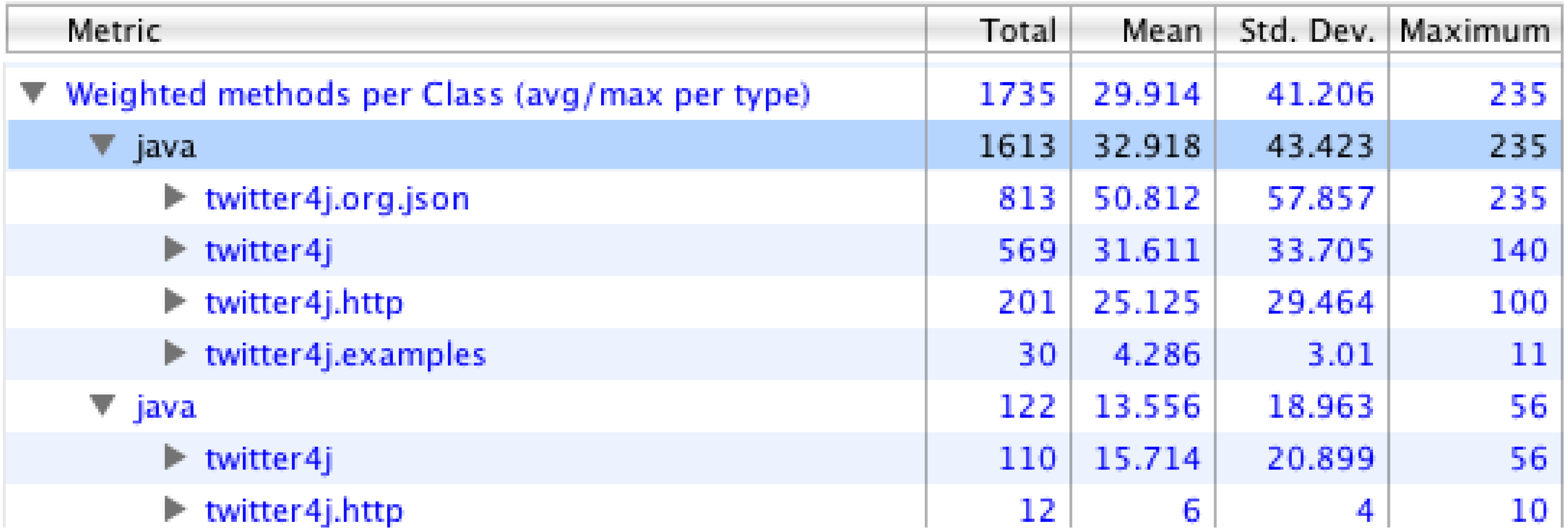


Metric	Total	Mean	Std. Dev.	Maximum
▼ McCabe Cyclomatic Complexity (avg/max per method)		2.15	3.569	46
▼ java		2.288	3.787	46
▼ twitter4j.org.json		4.212	5.9	46
▶ JSONML.java		10.286	15.229	46
▶ XML.java		11.5	12.42	36
▶ XMLTokener.java		12.143	9.463	28
▶ Test.java		21	0	21
▶ JSONObject.java		3.552	4.306	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)



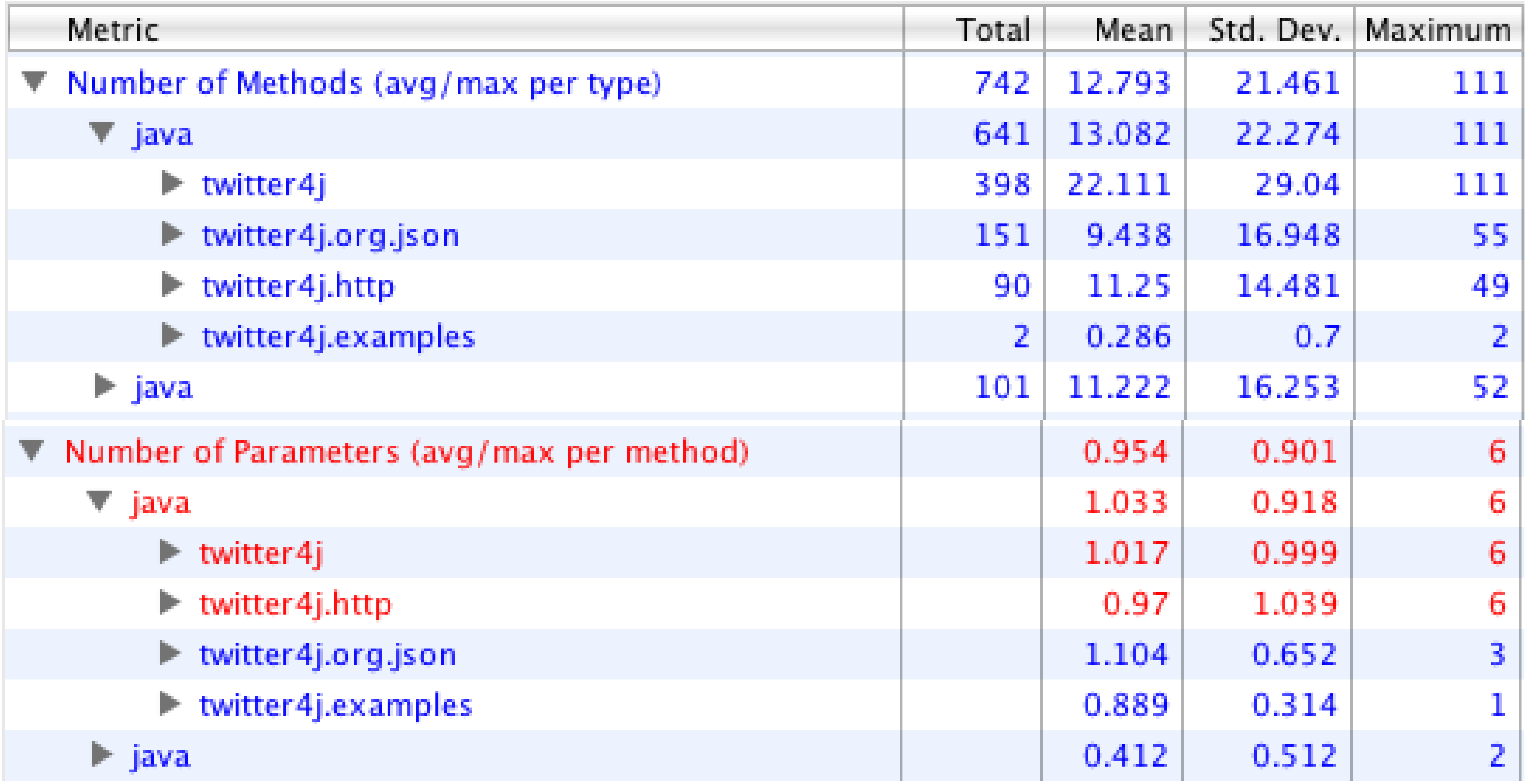
Metric	Total	Mean	Std. Dev.	Maximum
▼ Weighted methods per Class (avg/max per type)	1735	29.914	41.206	235
▼ java	1613	32.918	43.423	235
▶ twitter4j.org.json	813	50.812	57.857	235
▶ twitter4j	569	31.611	33.705	140
▶ twitter4j.http	201	25.125	29.464	100
▶ twitter4j.examples	30	4.286	3.01	11
▼ java	122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

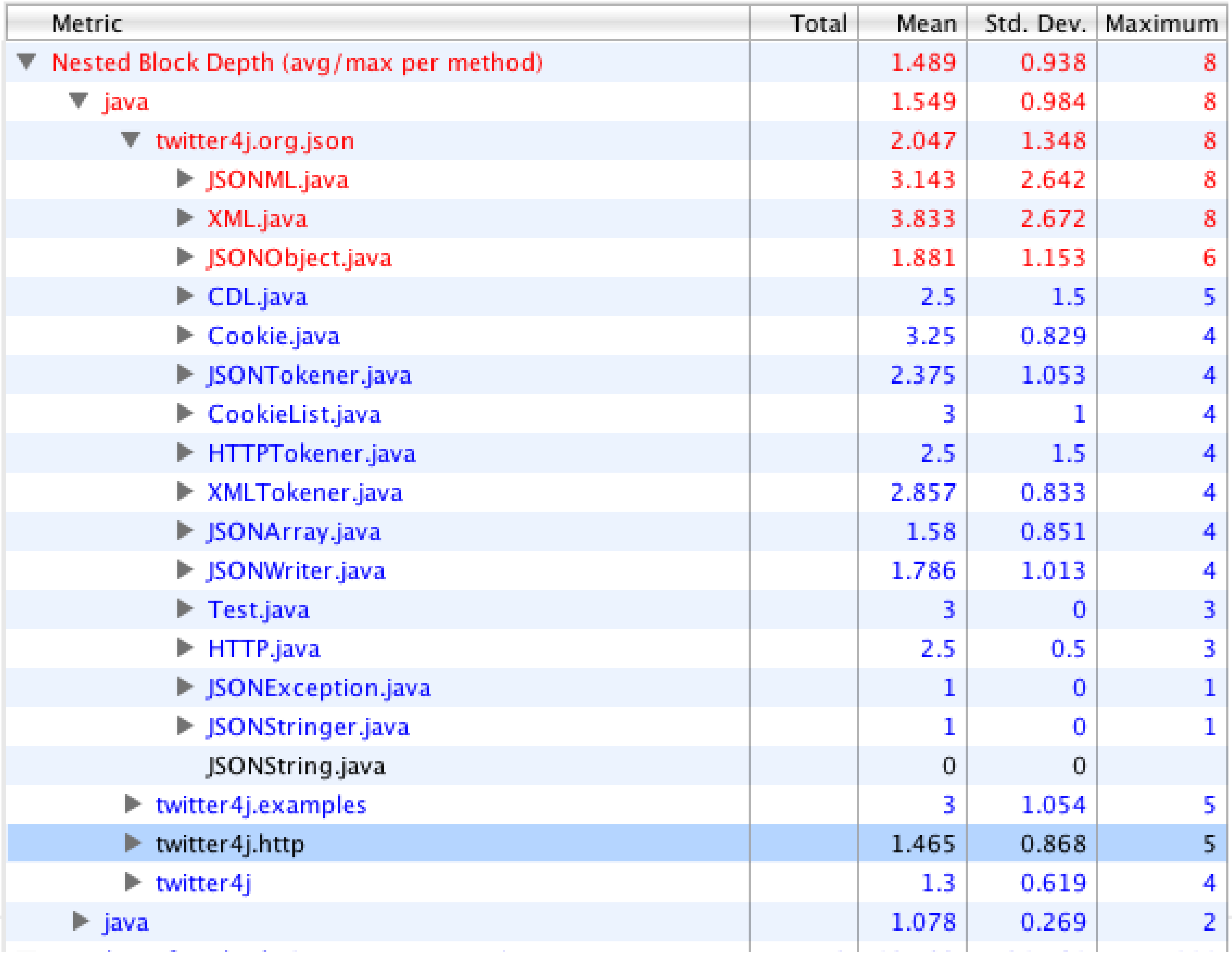
Nested Block Depth

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)

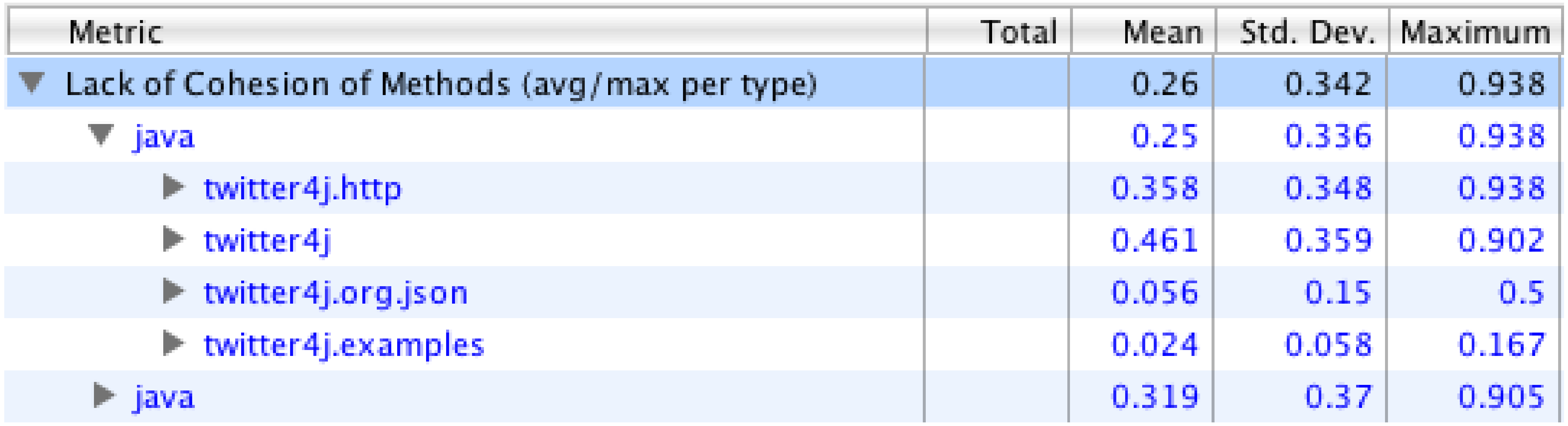
$$\frac{\langle r \rangle - |M|}{1 - |M|}$$

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

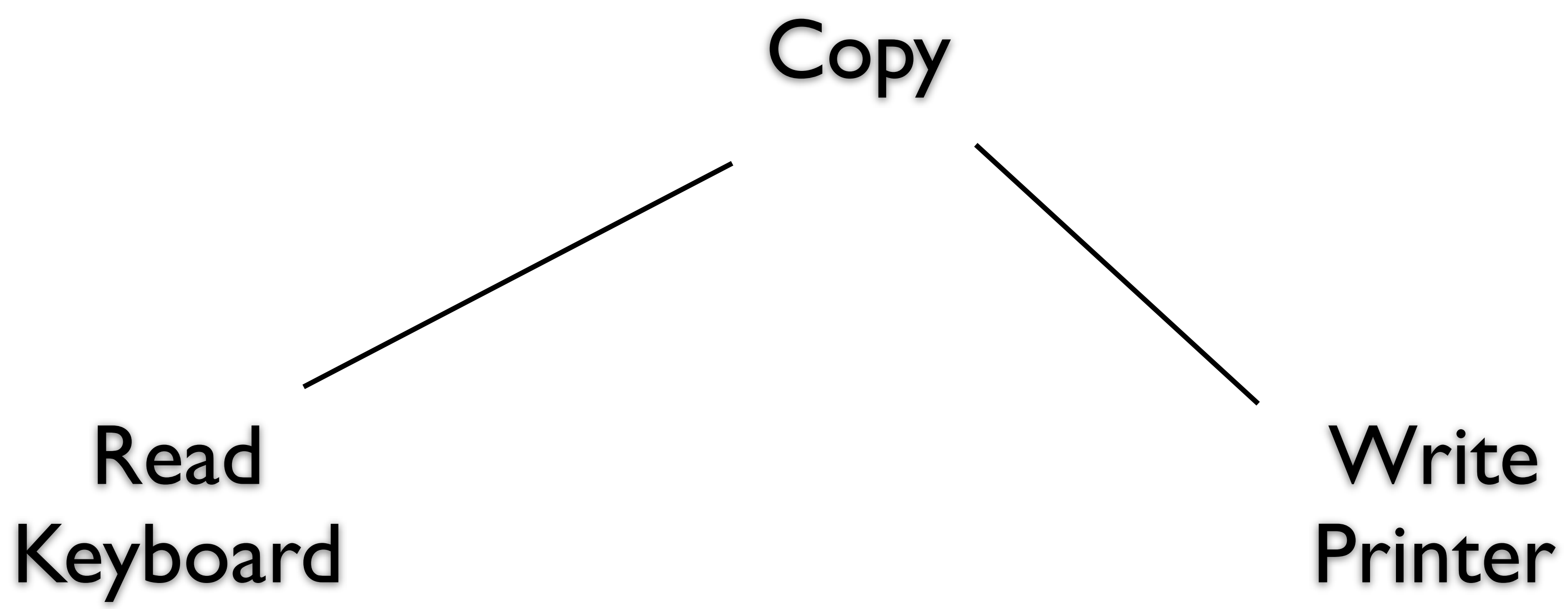
Lack of Cohesion of Methods



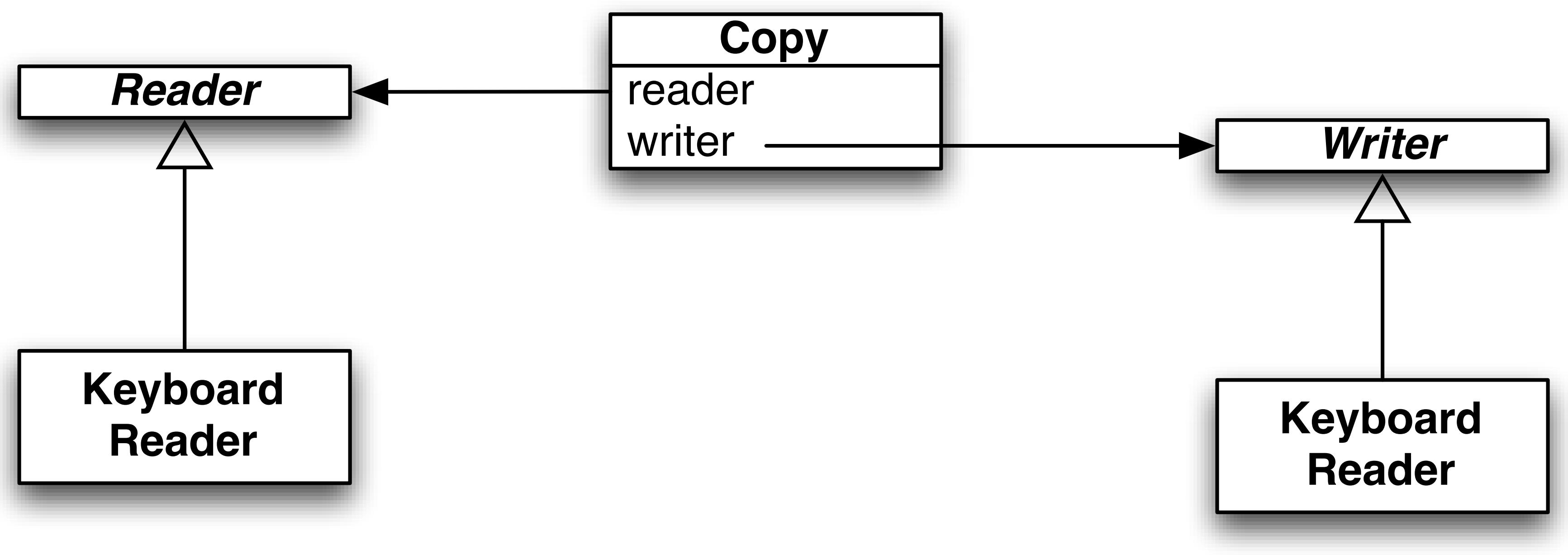
Metric	Total	Mean	Std. Dev.	Maximum
▼ Lack of Cohesion of Methods (avg/max per type)		0.26	0.342	0.938
▼ java		0.25	0.336	0.938
▶ twitter4j.http		0.358	0.348	0.938
▶ twitter4j		0.461	0.359	0.902
▶ twitter4j.org.json		0.056	0.15	0.5
▶ twitter4j.examples		0.024	0.058	0.167
▶ java		0.319	0.37	0.905

Metrics for Stable Code

Dependencies make code rigid, fragile and difficult to reuse



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

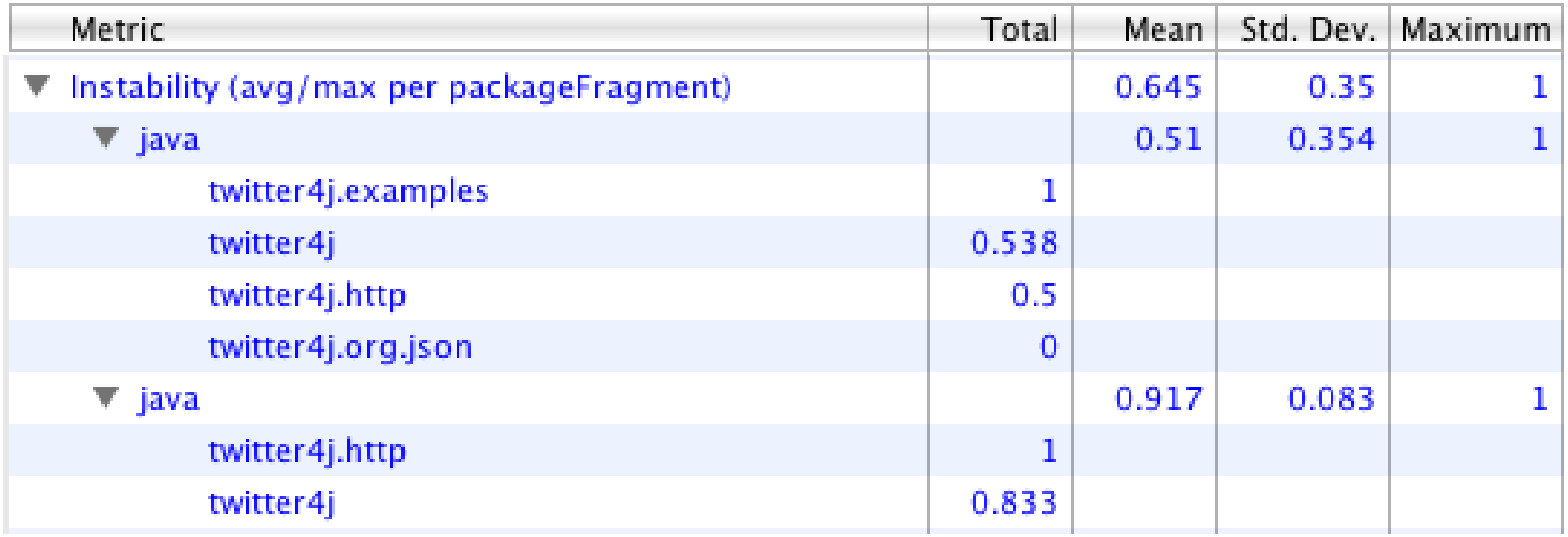
Instability (I)

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

I = 0 means a category is maximally stable

I = 1 means a category is maximally instable

Instability 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

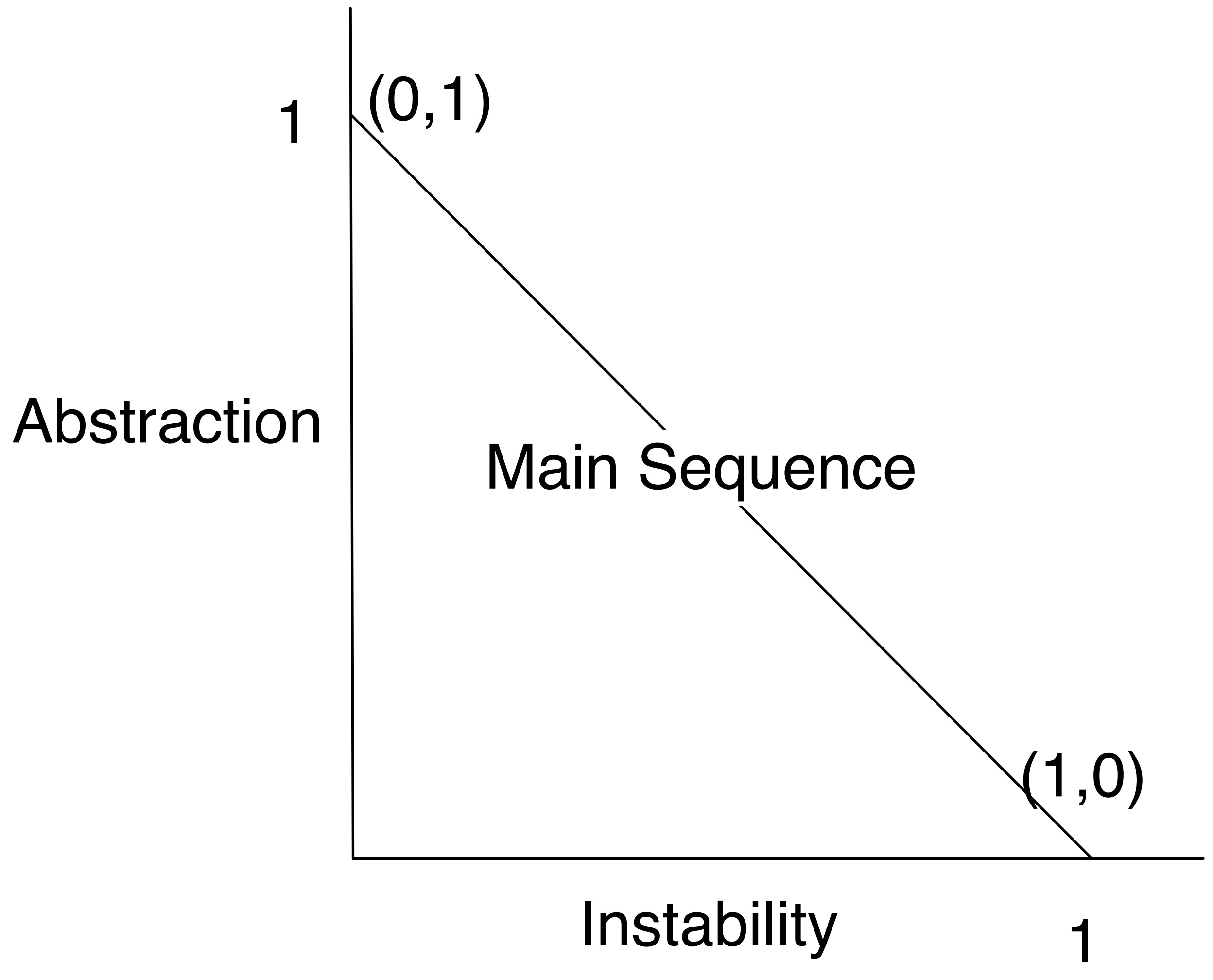
Abstractness (A)

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

A = 1, all classes are abstract

A = 0, all classes are concrete

Main Sequence



Distance From Main Sequence

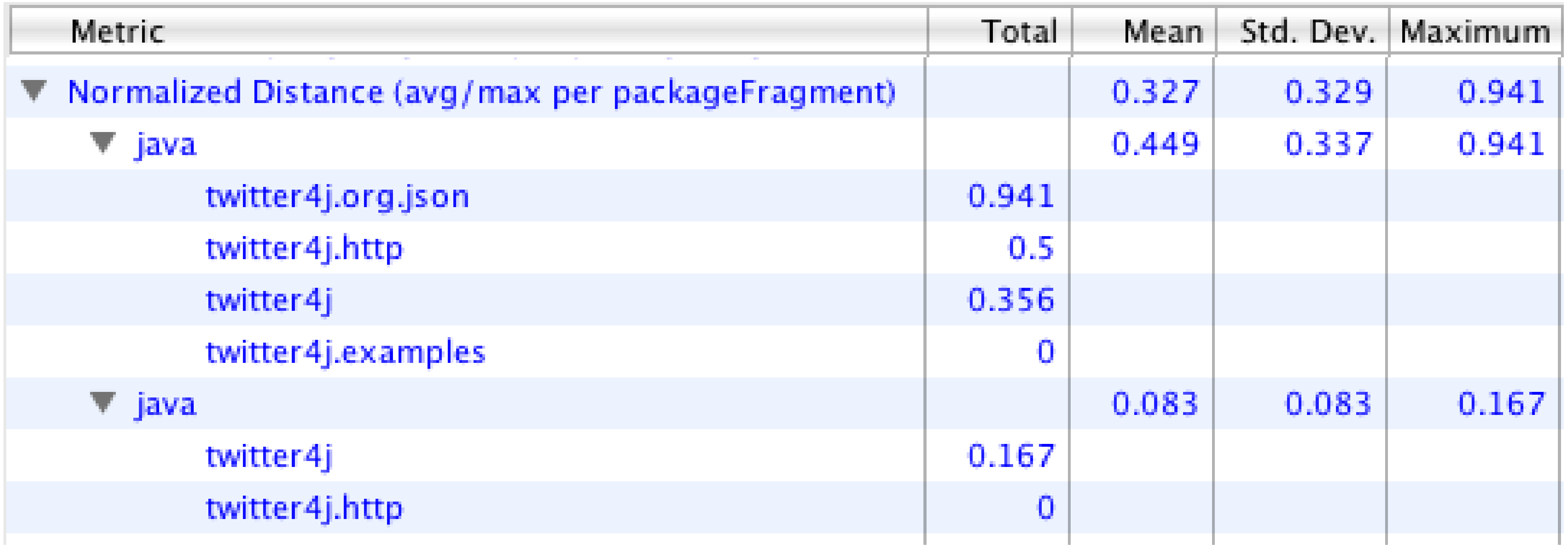
$$Dn = | A + I - 1 |$$

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			