COMPSCI 732:

Software Tools and Techniques

Tools for Producing Quality Software

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Research Interests

. . . to make programmers more productive, that is, help the people who actually produce code to do so faster, with less effort, fewer errors, and with more enjoyment than currently

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Theme

Software tools are needed for more than just the production of software.

Observation 1

Much of the pain in software development is due to having to deal with kludgey code.

$\Rightarrow$ We need to produce higher quality software than we currently do

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Much of the pain in software development is due to having to deal with kludgey code.

$\Rightarrow$ We need to produce higher quality software than we currently do
(whatever “higher quality” means)

Observation 2

We can't know whether or not we have improved the quality of our software if we can't measure its quality

$\Rightarrow$ we need tools that measure quality of software

$\Rightarrow$ we need to know how to measure quality

$\Rightarrow$ we need to know what we mean by quality

$\Rightarrow$ we need to know how to measure software

Research Agenda

- Develop software metrics that might tell us something about software quality
- Develop instruments to measure code according to the identified metrics
- Apply the instruments to existing code
- Analyse the resulting data to identify potential quality problems
- Determine whether or not the metrics actually do tell us something about software quality
- Incorporate the use of the metrics into the software development process

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  - describe some metrics
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- Incorporate the use of the metrics into the software development process
  - integrate instruments into IDEs

What is Quality?

Understandability If I want to completely understand a given class, what other classes do I need to understand?

Testability If I want to test a given class, what other classes do I need to test?

Reusability If I want to reuse a given class, what other classes do I need to reuse?

Readability . . .

Comprehensibility . . .

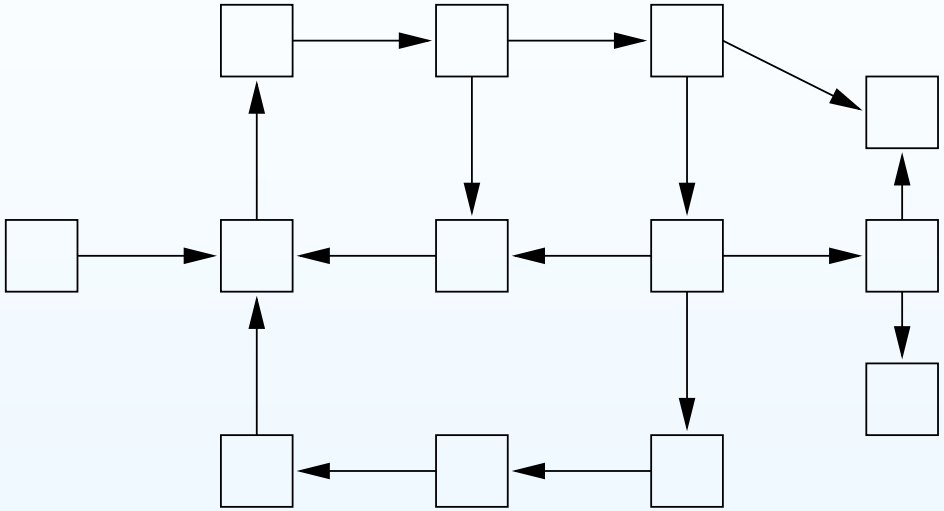
Changeability . . .

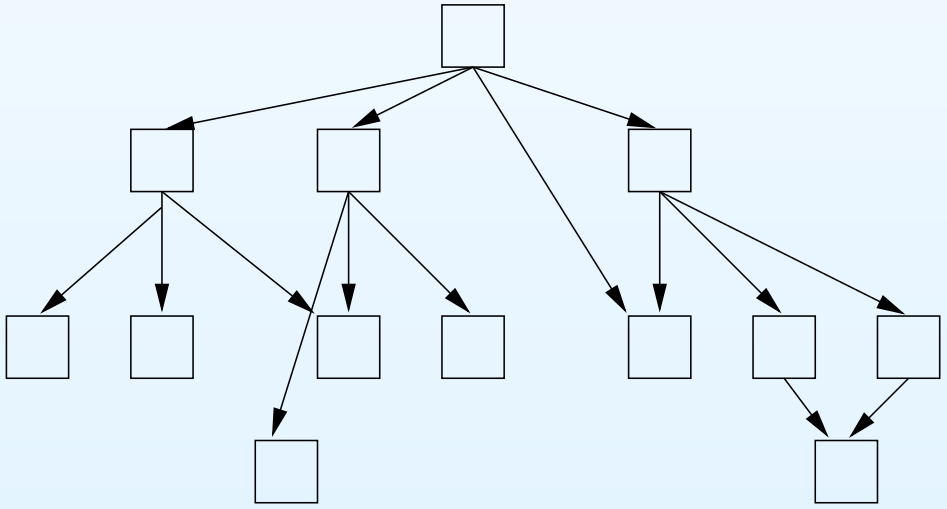
Maintainability . . .

. . .

$\Rightarrow$ possibly multiple metrics

Which is the better design?





Example

```
class A {
  public void aMethod1(B ab) {
    ...
  }
}
```

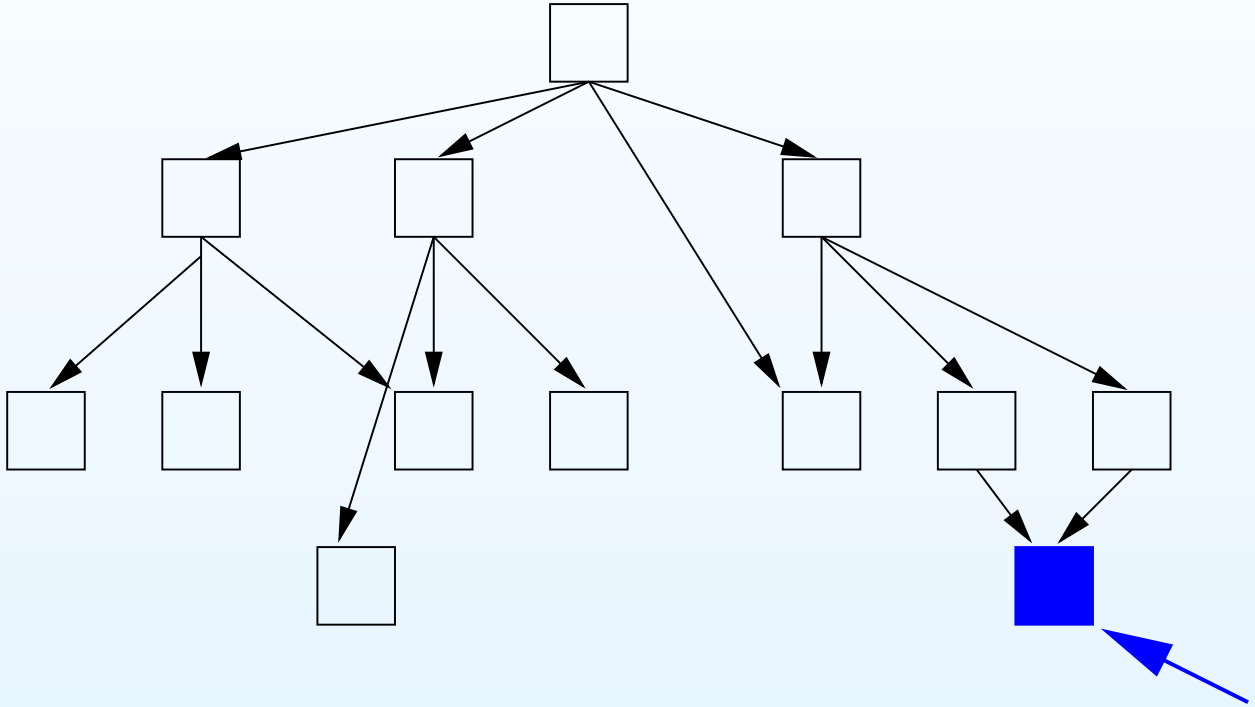
```
class B {
  public void bMethod() {
      C aC = new C();
    ...
  }
}
```

- understandability of A?
- testability of A?
- reusability of A?

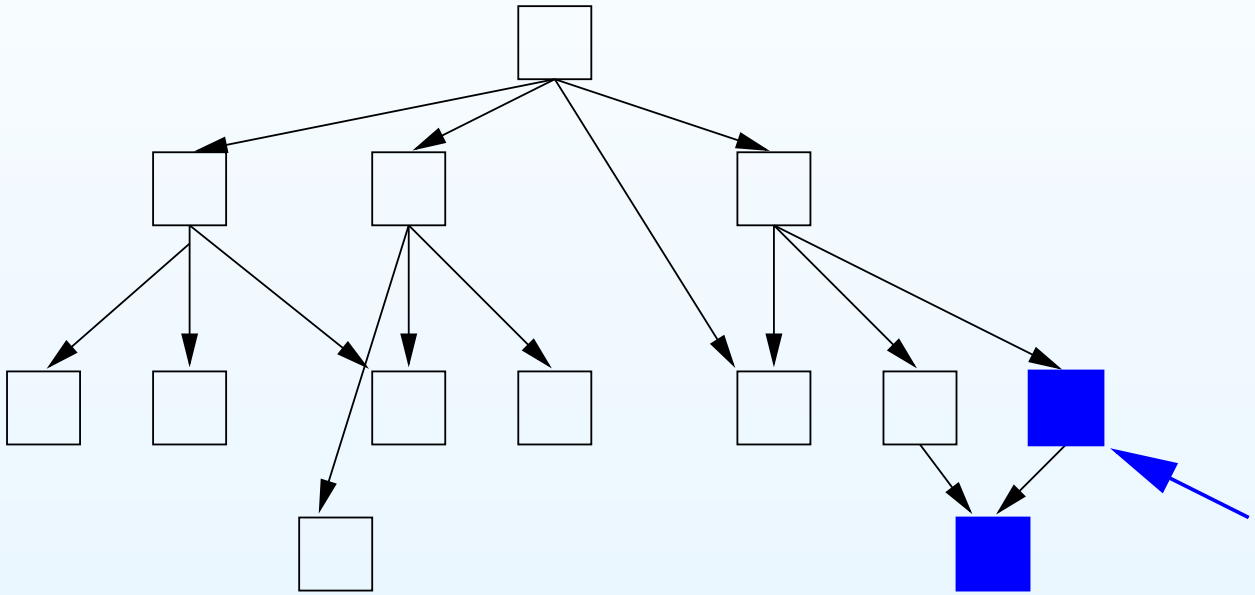
Class Reachability Sets

- Class reachability set for class A = the set of classes that A transitively depends on
- Class reachability set size (CRSS) — metric for transitive (compilation) dependence
- Hayden Melton's PhD research

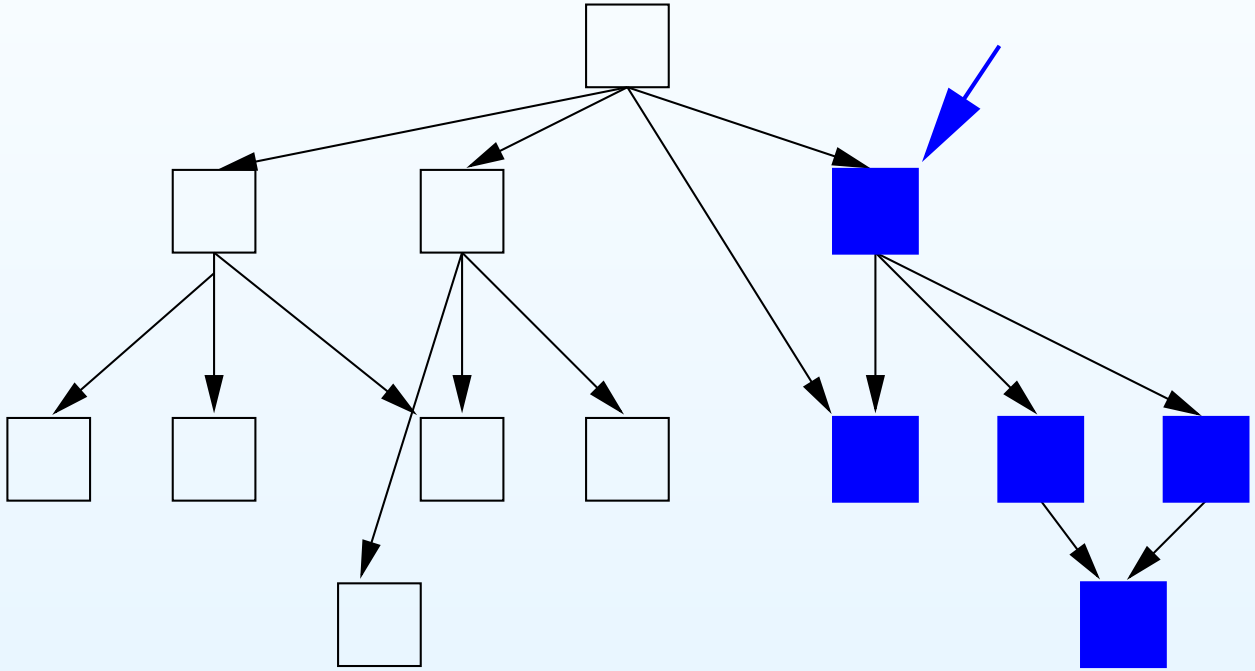
Class Reachability Sets



Class Reachability Sets



Class Reachability Sets



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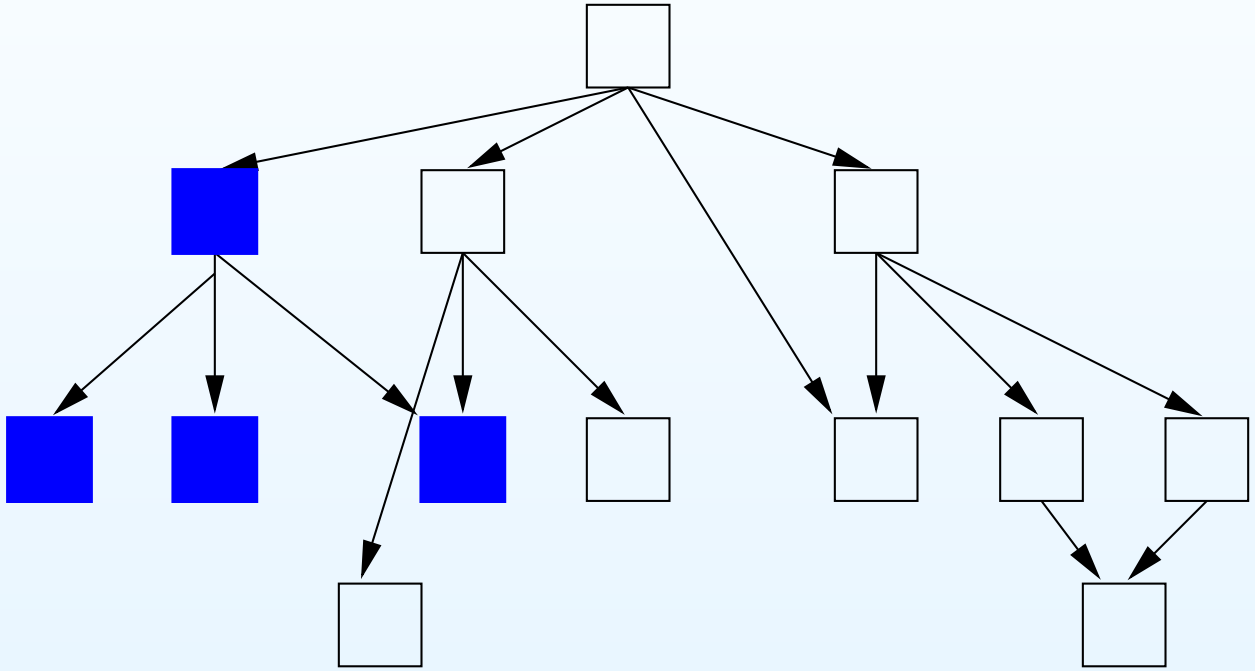
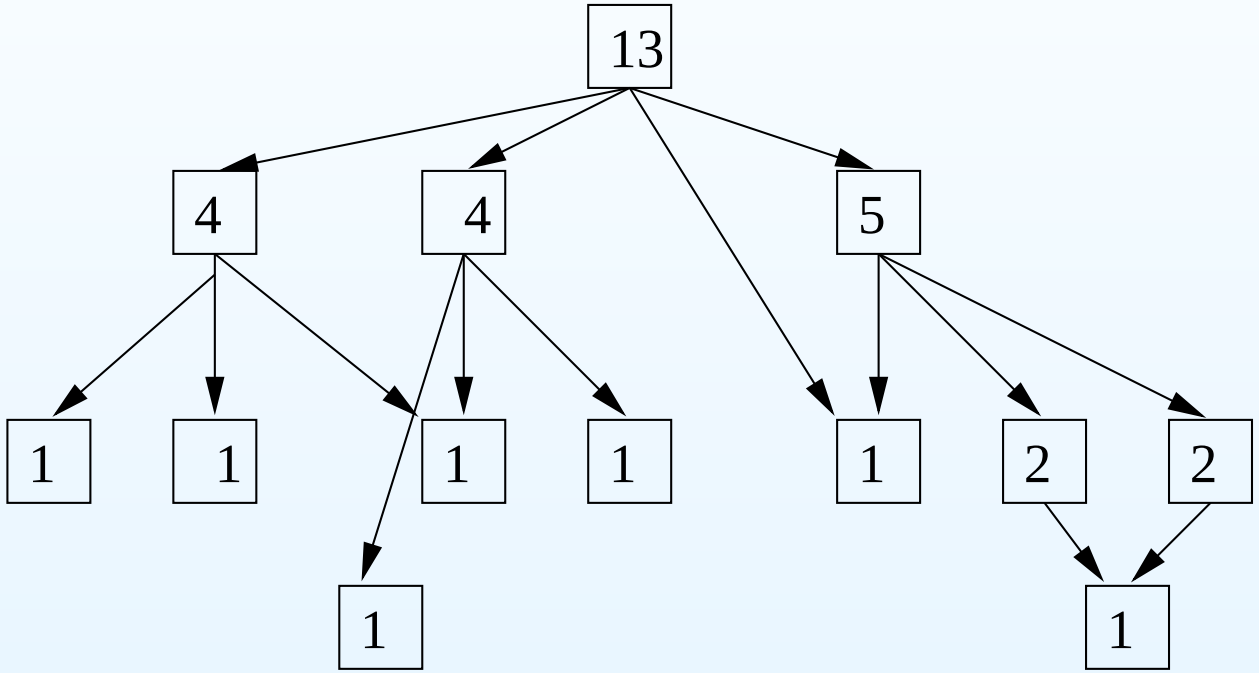
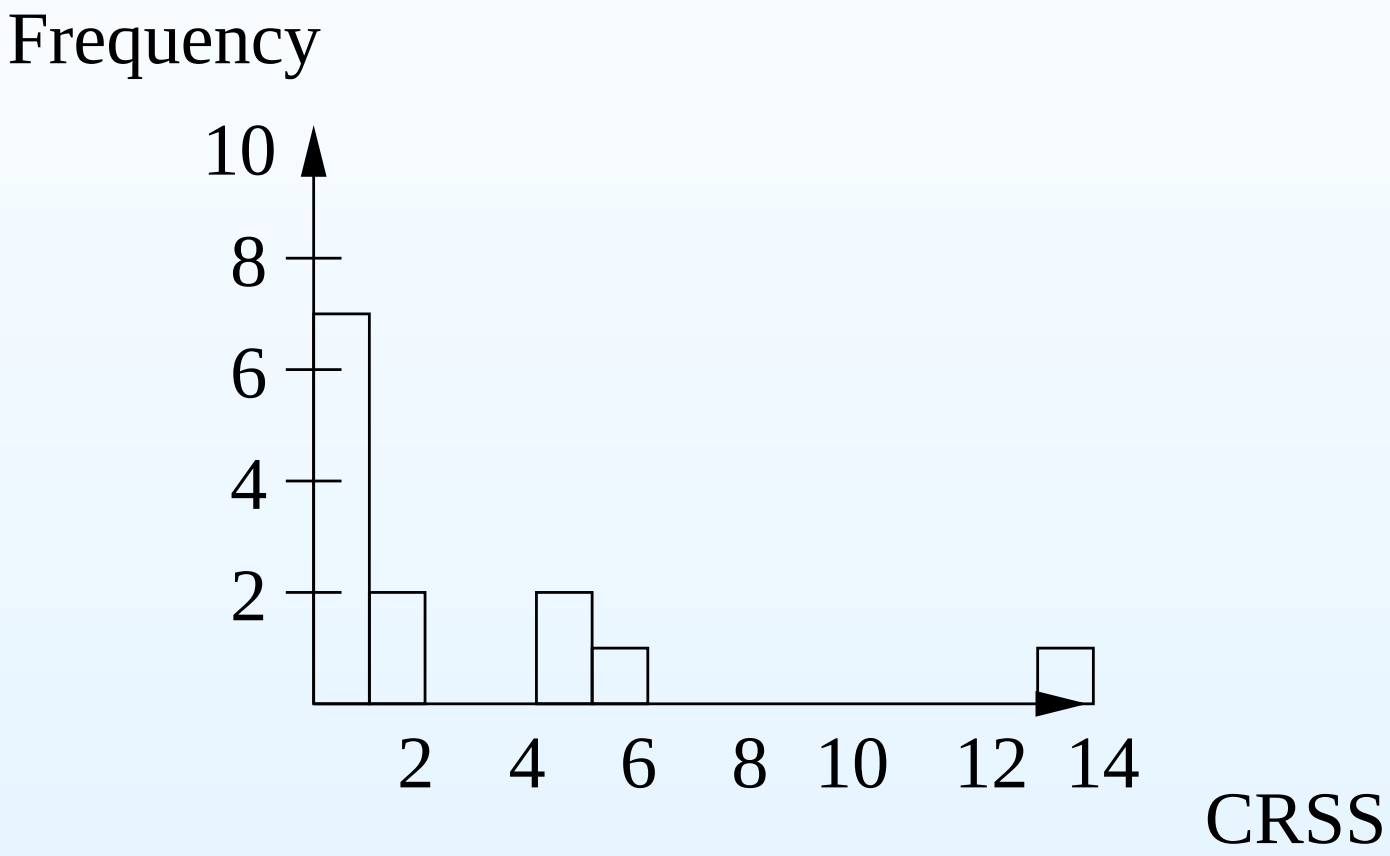


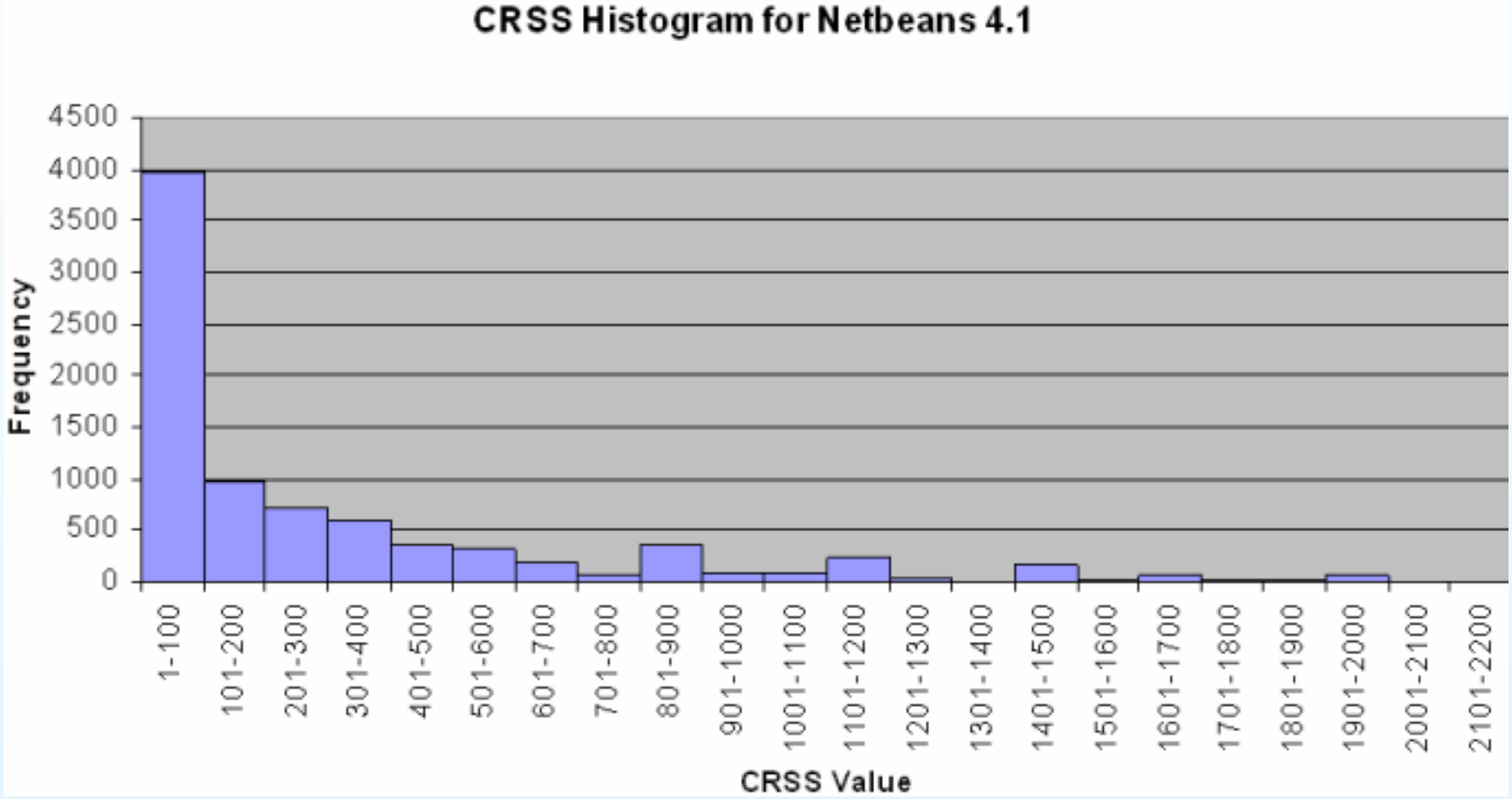
CRSS values



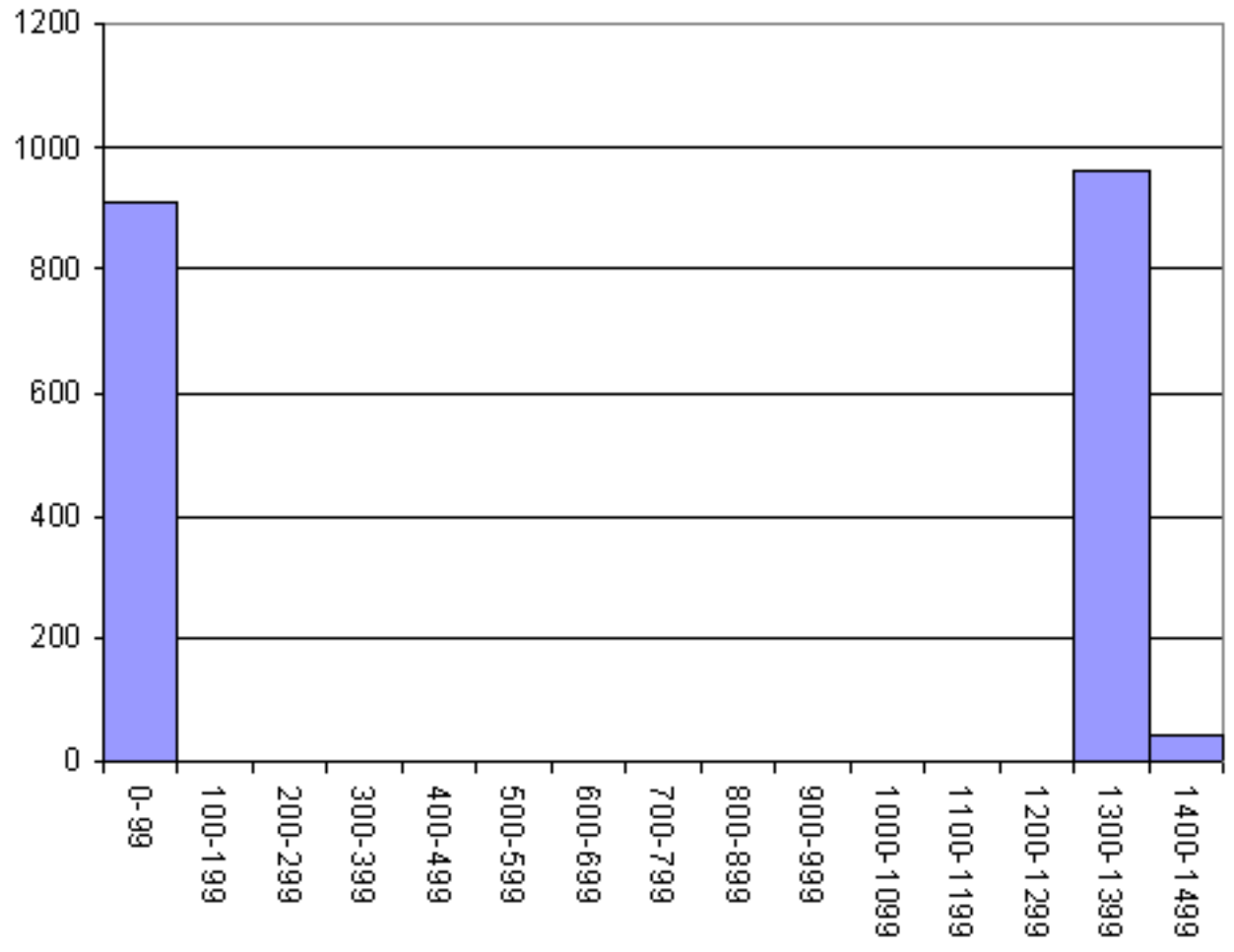
Presenting CRSS data



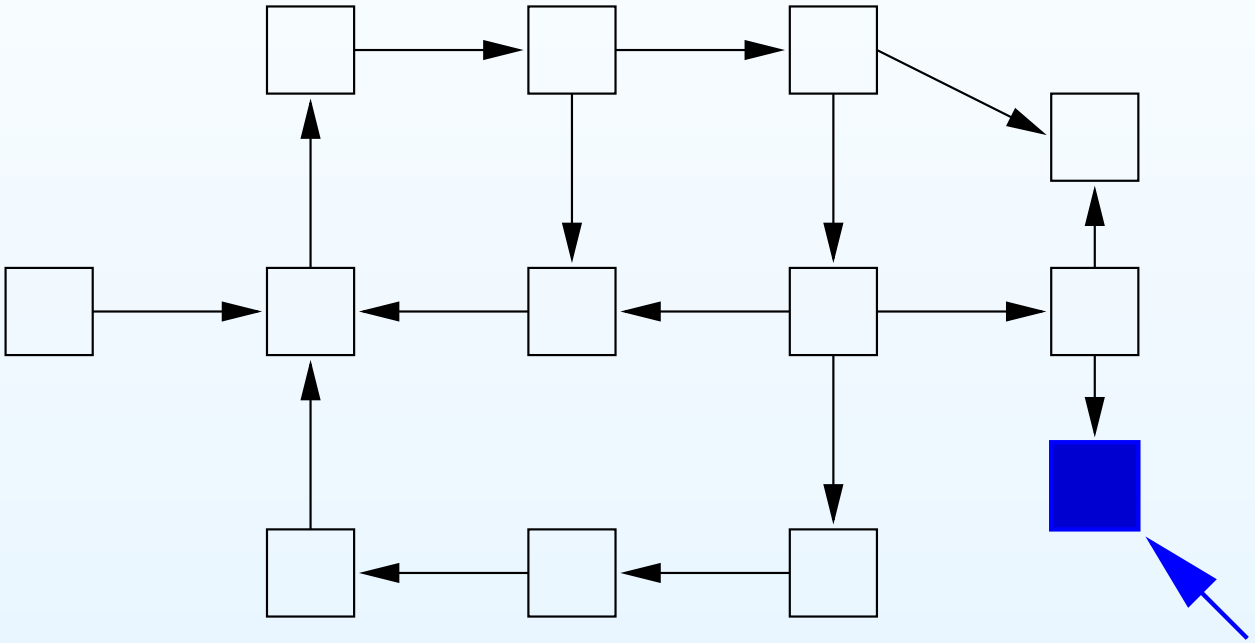
Netbeans CRSS



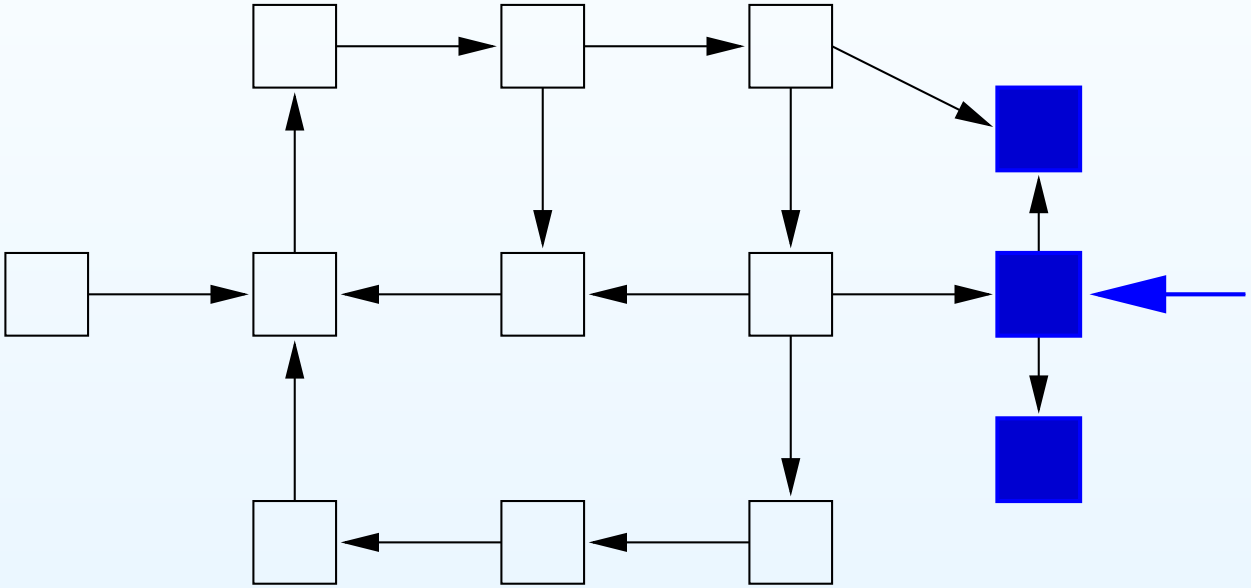
Azureus CRSS distribution



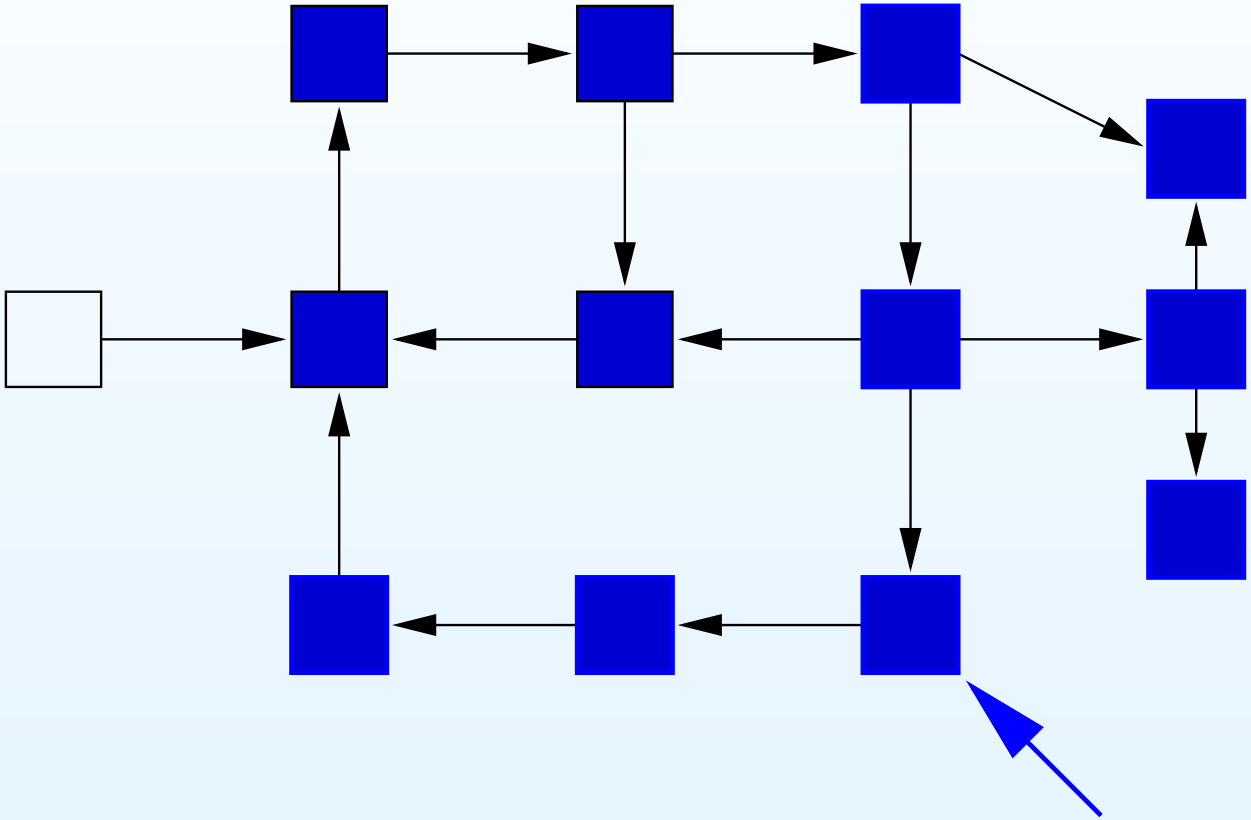
Class Reachability Sets



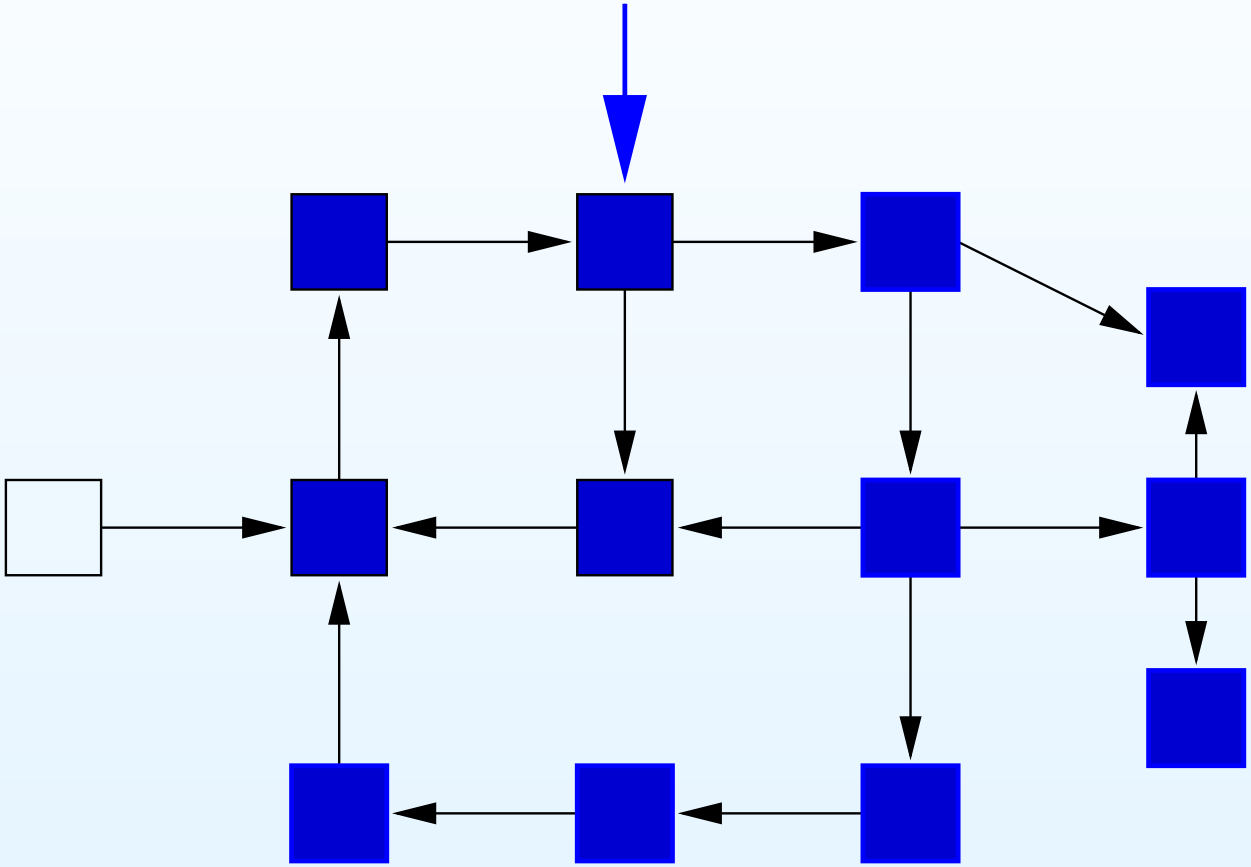
Class Reachability Sets



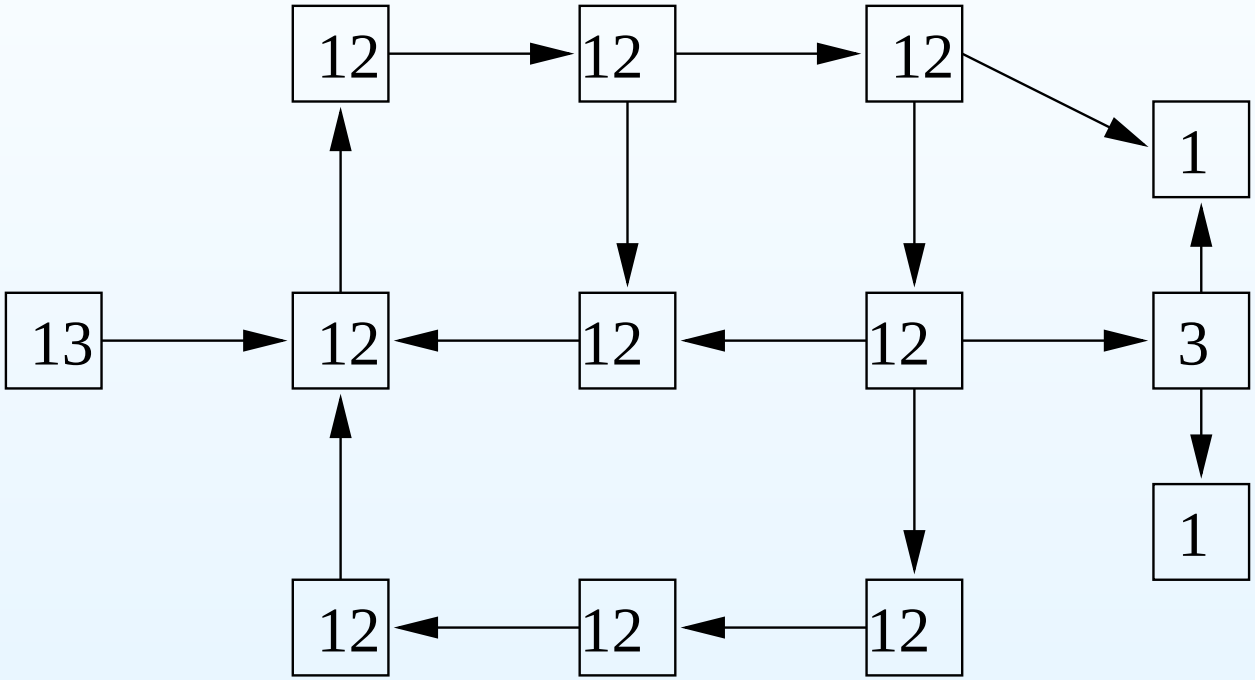
Class Reachability Sets



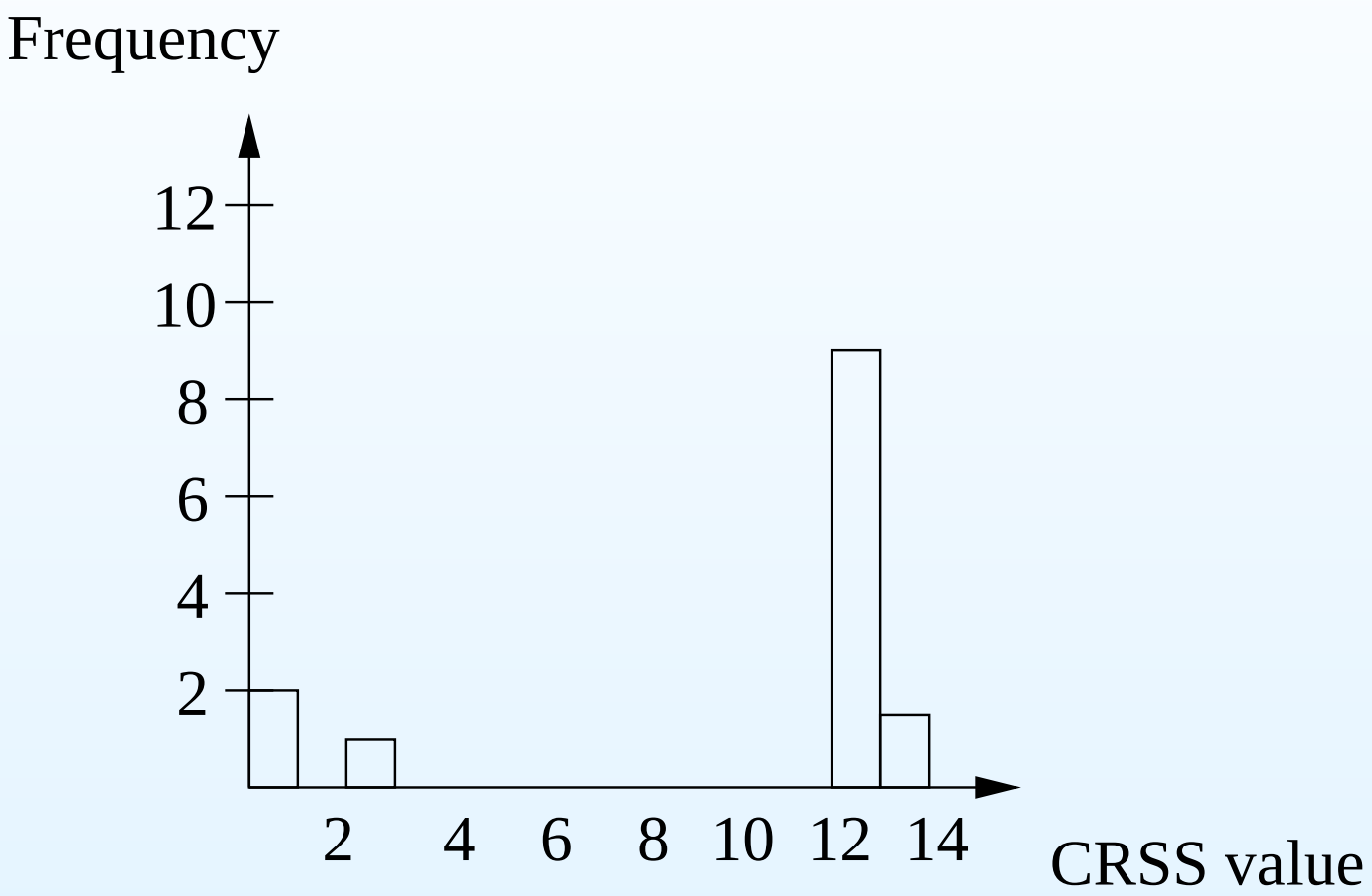
Class Reachability Sets



CRSS values



Presenting CRSS data



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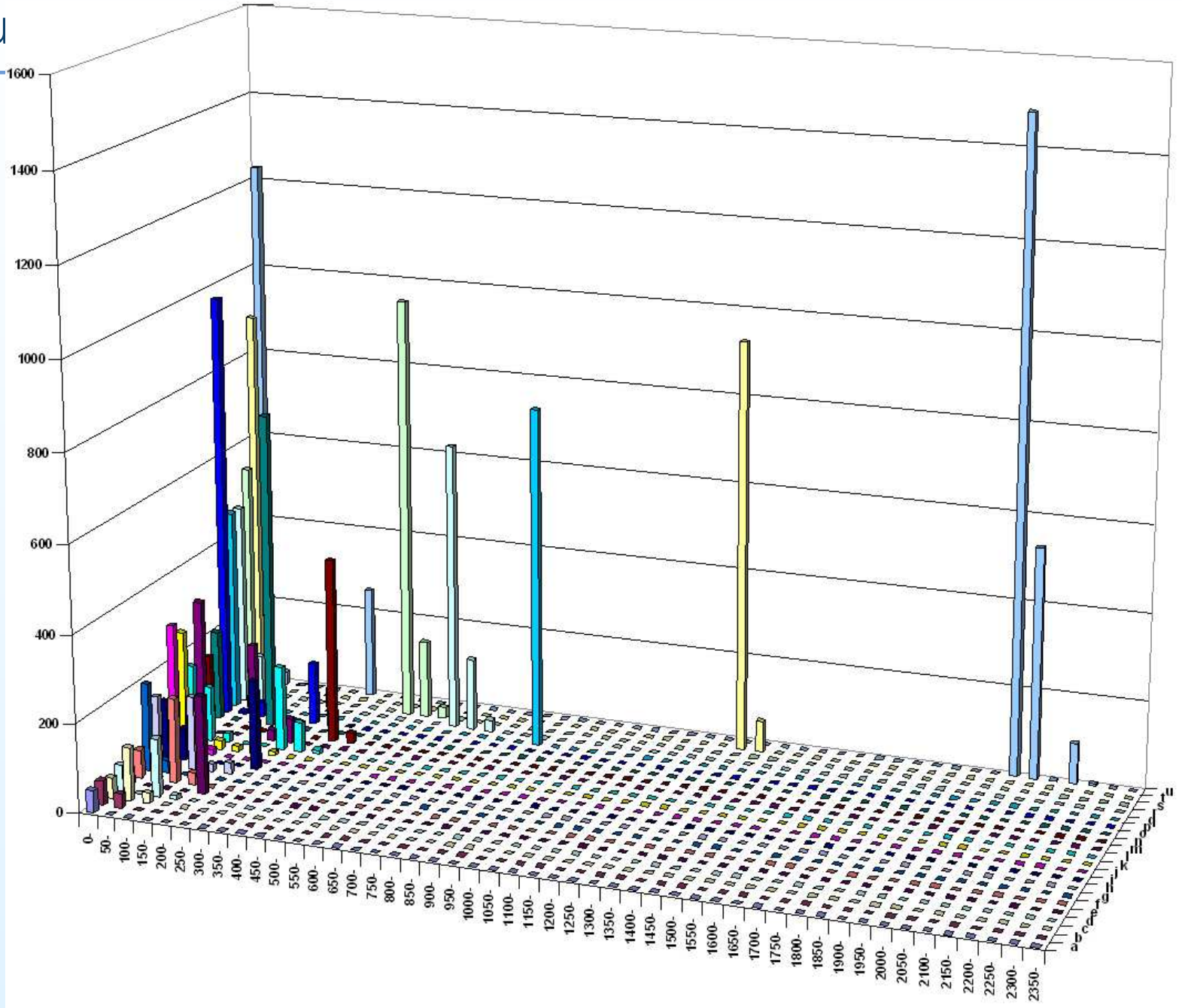
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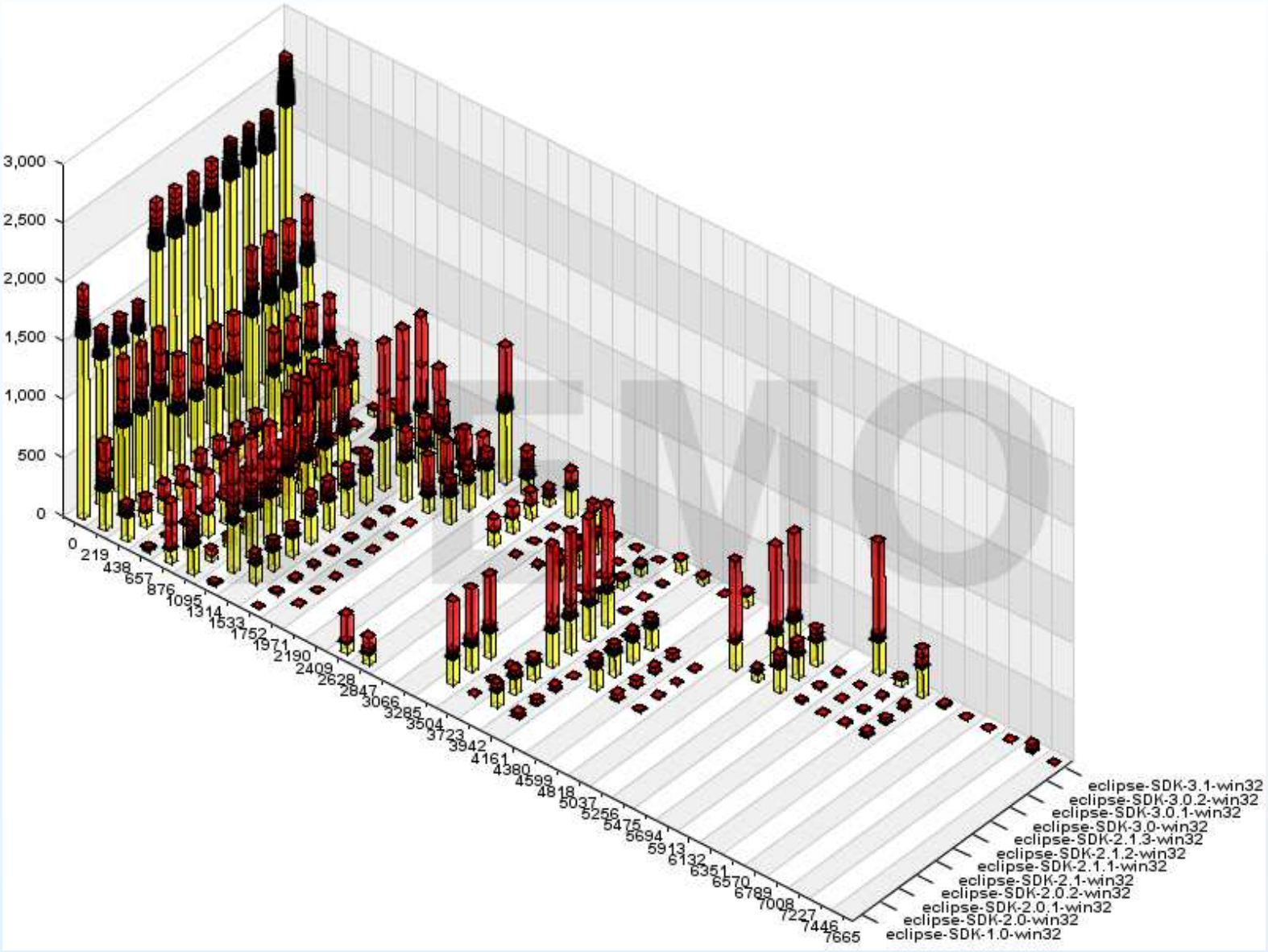
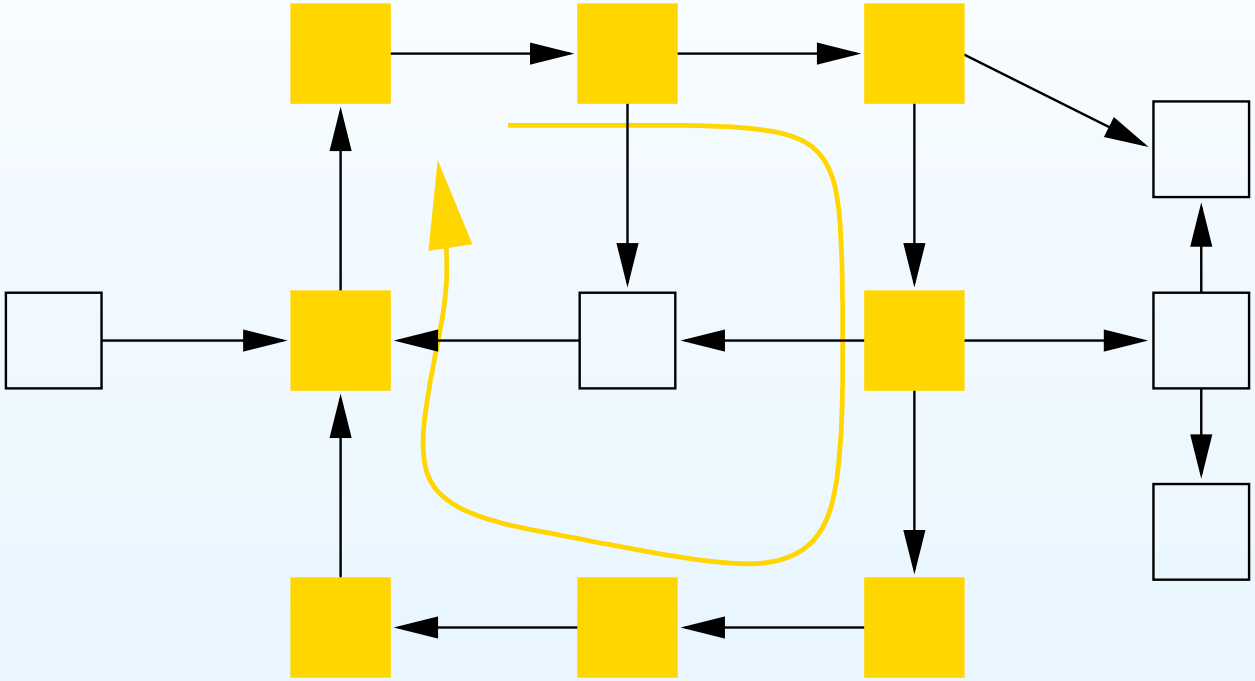
Eclipse CRSS progression



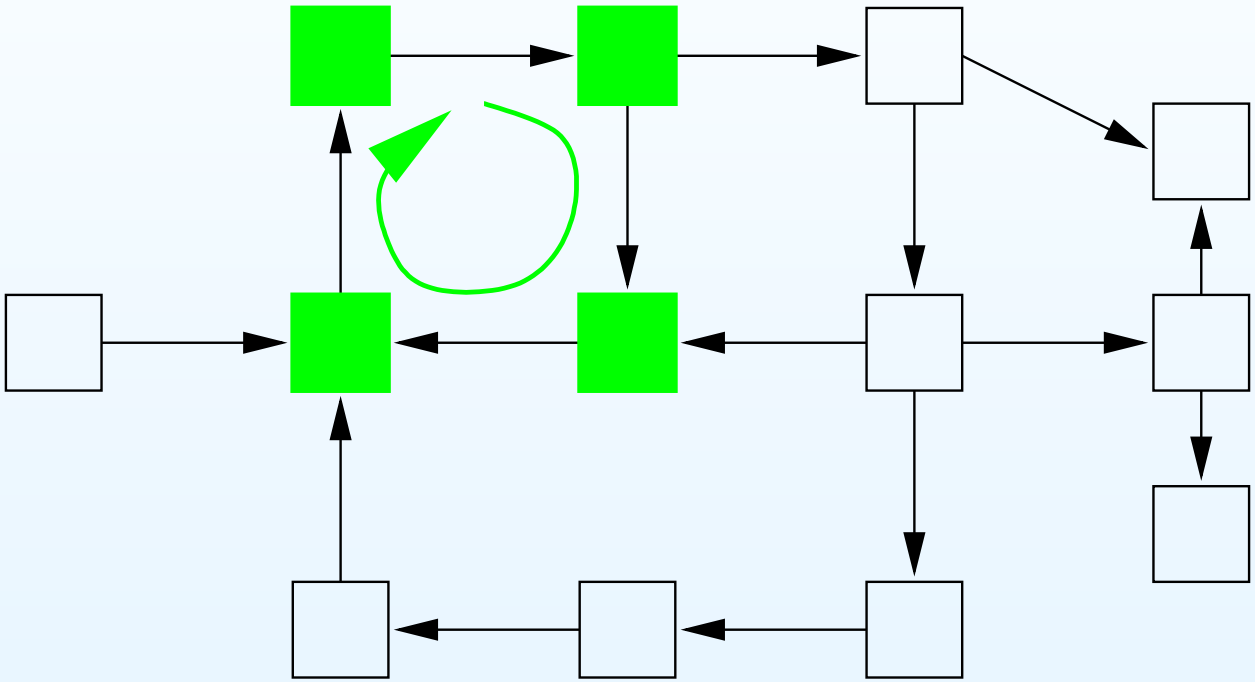
Why Cycles are bad

- Understandability — where to start?
- Testability — where to start?
- Reusability — have to take everything

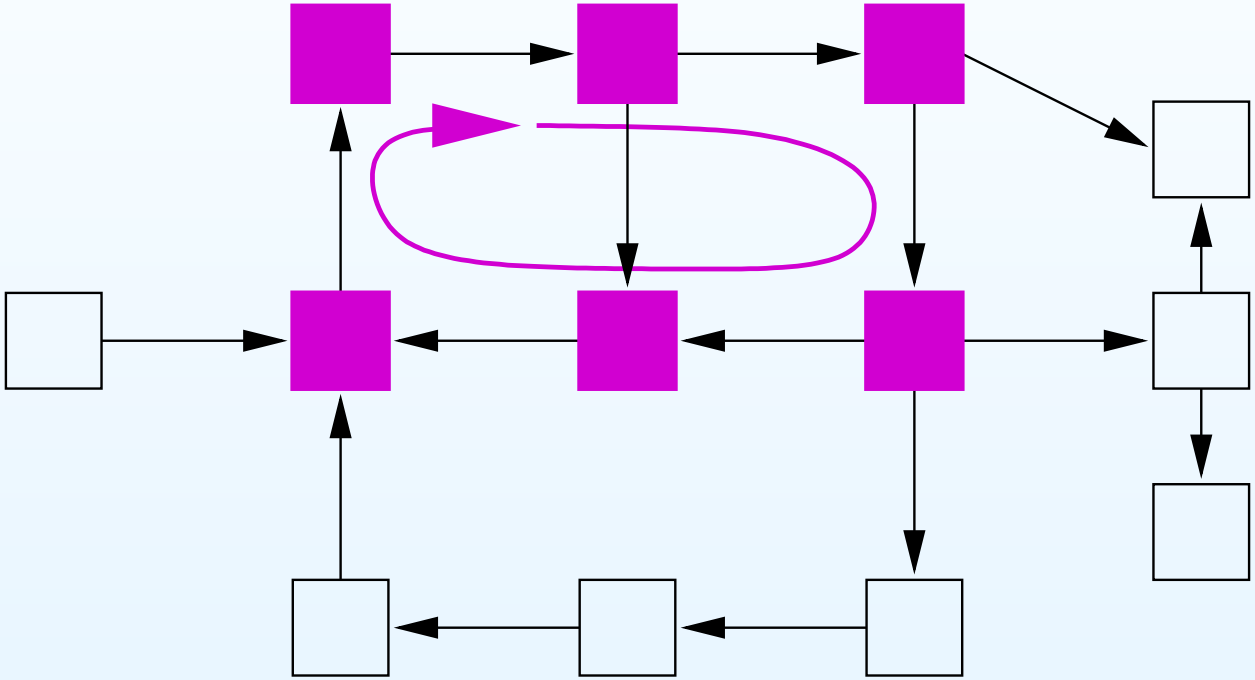
“Measuring Cycles”



“Measuring Cycles”



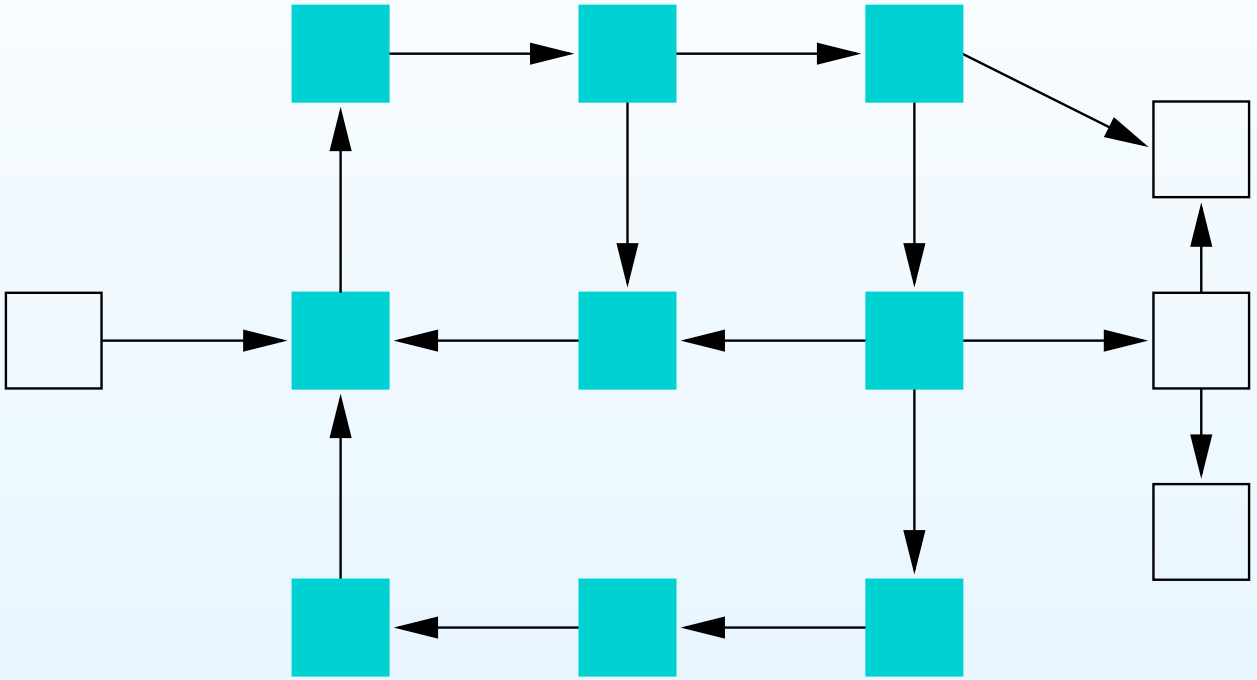
“Measuring Cycles”



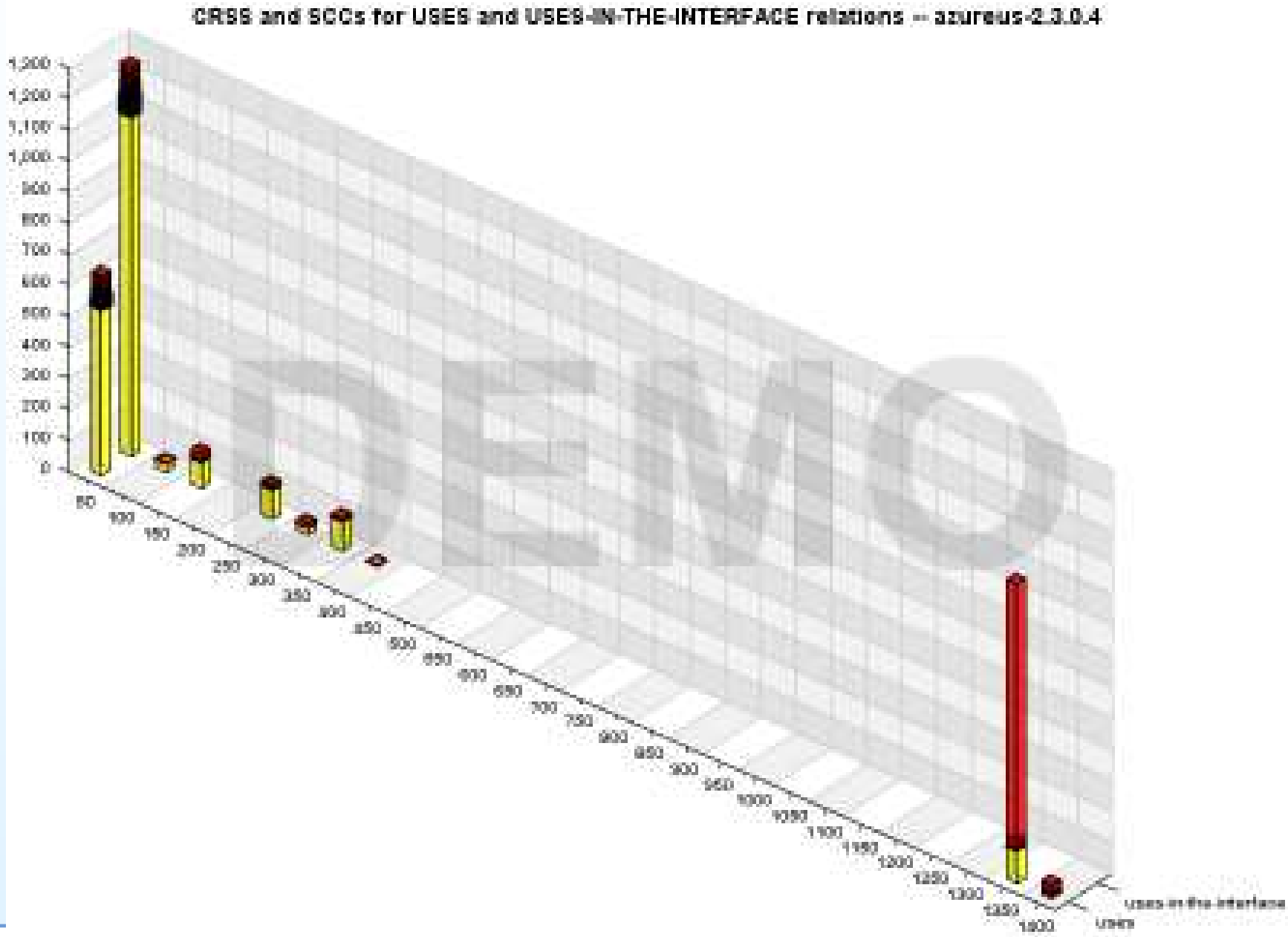
SCCS

- Strongly Connected Components (SCC) — subgraph in which every vertex is *reachable* from every other vertex
- Largest “cycle” for a given set of vertices
- SCCS — Strongly Connected Component Size

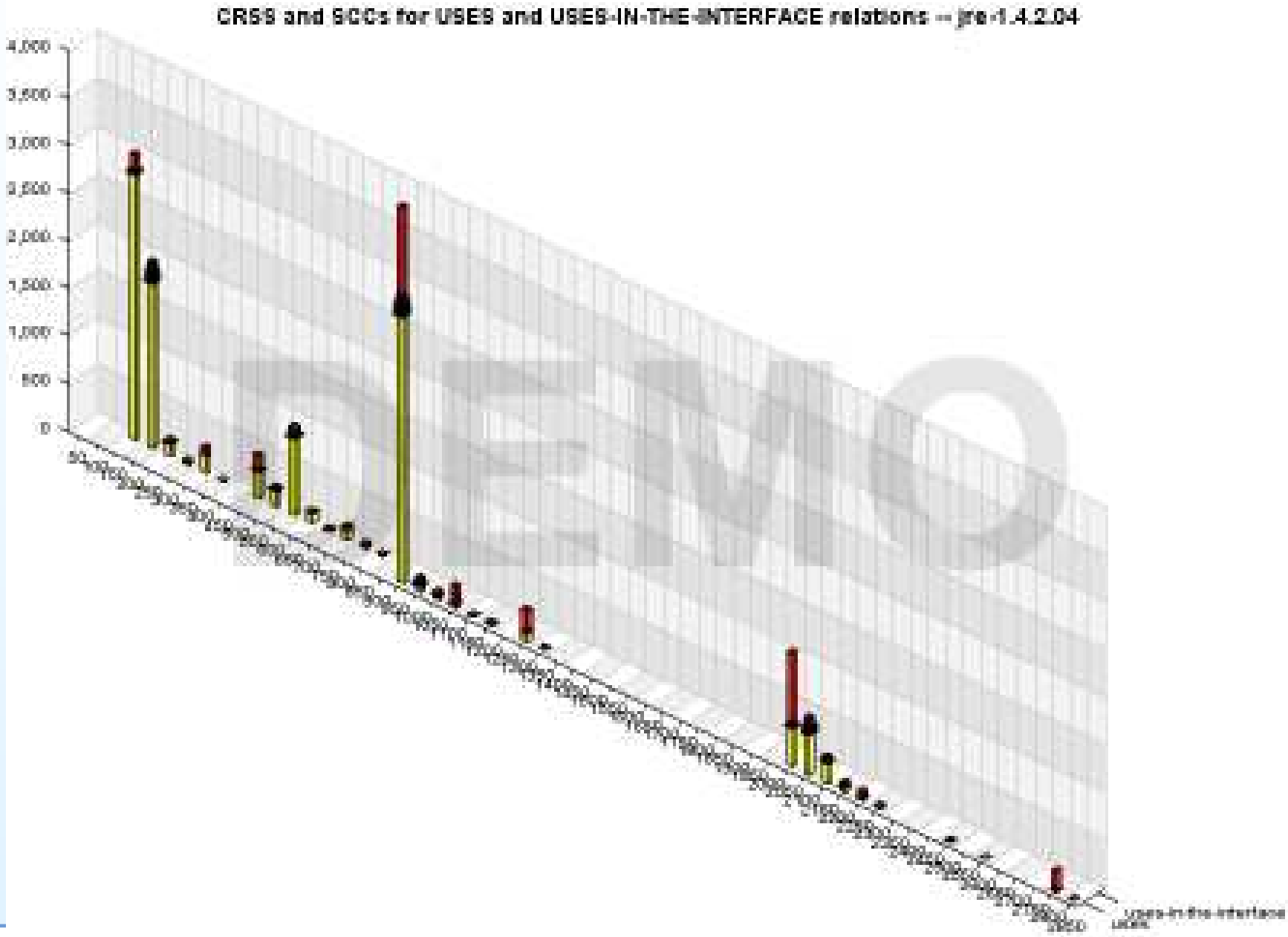
SCCS

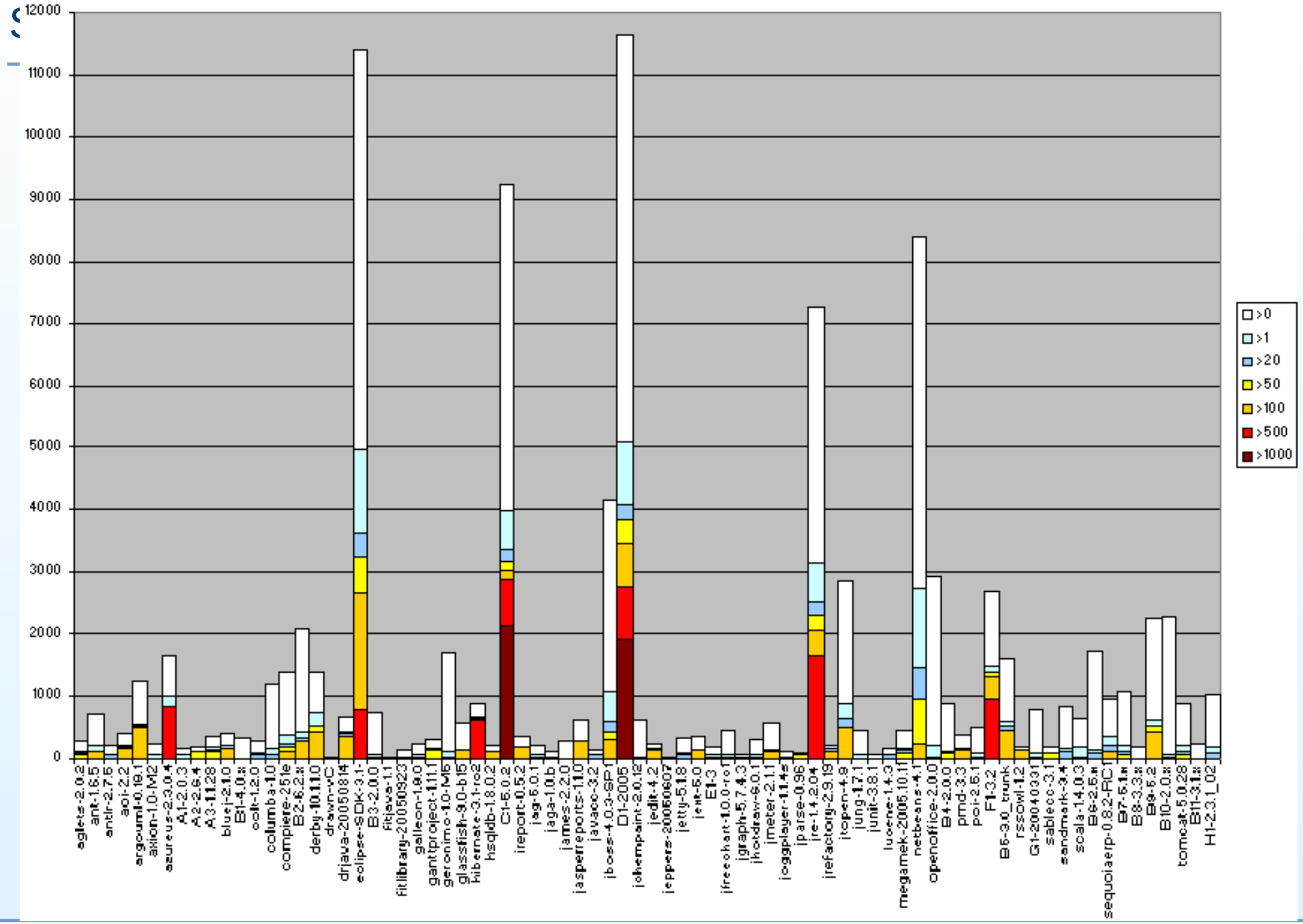


Azureus-2.3.0.4 SCCS



JRE-1.4.2.04 SCCS

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B8-3.3.x
B9-6.2
B10-2.0.x
tomcat-5.0.28
B11-3.1.x
H1-2.3.1_02

The joy of debugging

```
public class D {
  private String s;
  public D(String s) {
    this.s = s;
  }
  public void doD() {
    System.out.println(s.trim());
  }
}
```

- When executing an application containing this class, a `NullPointerException` occurs when `trim` is called.
- Questions we must answer in trying to identify the fault that led to the observed failure:
  - How is it that `s` is null?
  - Where did the `null` come from?

Finding null

```
public class A {
    public static void main(String[] args) {
        C c = B.create();
        D d = new D(c.get());
        d.doD();
        E.doE(c);
    }
}

public class C {
    private String str;
    public String get() {
        return str;
    }
    public void set(String str) {
        this.str = str;
    }
}
public class E {
    public static void doE(C c) {
        F f = new F();
        f.doF(c.get());
    }
}
```

```
public class B {
    String name;
    public static C create() {
        C c = new C();
        c.set(name);
    }
}

public class D {
    private String s;
    public D(String s) {
        this.s = s;
    }
    public void doD() {
        System.out.println(s.trim() );
    }
}

public class F {
    public void doF(String string) {
        D d = new D(string);
        do.doit();
    }
}
```

Use-Def Chains

```
public class A {
    public static void main(String[] args) {
        C c = B.create();
        D d = new D(c.get());
        d.doD();
        E.doE(c);
    }
}

public class B {
    String name;
    public static C create() {
        C c = new C();
        c.set(name);
    }
}

public class C {
    private String str;
    public String get() {
        return str;
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    public void set(String str) {
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    }
}

public class D {
    private String s;
    public D(String s) {
        this.s = s;
    }
    public void doD() {
        System.out.println(s.trim() );
    }
}

public class E {
    public static void doE(C c) {
        F f = new F();
        f.doF(c.get());
    }
}

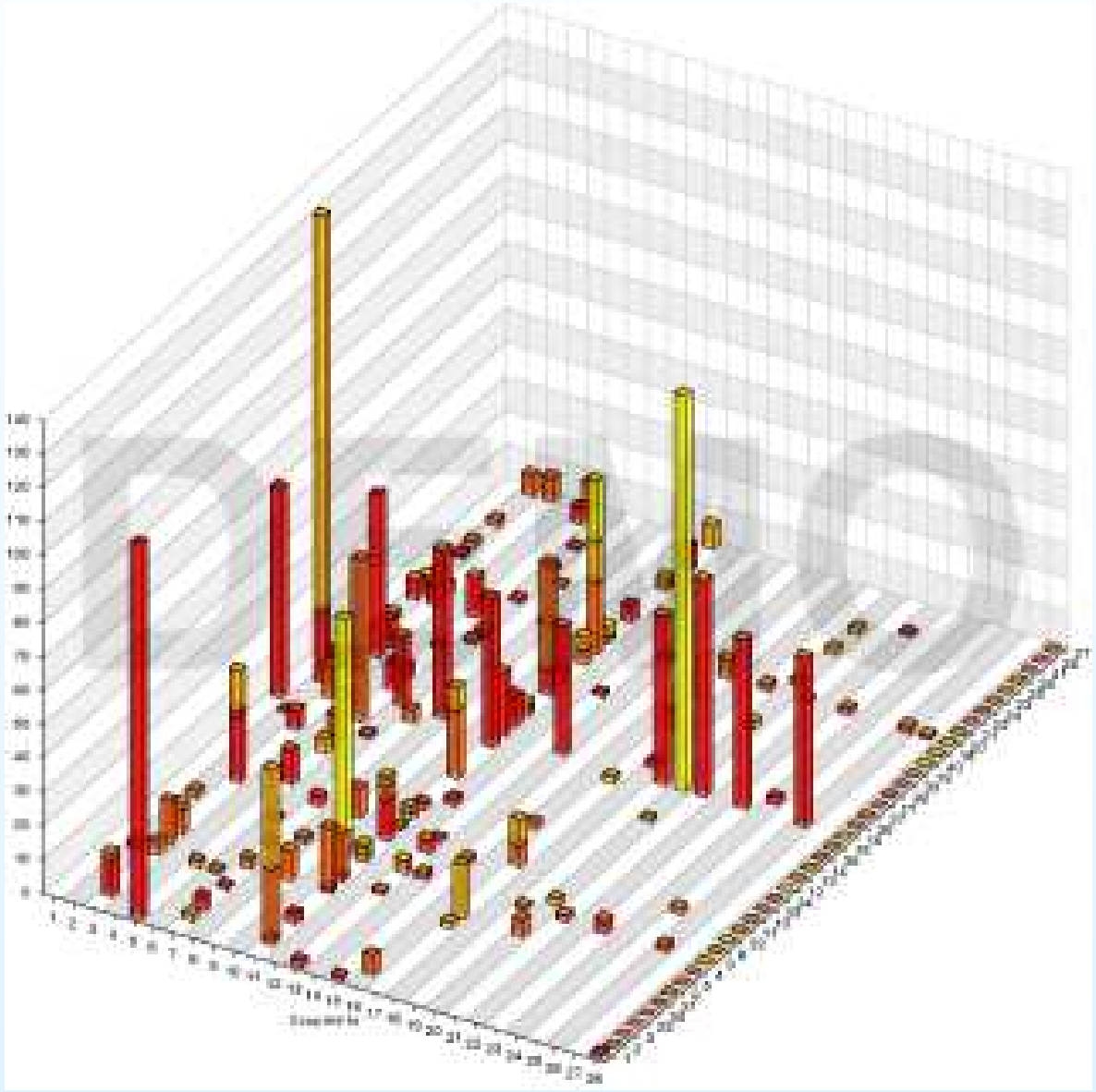
public class F {
    public void doF(String string) {
        D d = new D(string);
        do.doit();
    }
}
```

Use-Def Indirect Coupling

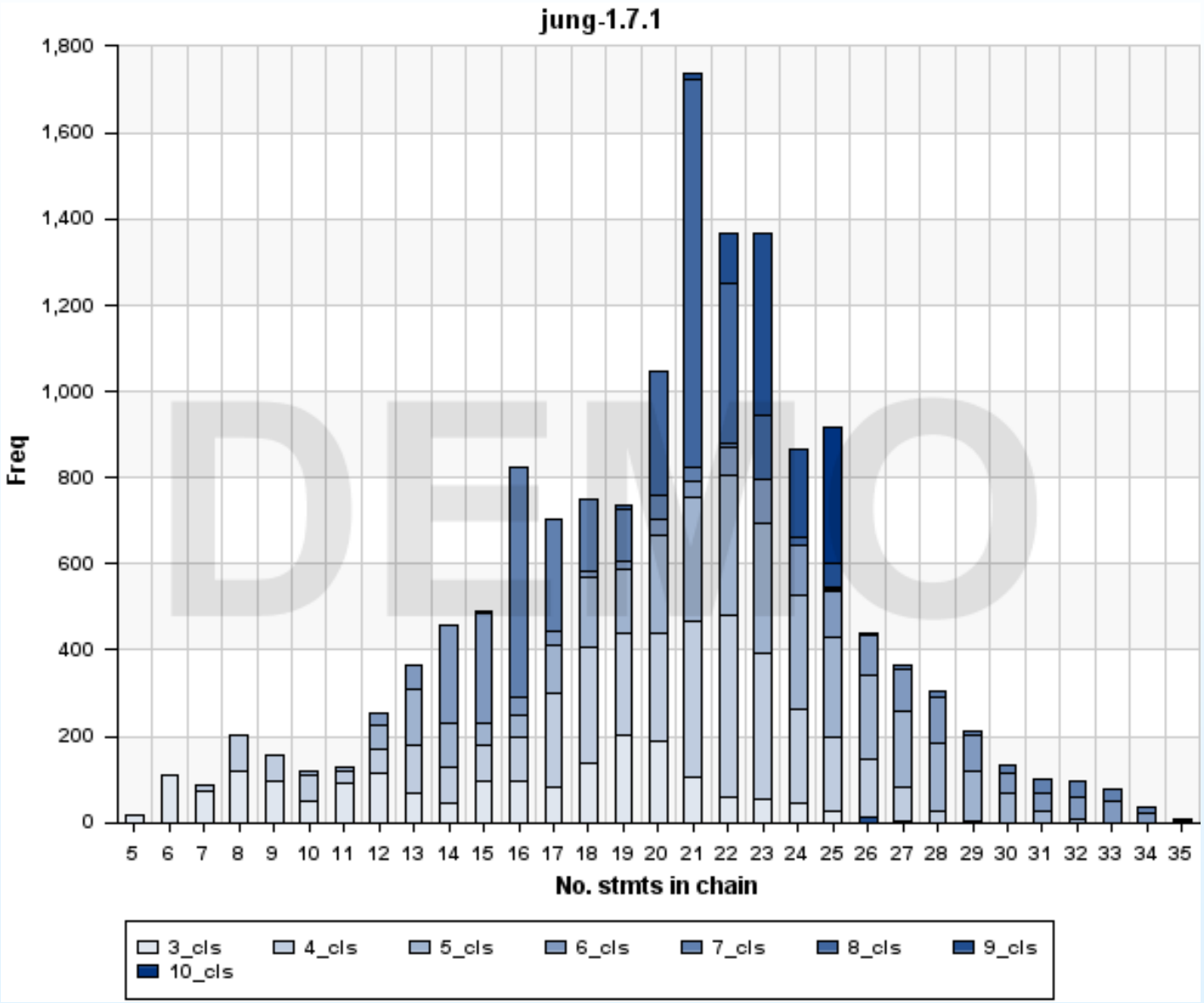
- A class A is use-def indirectly coupled to a class B if a value **defined** in B is **used** in A
- The path between use and def is called a use-def chain
- Intuition is that this kind of coupling can be a source of difficulty — when a failure occurs in D it's not obvious that one should consider B

Hong Yul Yang's PhD research

Indirect Coupling between classes



Lengths of chains



How to measure code?

- Need to parse code — create syntax model (aka abstract syntax trees)
- Need to resolve names — create semantic model
- Need sophisticated analysis for some metrics
- Need code!

Parsing Issues

- Different issues for different languages
- Even “simple” languages such as Java are not easy to parse
- Analysing code $\neq$ compiling code

Language Issues

```
#include <iostream>
#include <string>
#include "Address.cpp"

using namespace std;

int main() {
        Address add;
        cout << add.print() << endl;
}
```

But Java is a simple language!

- lots of parsers around, none of them easy to use
- lots of grammars around, all of questionable quality
- and Java isn't simple . . .
- (but it is simpler than C++)
- (and there's lots of code around)
- (and we can analyse bytecode!)

Source vs Bytecode

```
class A {
    E field;
    public void method(B aB, C aC) {
      D aD = aB;
      field.doit(aC.getIt(aD), Math.PI);
    }
}
```

Source vs Bytecode

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    }
}
```

Source vs Bytecode

```
enum MyEnum { A, B, C; }
```

```
class MyEnum extends java.lang.Enum {

}
```

Analysing code $\neq$ compiling code

- Need to build model for whole “program”
  - E.g., Eclipse is about 12,000 classes, 1.5 million LOC — one model?
- Some metrics require analysis not required in compilation
  - E.g., use-def chains

Software Corpora

- Corpus — A collection of writings or recorded remarks used for linguistic analysis
- If all analysis is done on the same corpus, then results are more likely to be comparable (benchmarks)
- If the corpus is representative of a population, then findings due to analysis might apply to the whole population
- Should work for software too!
  - $>$ 100 open-source Java applications
  - $>$ 250 versions (e.g. 13 versions of eclipse)
  - source code of most
  - byte code of most
  - needs to be managed

From Metrics to Process

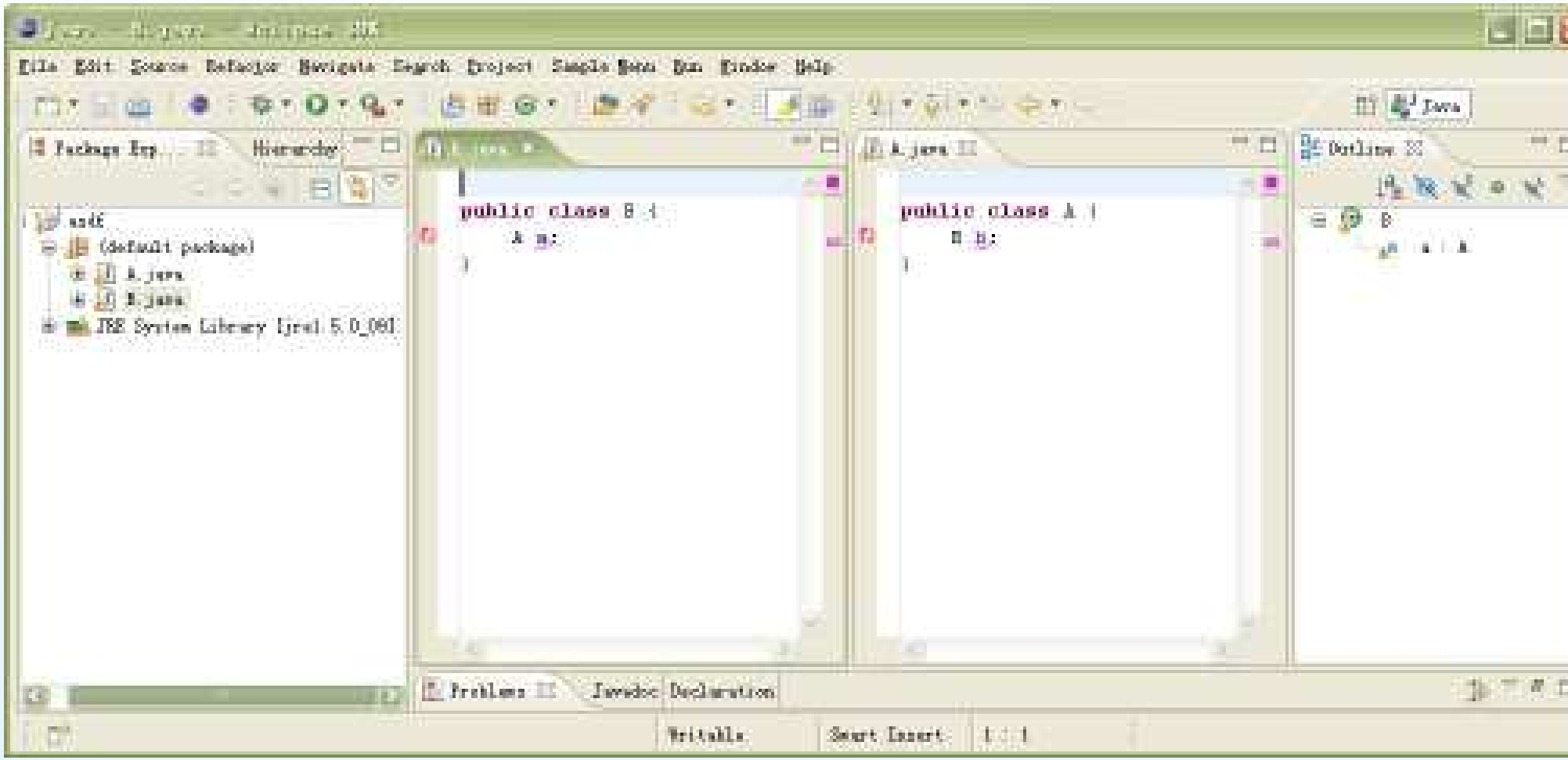
- If cycles are bad, let's not have any

$\Rightarrow$ tool support for detecting cycles

$\Rightarrow$ should be part of development environment

$\Rightarrow$ JooJ

JooJ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}
A.java
public class A {
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}
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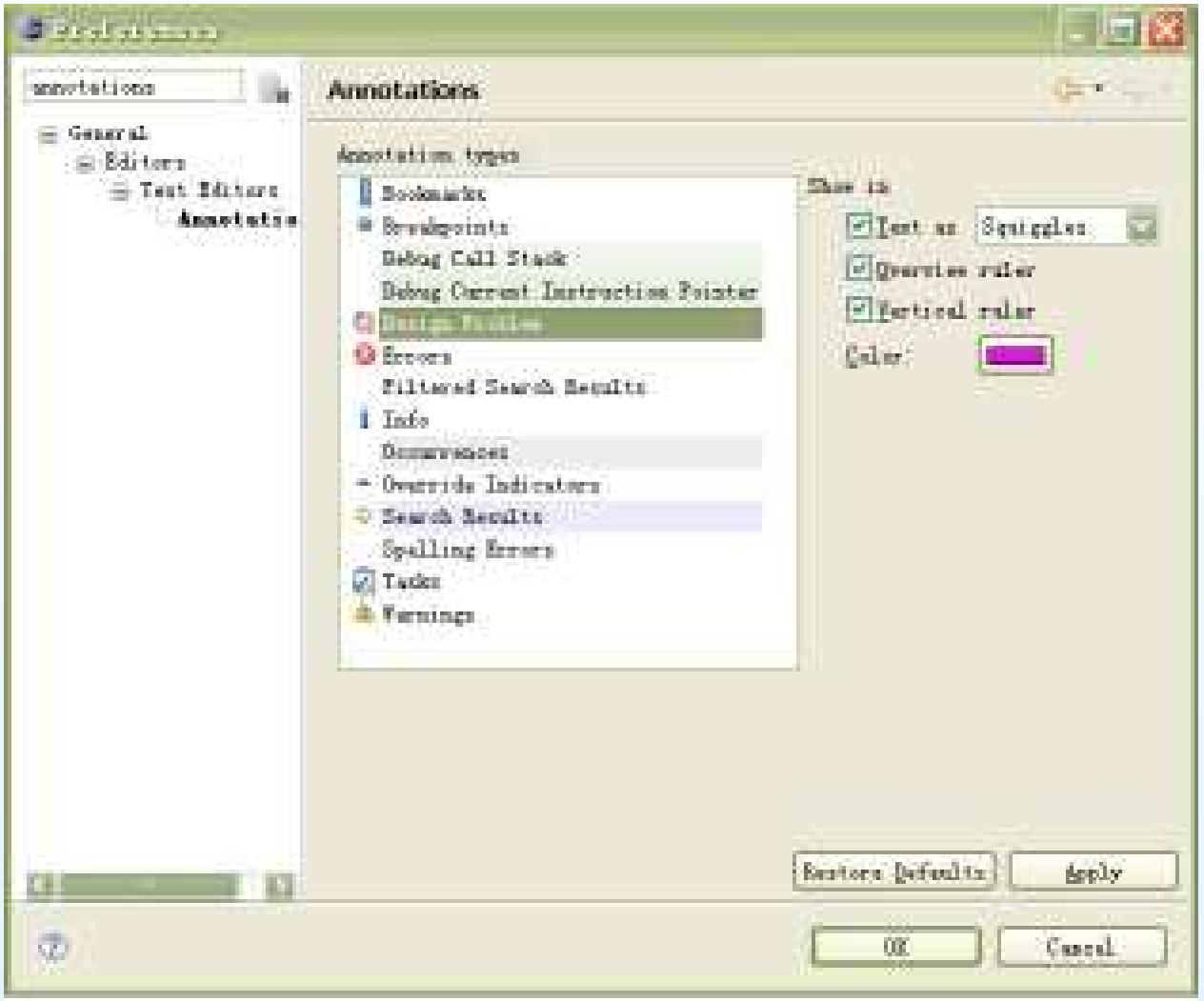
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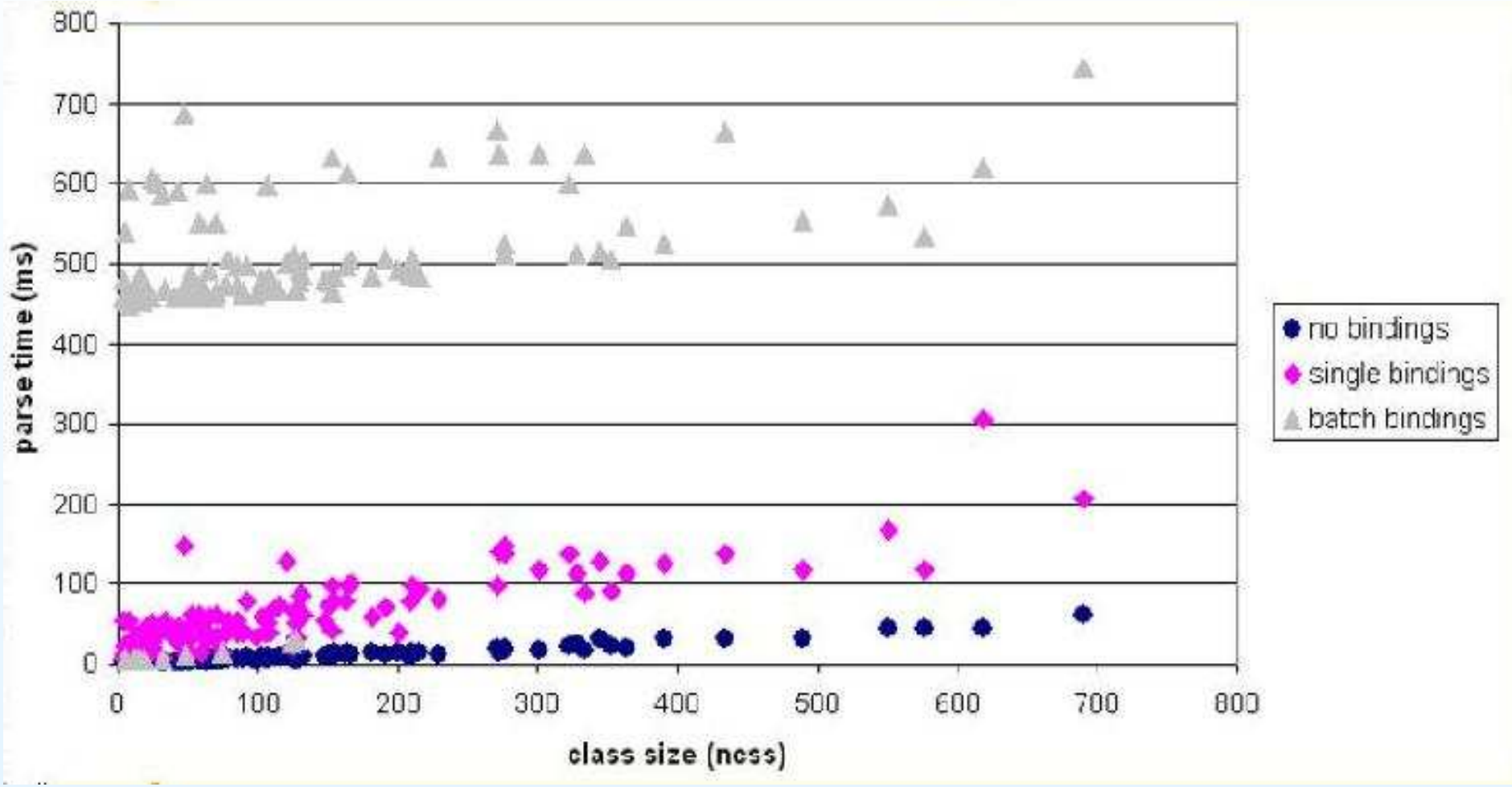
Spelling Errors
Tasks
Warnings
Text as
Squiggles
Vertical ruler
Color
Restore Defaults
Apply
OK
Cancel

How Fast?


800
700
600
500
400
300
200
100
0
parse time (ms)
0
100
200
300
400
500
600
700
800
class size (ncss)
no bindings
single bindings
batch bindings

Tools for Producing Quality Software

- Measurement instruments
  $\Rightarrow$ development support
- Corpus Management
- Data analysis and presentation