Practical Challenges in Object-Oriented Dependence Analysis

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Introduction

Context

- OO paradigm is the de-facto choice for software development
- Subject to several factors that hamper dependence analysis

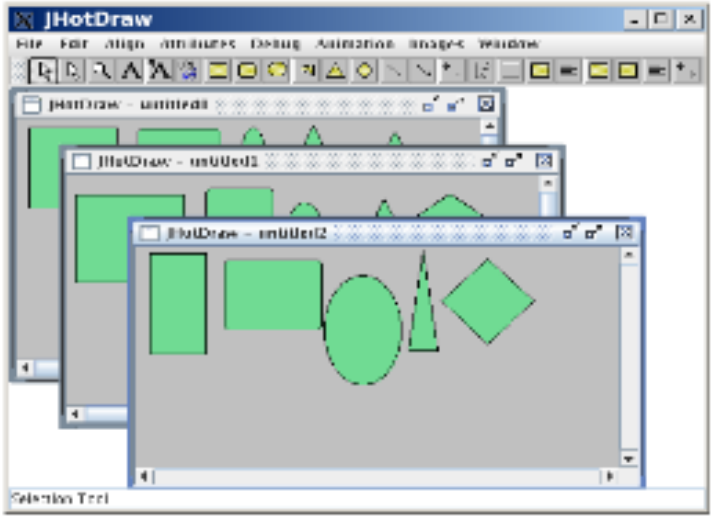
Aim of the talk

- To show problems that arise with static analysis of OO code
- From the perspective of my thesis work
  - Develop a source code reading tool
  - Purpose: To navigate the source code related to a given system-level feature

To bear in mind...

- Thesis work carried out 2002-2005
  - Some opinions could be out of date
- Have tried to link relevant slides to discussion on functional slicing
  - Relevant slides marked

The Challenge of OO Feature Identification



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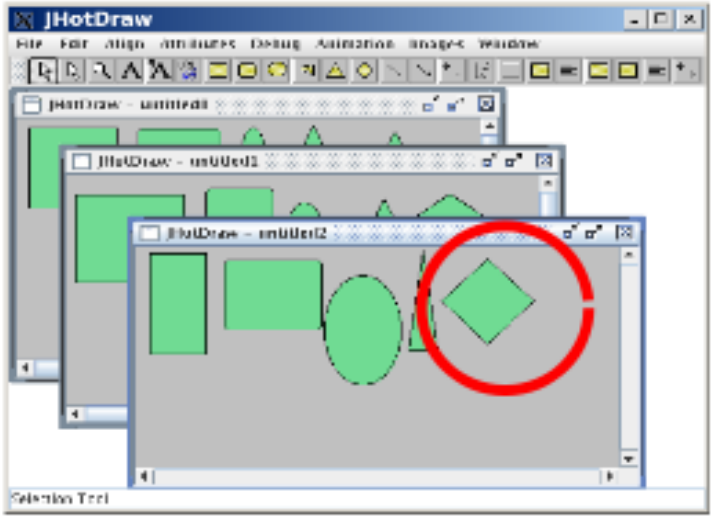

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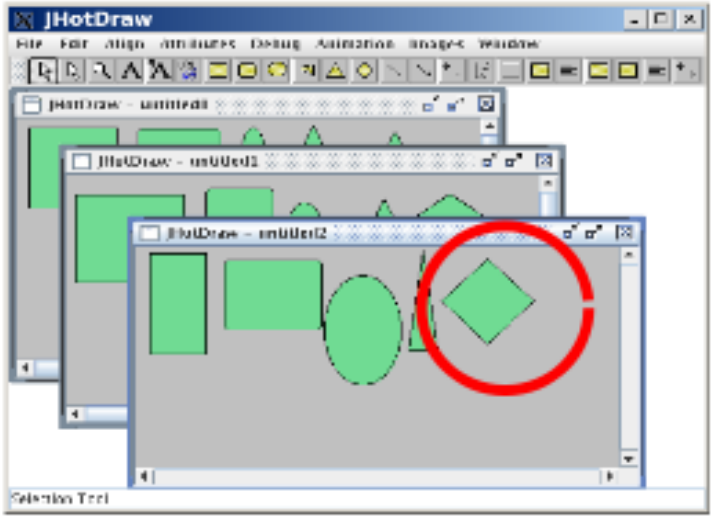

370 classes

1752 methods

3203 calls

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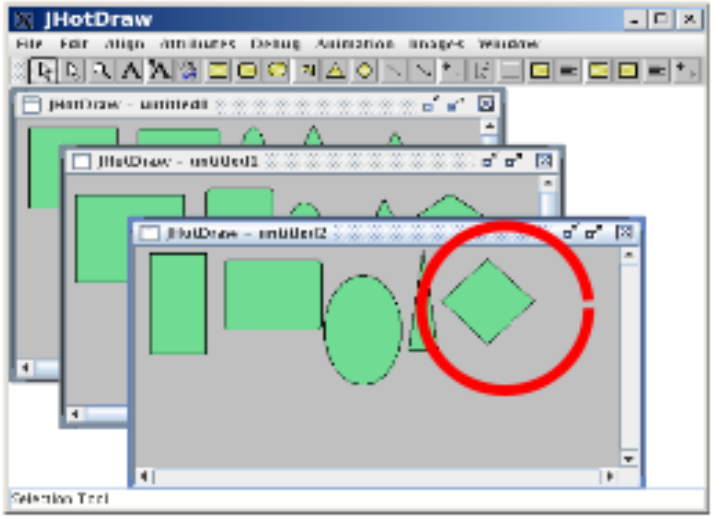

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How to identify and navigate through the code corresponding to the diamond tool?

Thesis idea

Use static code analysis, with limited input from developer

- Combine slicing, call graph analysis and developer input
- Should identify relevant methods and method calls
- Integrate into a code-reading interface

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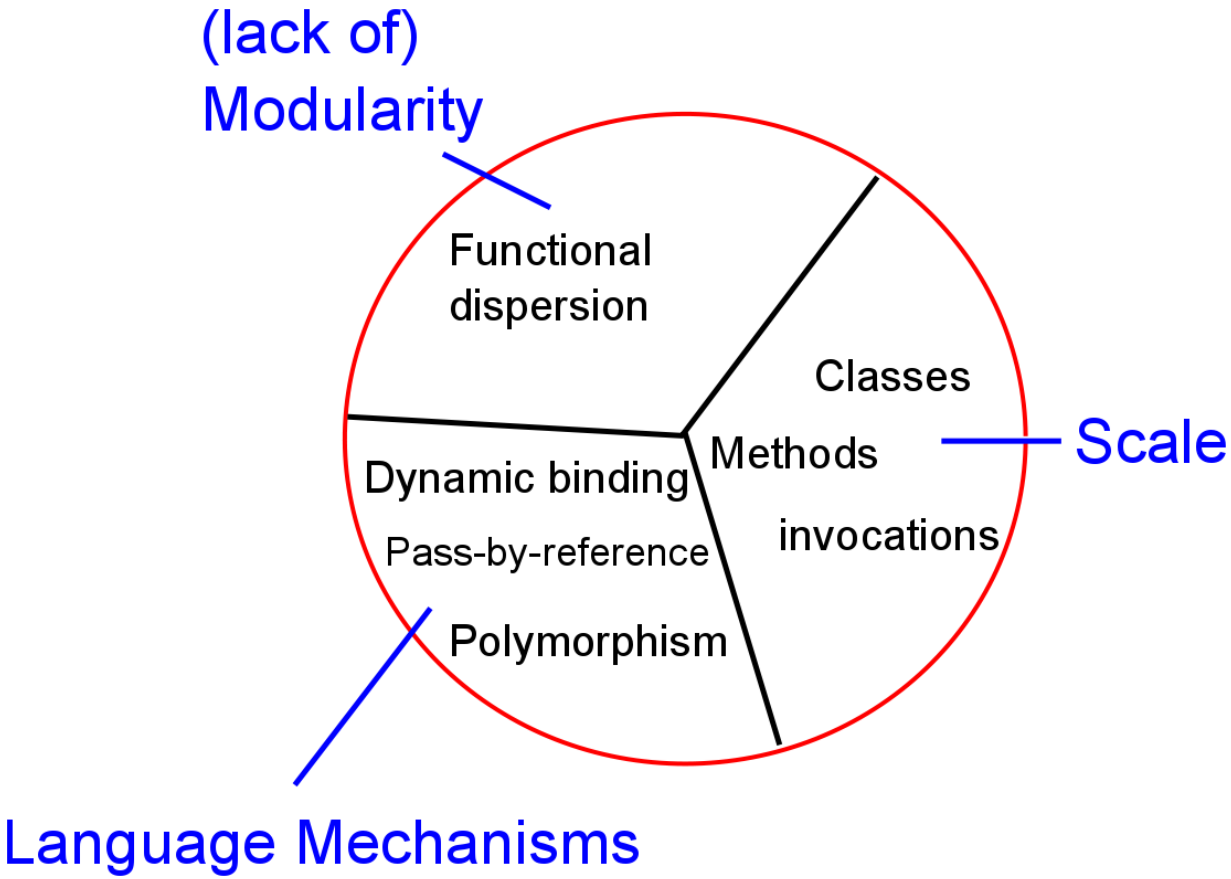
Outcome

- Possible to produce an accurate result
  - ... but only with large amount of help from the developer
- Problem massively exacerbated as scale increased

OO Static Analysis Challenges



Problems Posed by OO Mechanisms

Polymorphism and Dynamic Binding

- Type of an object is defined by the interface it provides
  - Implementations for methods declared in hierarchy
  - Methods bound to their implementations at runtime

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public void printArea(Figure f){
   double area = f.calculateArea();
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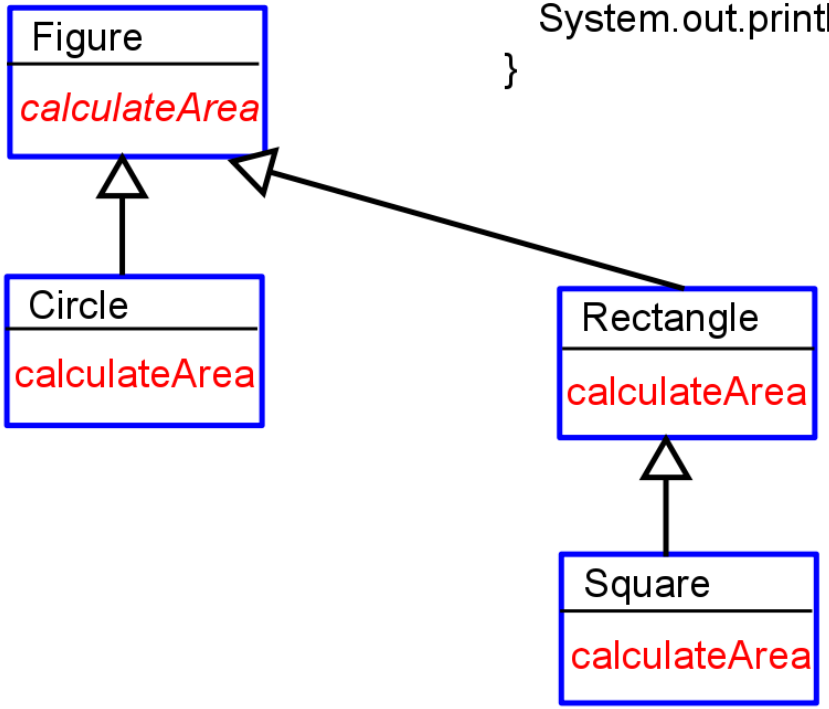

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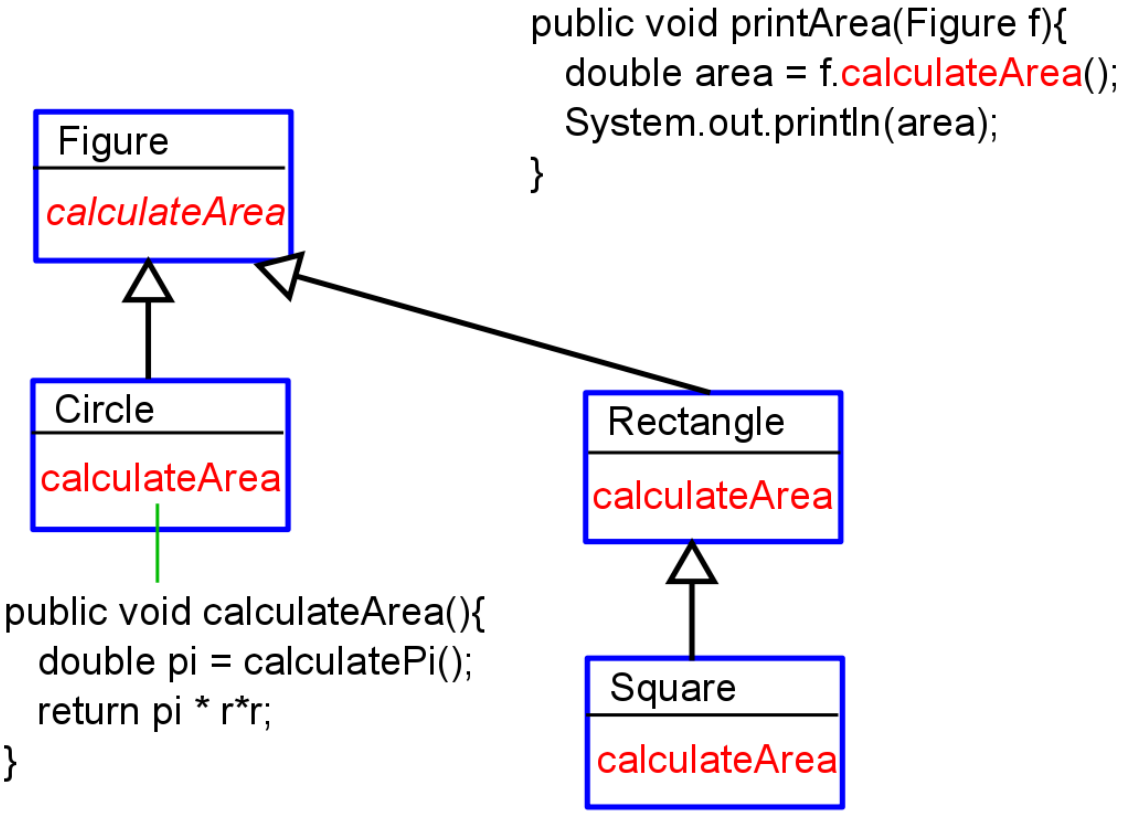

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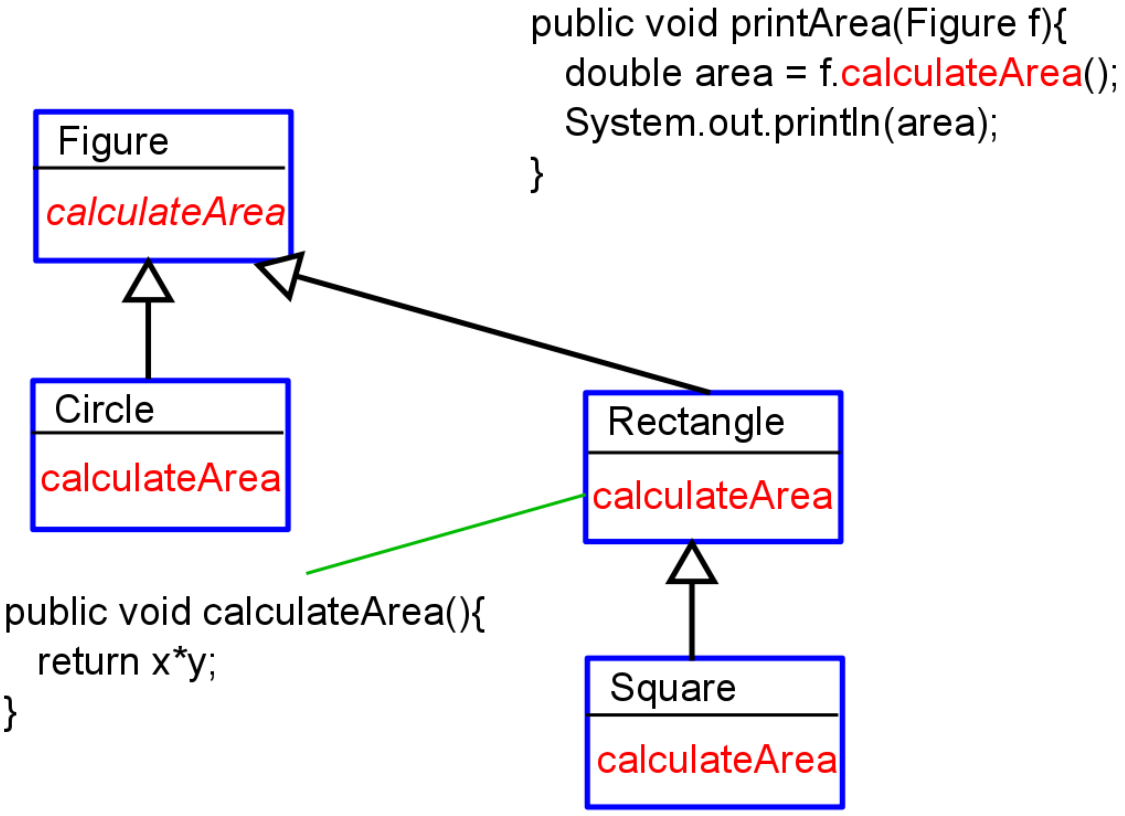

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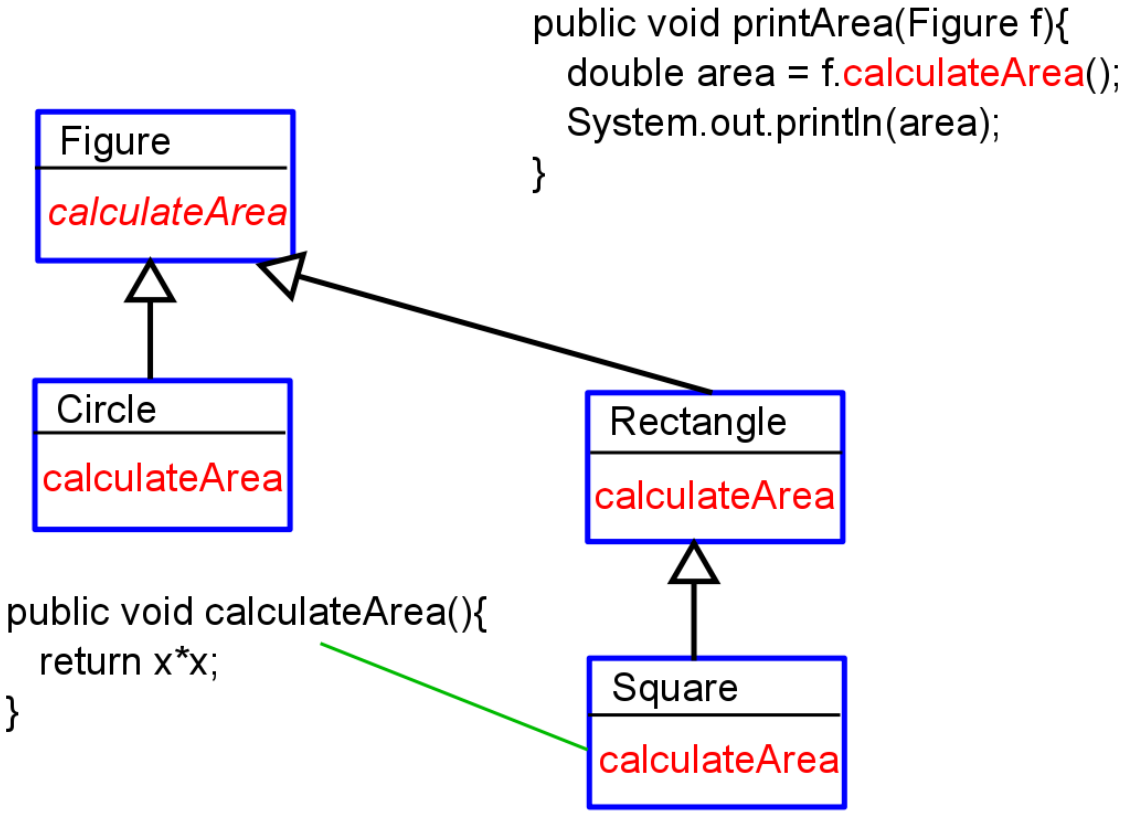

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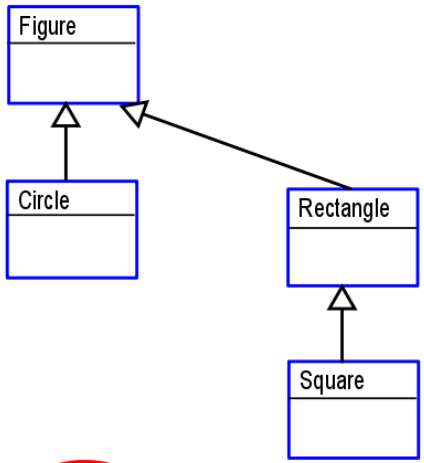

```
public void printArea(Figure f){
   double area = f.calculateArea();
   System.out.println(area);
   plot(f);
}

public void plot(Circle c){
    …
}

public void plot(Rectangle r){
    …
}

public void plot(Square s){
    …
}
```

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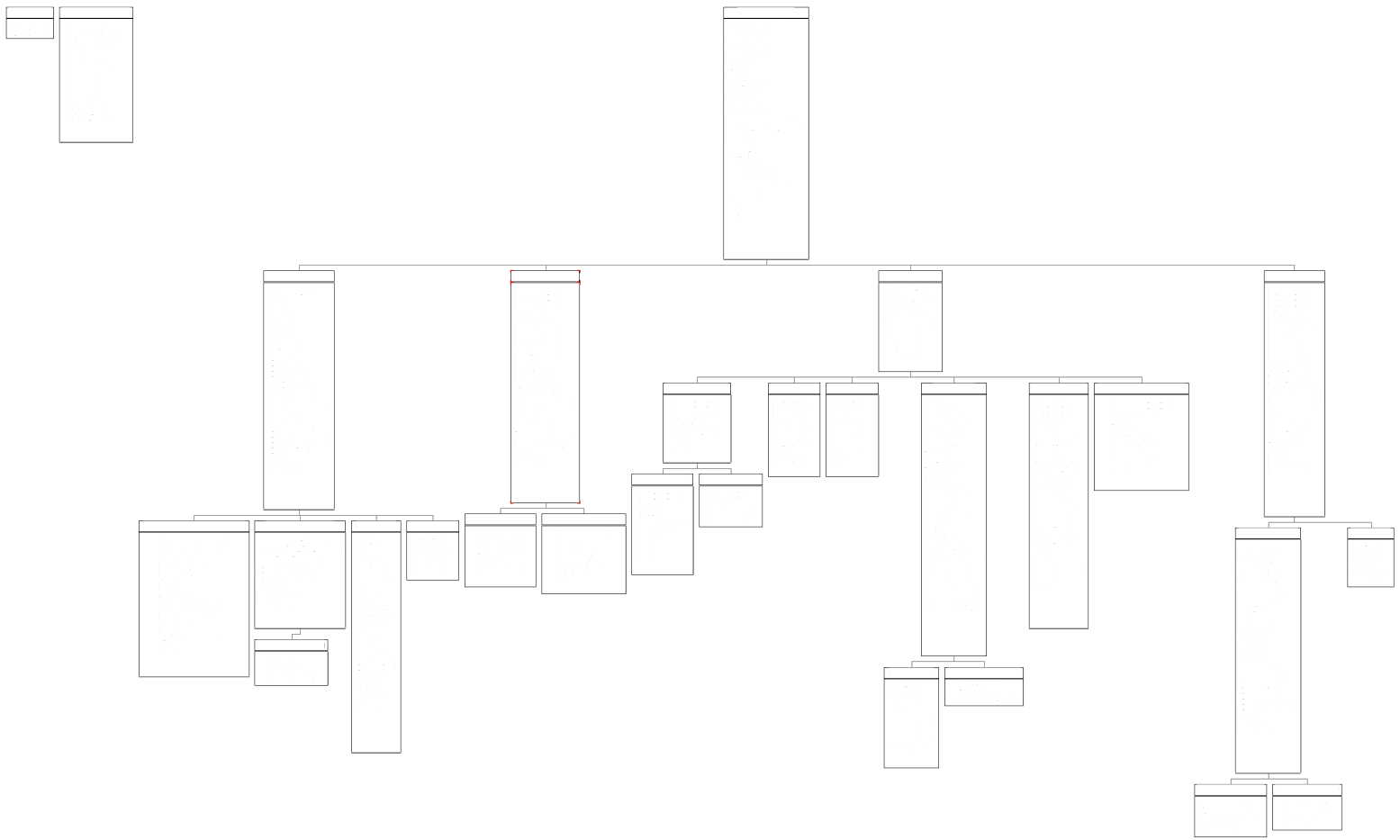
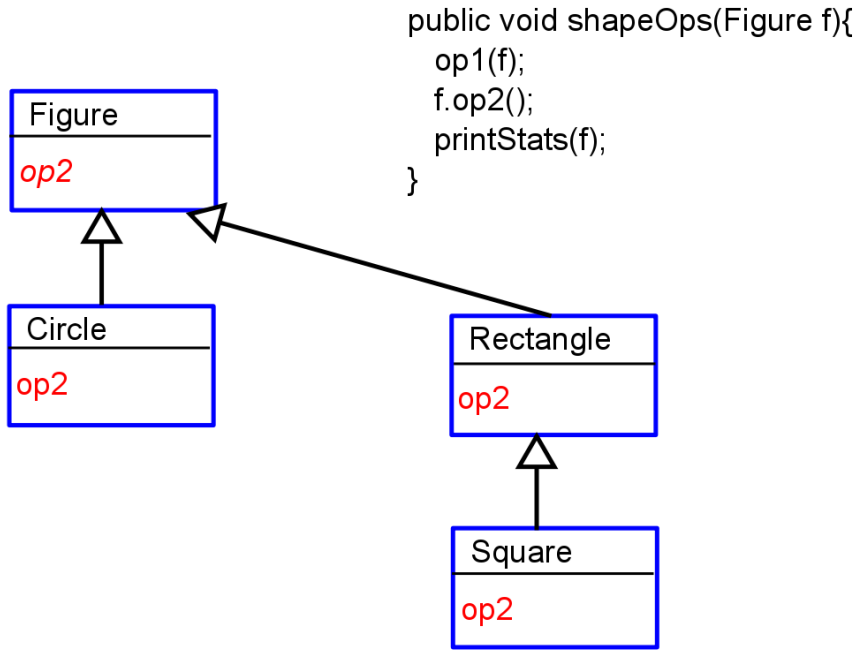


Problems Posed by OO Mechanisms

Data dependence computation relies on inter-procedural analysis

- A **def** or a **use** of a variable can depend on the called method
  - Does call to an object method mutate or access it?
  - If passed as an argument, is it accessed or mutated?
- Demands inter-procedural analysis
  - Erroneous pointers can result in def-use errors
  - Static analysis forced to include library methods



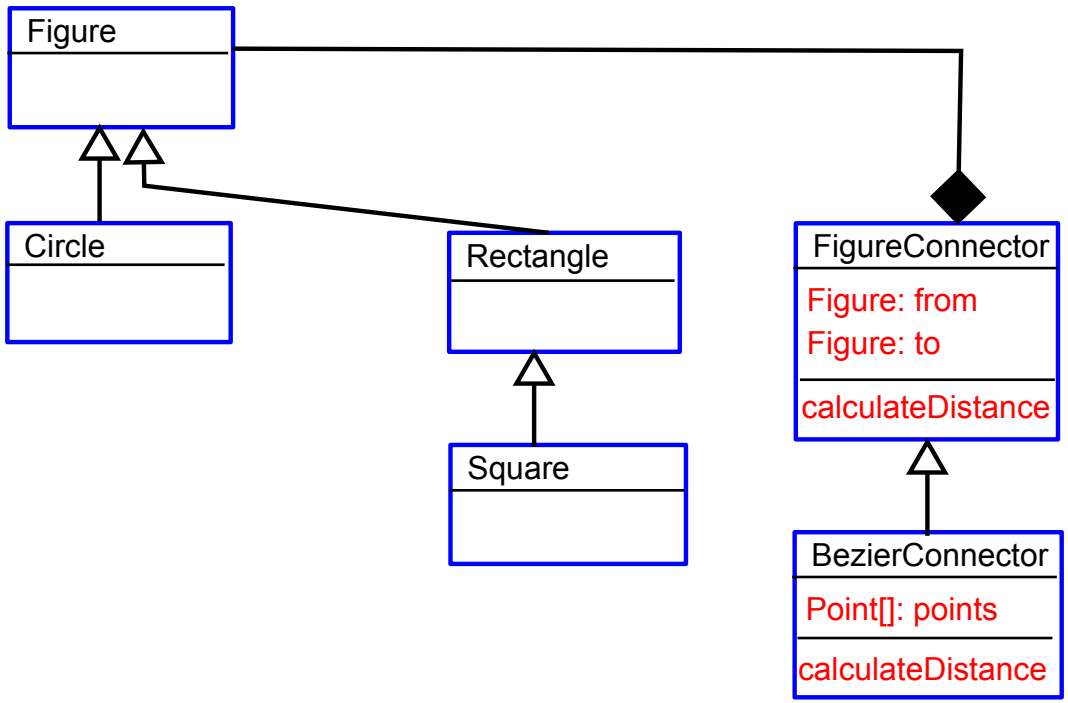
Problems Posed by OO Mechanisms

Object associations

- Objects do not occur in isolated hierarchies
  - Objects can contain other objects belonging to different hierarchies
- The possible types of the associated objects (and their objects) have to be accounted for
- Dependence analysis needs to account for every possible combination of types
  - Parameter trees

Problems Posed by OO Mechanisms

```
printDistance(FigureConnector fc){
    double distance = fc.calculateDistance()
    System.out.println(distance);
}
```



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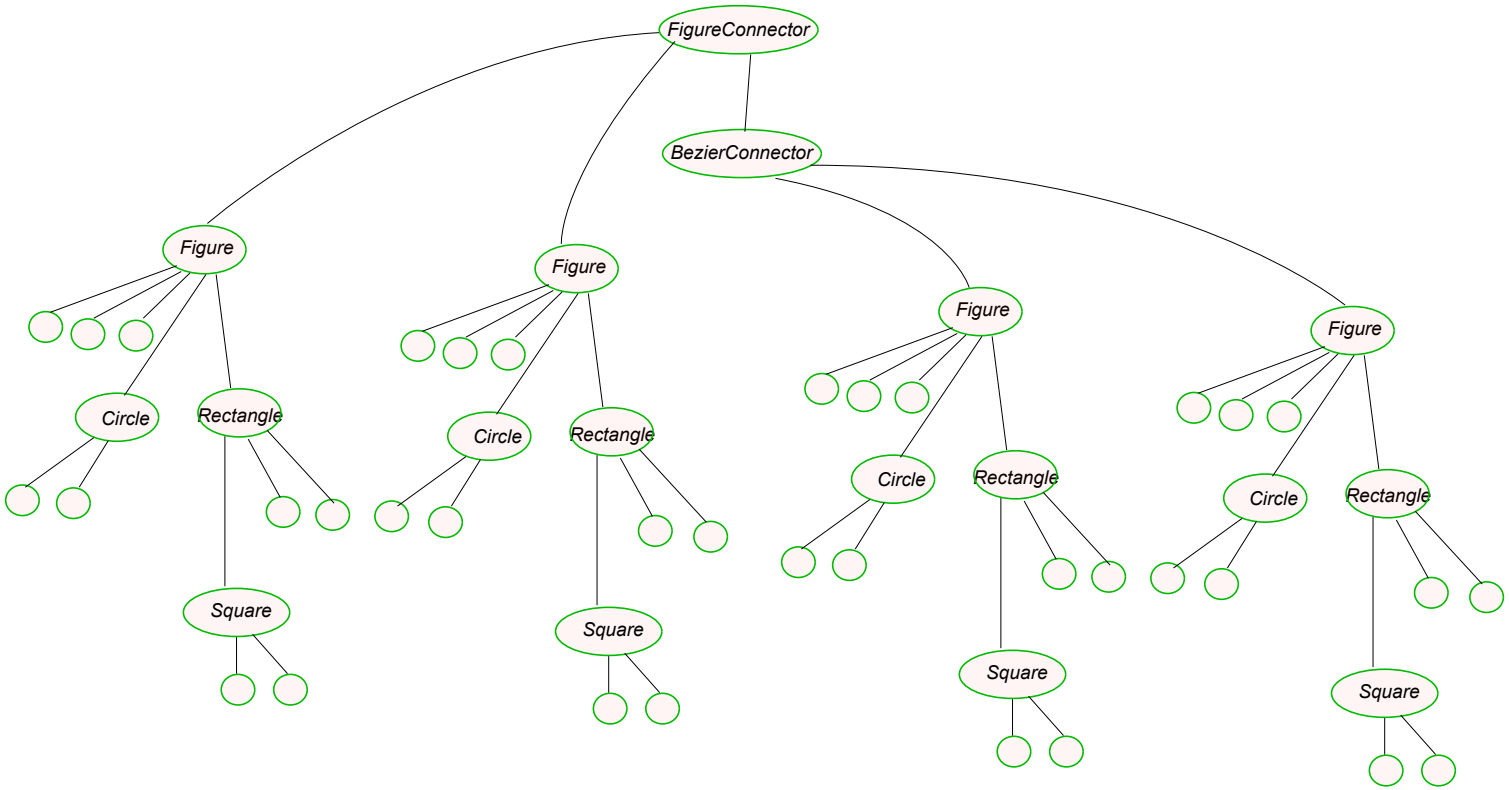

Delocalised Design

Dependencies are heavily delocalised

- Classes of objects represent units that are conceptually aligned with problem domain
  - Dependencies tend to span the system
  - Some evidence that OO dependencies obey principles of small-world networks
    - "Software systems as complex networks...", C. Myers, 2003

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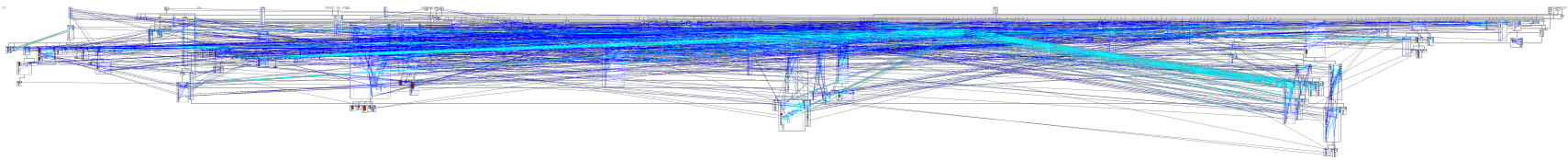

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Good OO design fosters fragmentation 

- Large classes and long methods are "code smells"
- Small classes and methods facilitate reuse and program understanding
  - Remedy: Break the system up into smaller classes, with smaller methods

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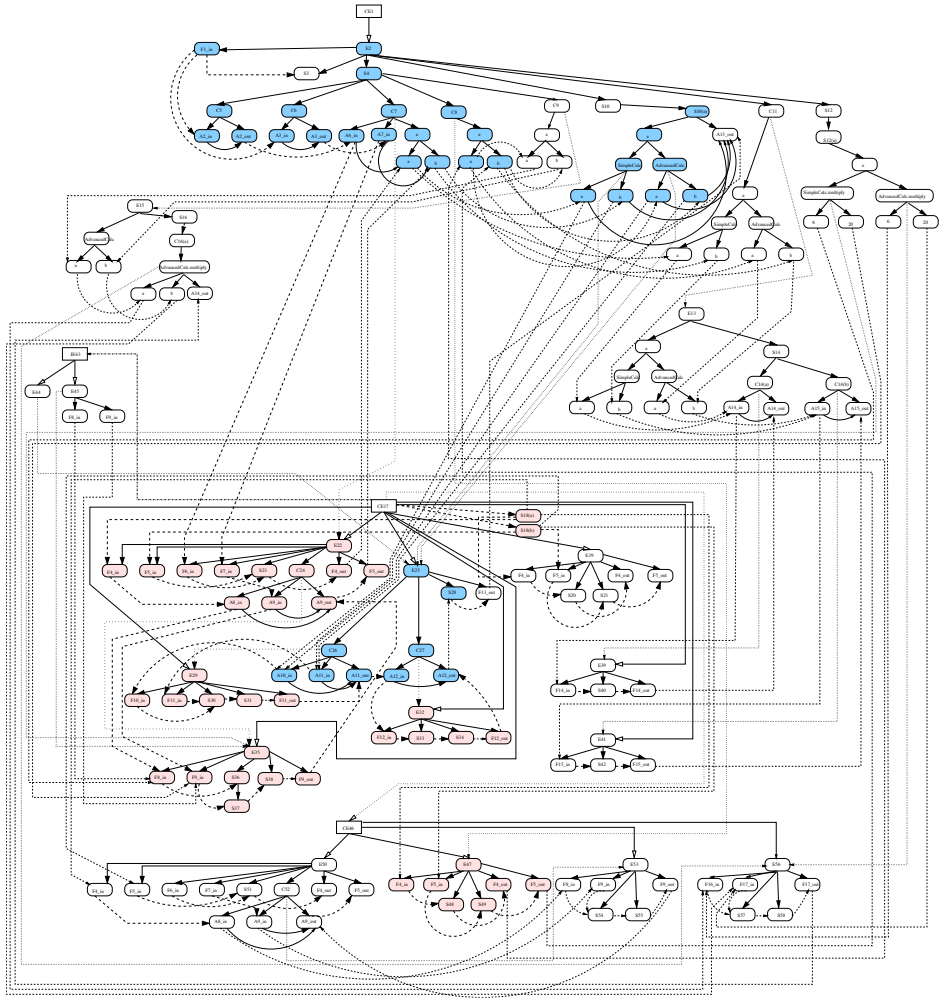
Results in a problem of scale

- Dependence graph size for procedural programs is more or less linear
- This is certainly not the case for object-oriented programs:
  - More classes and methods with their respective parameter vertices
  - Many polymorphic calls (with parameter edges)

Scale



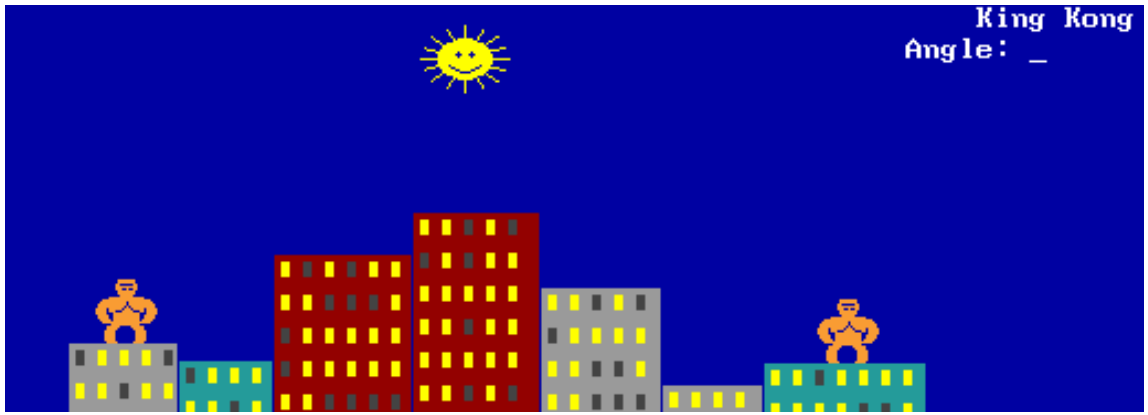
Summary

- Conspiracy of three problems:
  1. Accurate prediction of runtime dependencies from code is impossible
  2. Dependencies tend to cut across the system
  3. Granular decomposition causes scalability problems
- Each ill-computed dependency will significantly amplify problems 2 and 3
- The better designed a system is, the worse these problems become

Summary

> *"The problem with object-oriented languages is they've got all this implicit environment that they carry around with them. You wanted a banana but what you got was a gorilla holding the banana and the entire jungle."*

– Joe Armstrong



Conclusions

- Accuracy of dependence analysis intricately tied to accuracy of underlying analyses
  - Results tend to be grossly inaccurate
- Cannot be ignored when interpreting OO dependence analysis results
  - Slices can easily become misleading
  - Implications for comprehension tasks
  - Implications for slice-based metrics?
- Demands new OO dependence analysis techniques
  - Or at least new ways to interpret their results

Several of potential solutions

- Associate confidence measure with each dependence?
- Incorporate dynamic analysis - trace / profiling information
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- Associate confidence measure with each dependence?
- Incorporate dynamic analysis - trace / profiling information
  - Can use test-set executions
- Incorporate infrastructures of code-based model-checking platforms
  - Exploit symbolic reasoning capacities of model-checking platforms such as JPF, Bandera etc.
  - These enable the incorporation of invariants, behavioural models etc. into the analysis
  - Use their ability to provide abstract models of irrelevant classes