Finding the Missing Eclipse Perspective: the Runtime Perspective

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Outline

- Motivation
- For each feature in the Runtime Perspective, discuss:
  - closely related Eclipse views
  - new features
- Demonstration
  - Pick tasks to implement
  - Use features from the Runtime Perspective

Program comprehension is hard

- Software maintenance costs 50%--90%
  - Of that, 50% spent in program comprehension

    [Bennett et al., Advances in Computers'02]
- Different views to aid comprehension:
  - Static/code structure
  - Dynamic/runtime/execution structure
  - Other: deployment, etc.

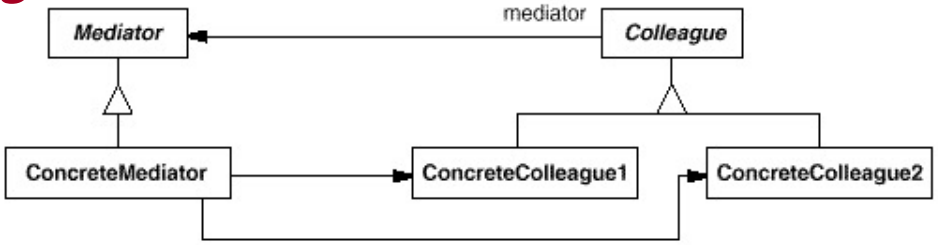
Object-oriented design is hard

- Developers need to understand both:
  - code structure
    - it is "right there"
    - much tool support
  - runtime structure
    - different from code structure
    - some code/design patterns make differences bigger
    - less mature tool support

Structure

Code structure

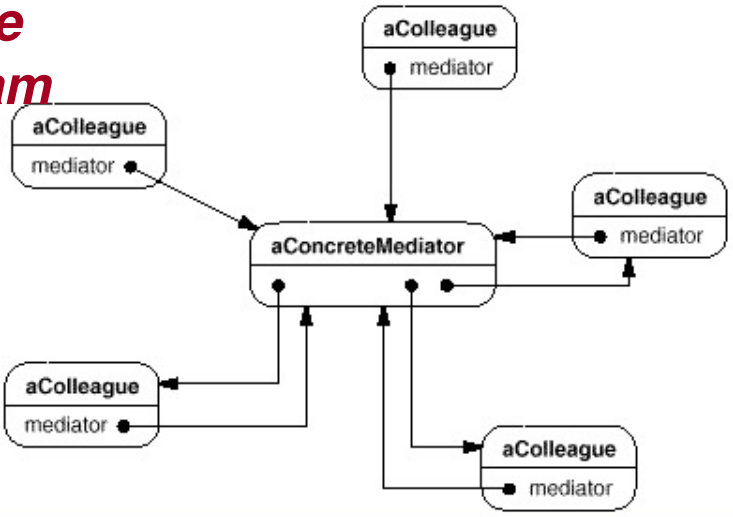
E.g., class diagram

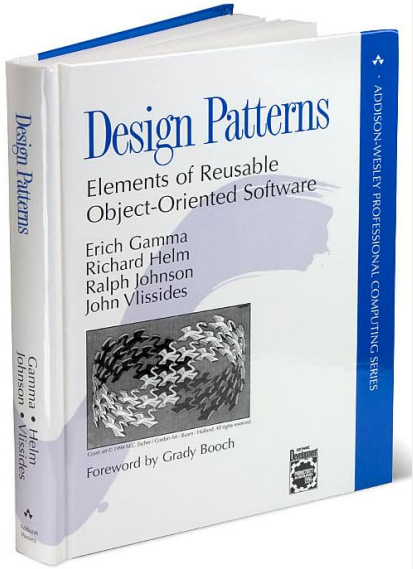


A typical object structure might look like this:

Run-time structure

E.g., object diagram





IDEs present to OO developers mainly a hierarchy of classes

- Current/popular IDEs (e.g., Eclipse) predominantly emphasize code structure:
  - Class-oriented view
  - **Hierarchy of classes**
- Hard for novice programmers (e.g., undergrads) to "understand" the objects

Why not present to OO developers a hierarchy of abstract objects?

- Use abstract runtime structure as a design-time perspective
  - abstract objects
  - abstract edges (relations between objects)
- Abstraction keeps things manageable
  - **Hierarchy of abstract objects**
  - Summarization of runtime objects
- Use static analysis so tool works at design time
  - Will not replace debugger (the real runtime structure)

Hierarchy of Classes vs. Objects

Hierarchy of classes

```
+- package/
   +- package/
   | +-
   | +- class/
   |    +- innerclass/
   +- package/
   | +- class/
   |    +  innerclass/
```

Hierarchy of abstract objects

```
+-root/
   +- TLD1/
   | +- object1: B
   |    +- MAPS
   |       +-
   |    +- OWNED
   |       +-
   +- TLD2/
   | +- object2: B
   |    +- OWNED
   |
```

Trace to code

```
package x;
class Hashtable {
...
}
```

```
class B {
 public void m() {
  @Domain("OWNED")
  Hashtable hash2 = new Hashtable();
 }
}
```

Eclipse Runtime Perspective: missing link between Java and Debugging

Java Perspective:

- Package Explorer
- Outline View
- File/Java Search
- Type Hierarchy
- Javadoc
- Call Hierarchy
- Class Diagrams

Debugging Perspective:

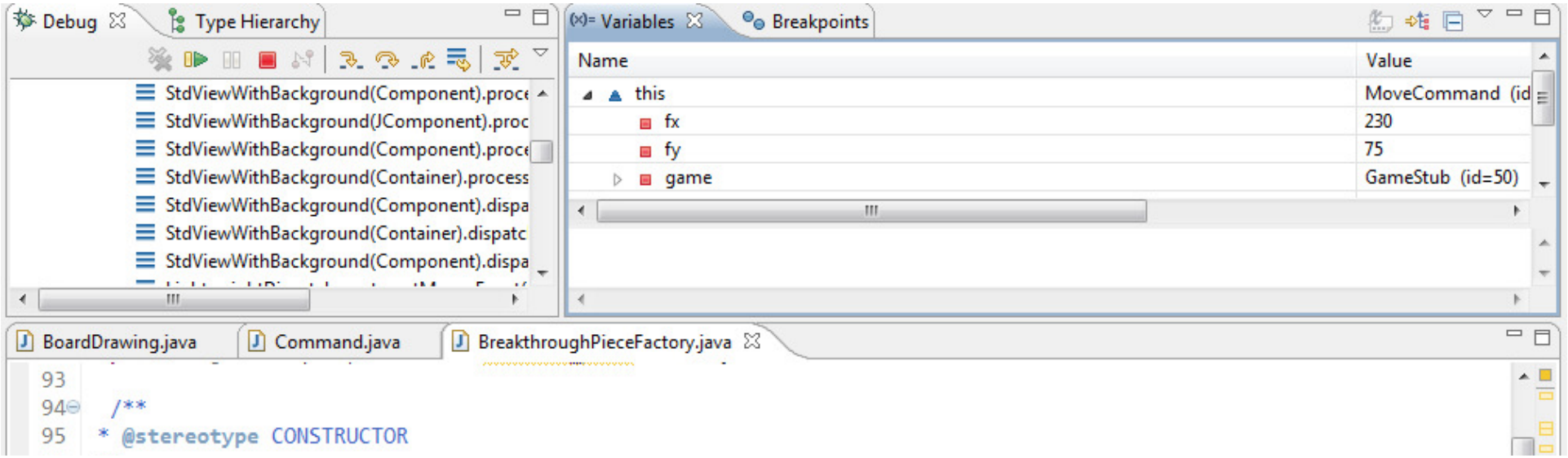
- Call stack
- Watch window

Runtime Perspective:

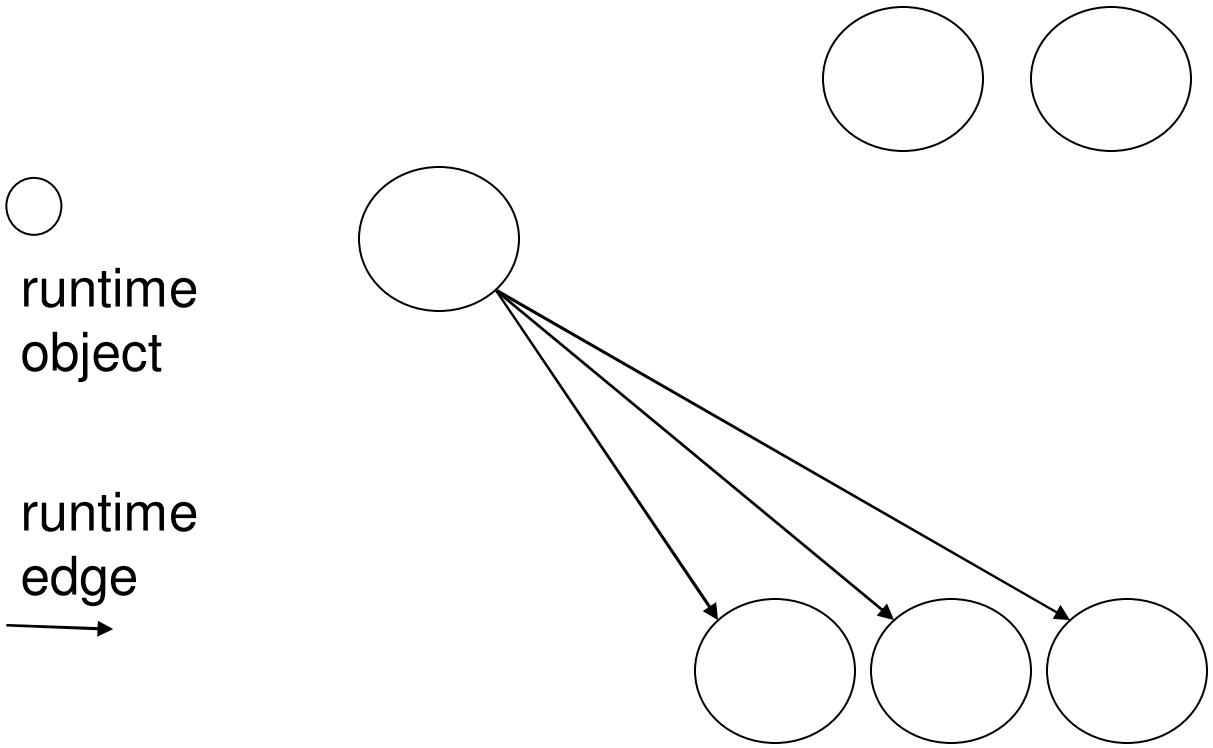
- Abstract Object Tree
- Classes behind interface
- Summary View
- Abstract Stack
- Partial Graph View
- Related Objects and Edges

Debugger

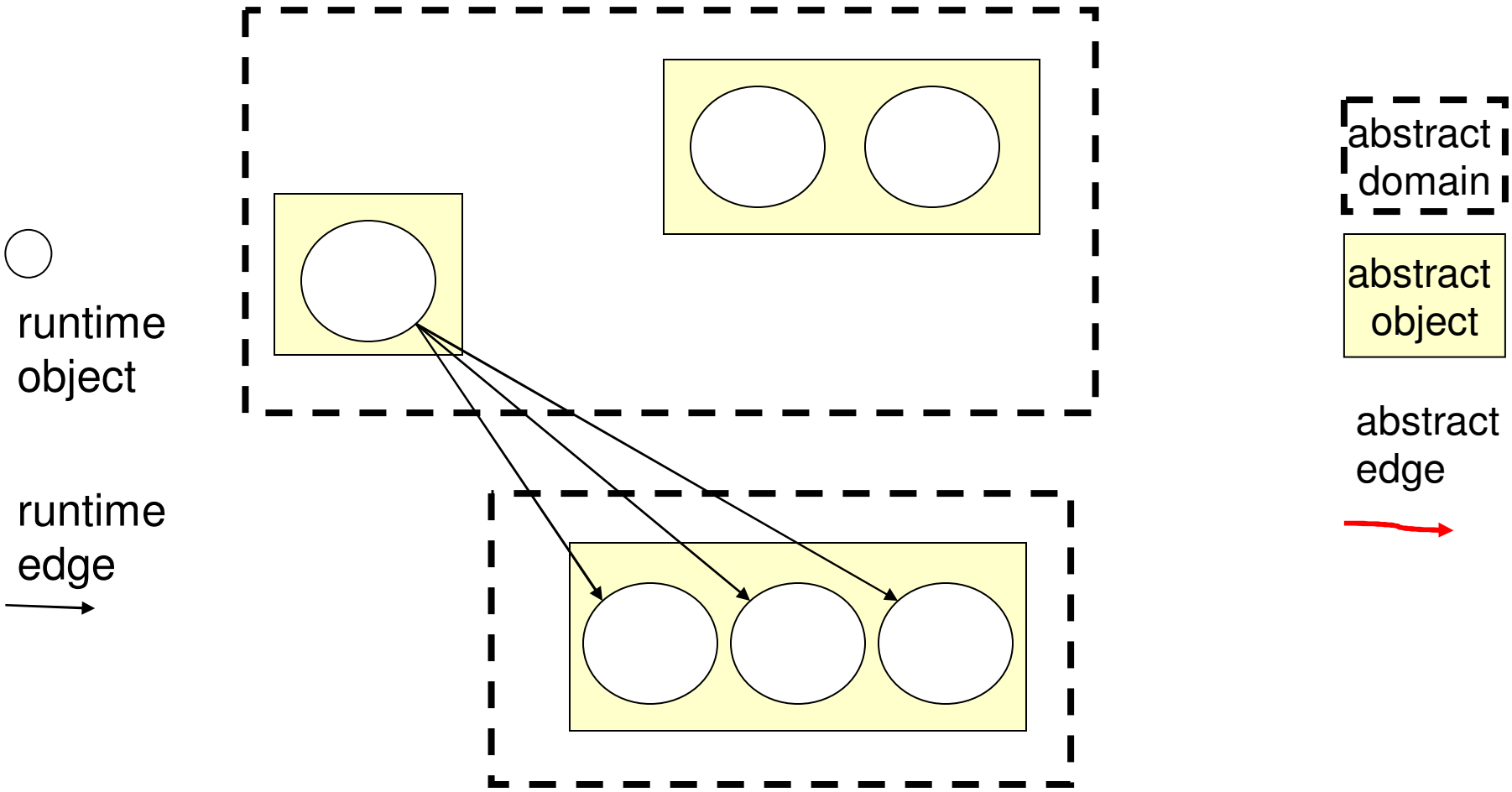
- Shows runtime objects (specific instances) of a program in execution.
- Limitations: too many specific instances that may not even matter for most tasks



At runtime, object-oriented program appears as a Runtime Object Graph



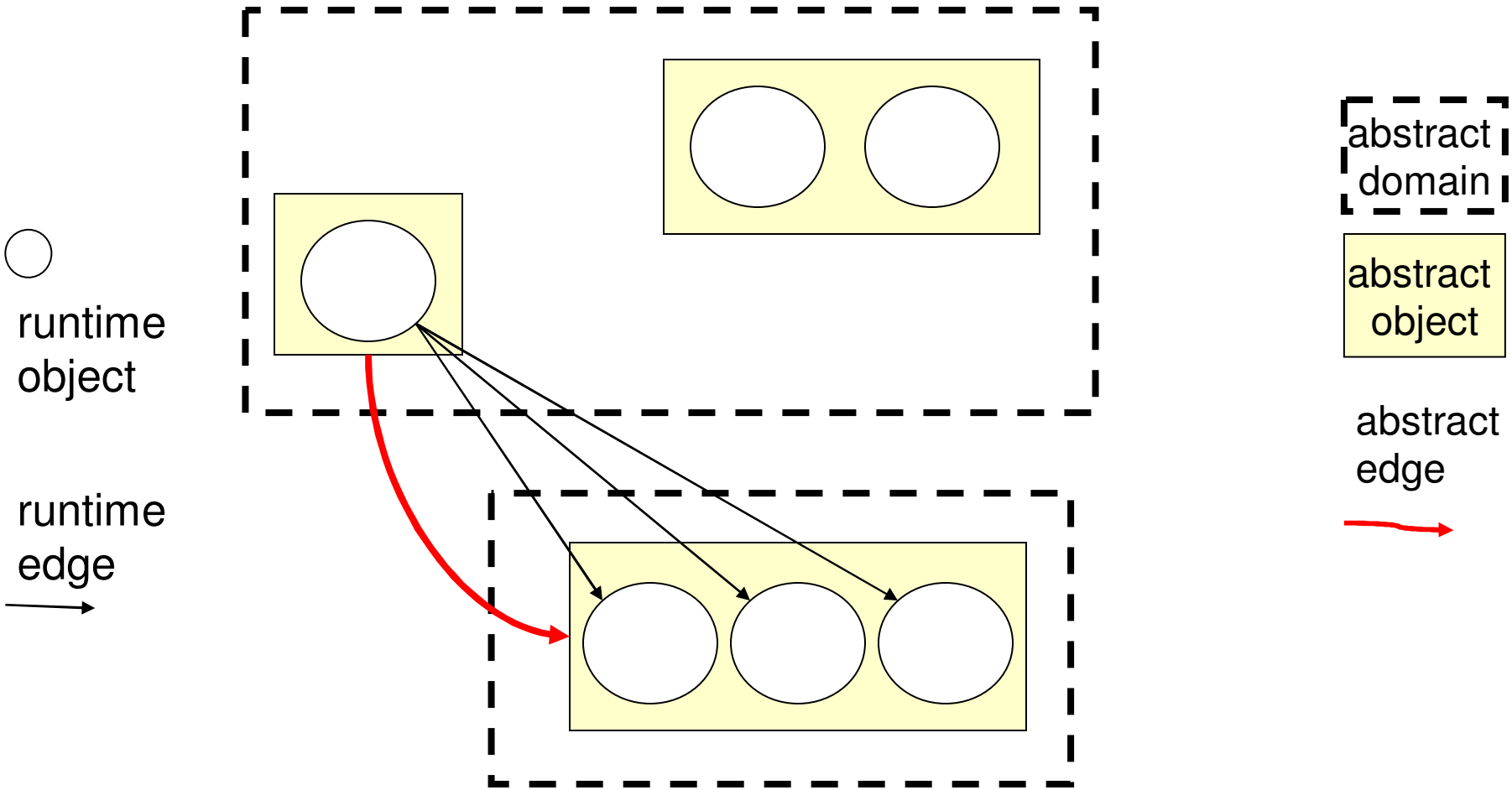
Abstract zero or more runtime objects into an abstract object



Abstract object represents a role

- **Abstract object** merges objects that have same **role**, i.e., **<type, domain, parent type>**
  - Domain: named, conceptual **group** of objects
  - Each object can have nested domains
  - Achieve hierarchy of abstract objects
- With hierarchy, collapse objects under other objects
  - Architecturally significant objects near top of hierarchy
  - Implementation details (data structures) further down
  - High-level understanding and detail

Abstract edges show relations between abstract objects



Different types of abstract edges are extracted

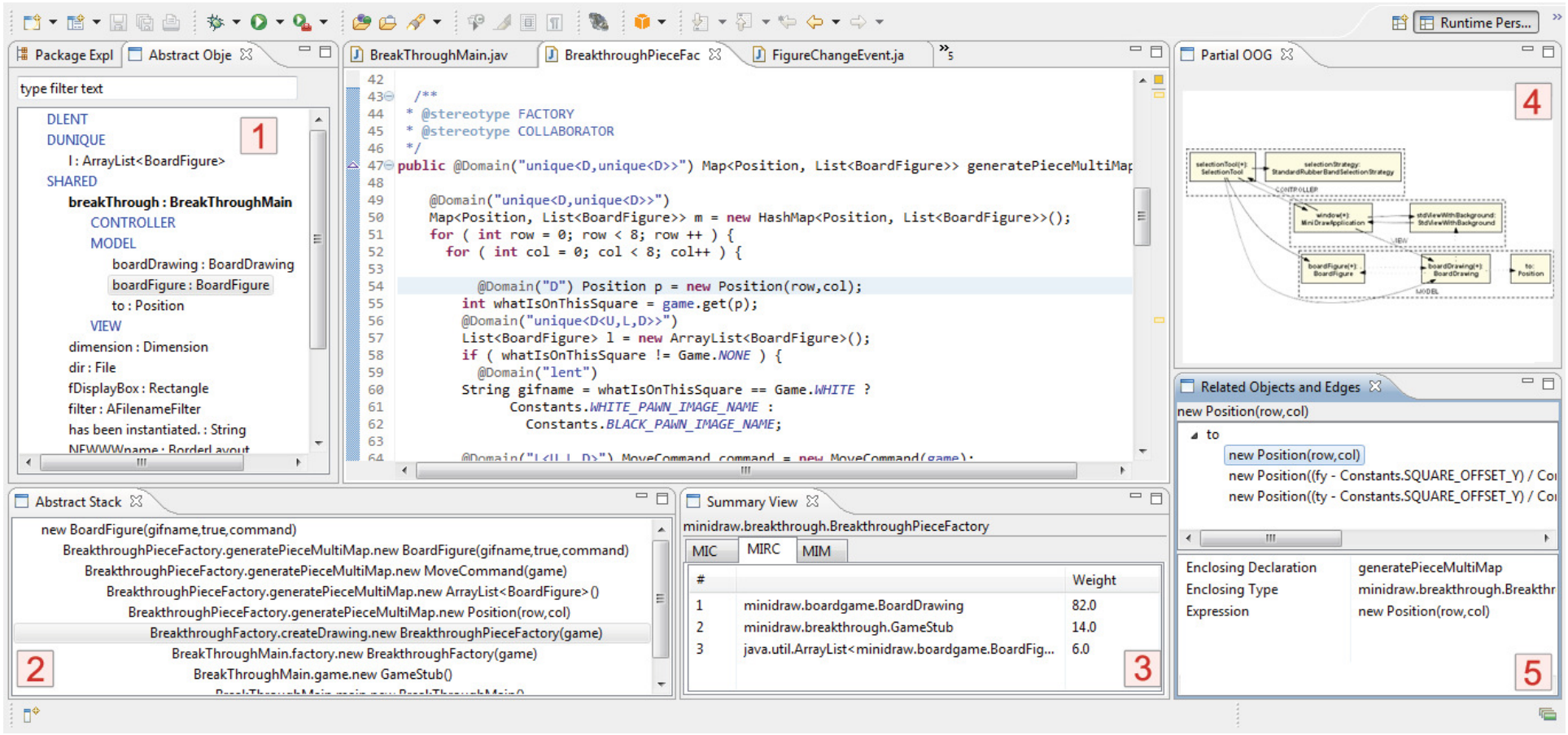
- Points-to edges (PT) due to field references
- Dataflow edges (DF) due to usage
  - field read
  - field write
  - method invocation
- Some edges can refer to objects

  o1 : C1 → o2: C2 [o: O]

Extracting the Runtime Perspective

- Add annotations and type check them
- Extract abstract graph with static anaysis
  - Save abstract graph to external file
  - File maintains traceability to code
- Switch to Runtime Perspective
  - Loads the abstract graph from external file
  - Mines the abstract graph
  - Displays information in various views

Using the Runtime Perspective



(1) Abstract Object Tree
(2) Abstract Stack
(3) Summary View
(4) Partial Graph
(5) Related Objects & Edges

For each Eclipse view

- Discuss limitations
- Discuss closely related view from the Runtime Perspective:
  - main features
  - how it complements existing information sources

Code vs. Runtime Perspective

Java Perspective:

- Package Explorer
- Outline View
- File/Java Search
- Type Hierarchy
- Javadoc
- Call Hierarchy
- Class Diagrams

Debugging Perspective:

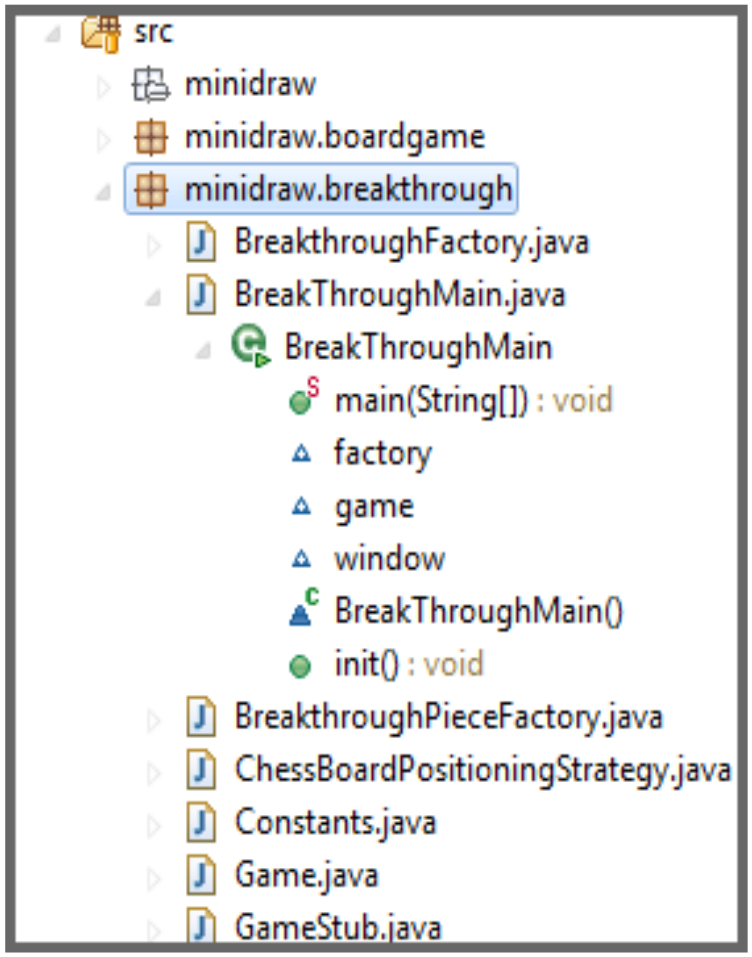
- Call stack
- Watch window

Runtime Perspective:

- Abstract Object Tree
- Classes behind interface
- Summary View
- Abstract Stack
- Partial Graph View
- Related Objects and Edges

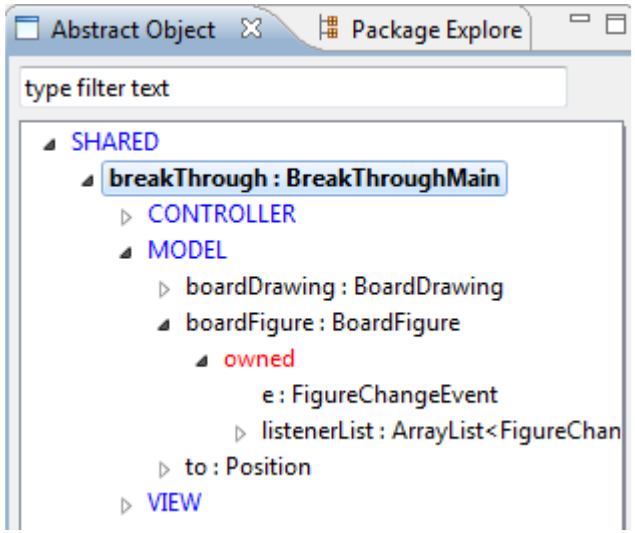
Eclipse Package Explorer

- Hierarchy of classes
- Organized by package
  - Note: a class cannot contain a package
- Limitation: packages, classes/interfaces sorted alphabetically.



Abstract Object Tree

- Hierarchy of abstract objects and domains



- Domain
- Object
- BOLD **Main Object**
- owned Domain

Abstract Object Tree Usefulness

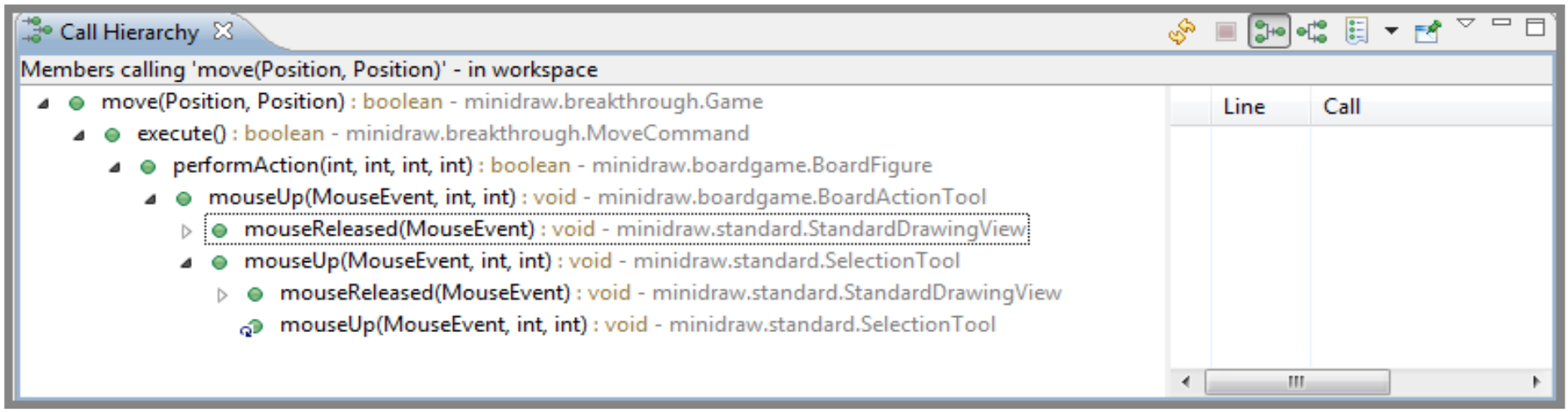
- Search for abstract objects by name, type:
- Trace to code:
  - Trace to expressions – not declarations
  - From object to object creation expression
  - From edge to field read, field write, etc.

Demo

- Switch to Runtime Perspective
- Go to Abstract Object Tree
  - Talk about Main object
  - Three top-level domains
  - Low-level objects further down
- Search for: game
- Trace to code

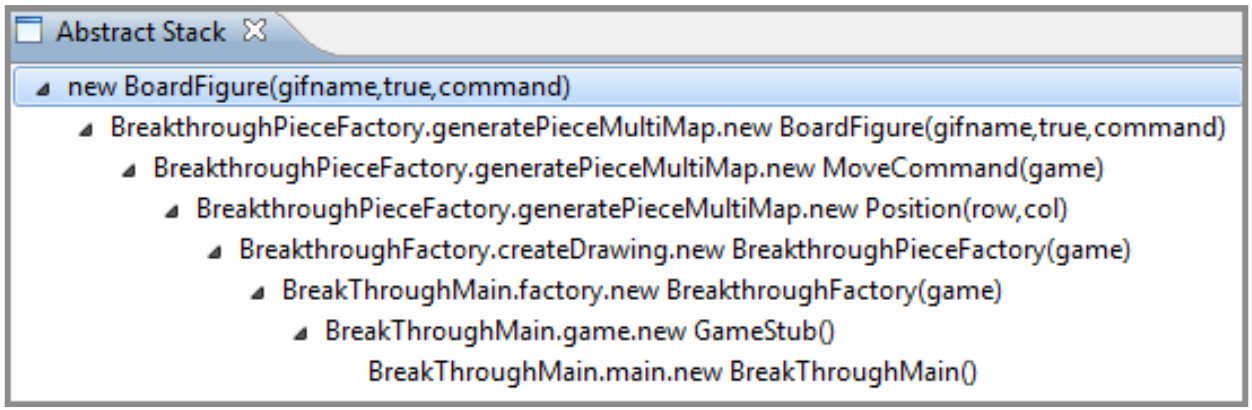
Call Hierarchy

- Shows caller and callees starting from a selected method
- Limitation: traces to method invocations



Abstract Stack

- Each abstract object is due to an object creation expression in the code
- From abstract object, select the abstract stack



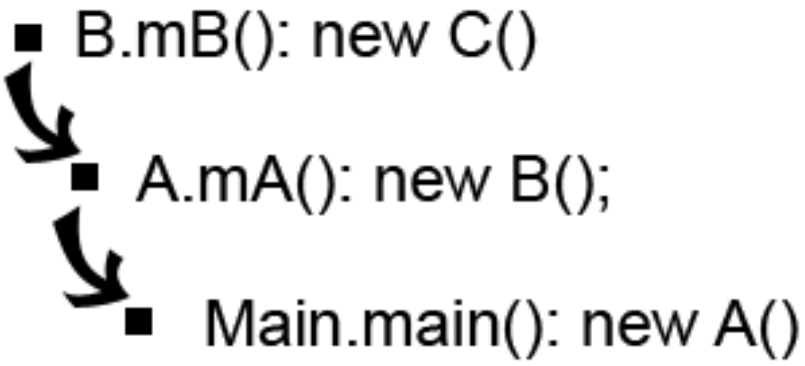
Abstract Stack Usefulness

- Usefulness: show the nested abstract interpretation contexts that lead to the creation of an abstract object.
  - Expose notion of "object sensitivity" in program analysis to developers
  - Make explicit the receivers in "call stack"

Abstract Stack Example

```
A a= new A();
a.mA();
```

```
class A {
        void mA() {
            B b = new B();
        }
}
class B {
        void mB() {
         C c = new C();
        }
}
```

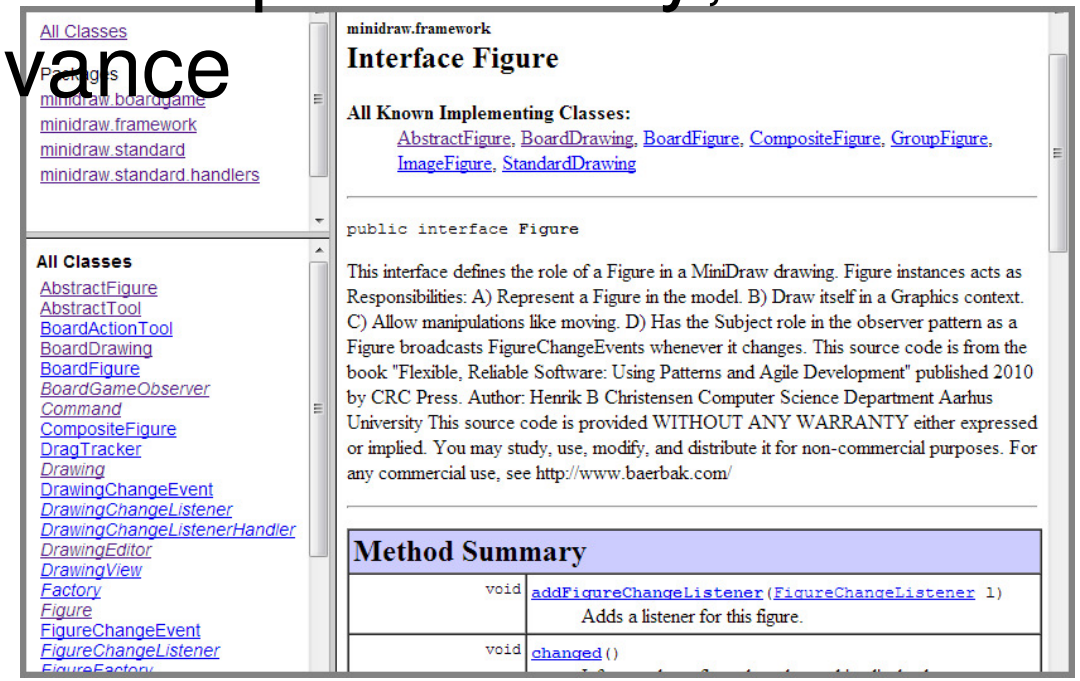


Demo

- Switch to Runtime Perspective
- Go to Abstract Object Tree
- Search for: boardDrawing
- Go to Abstract Stack trace

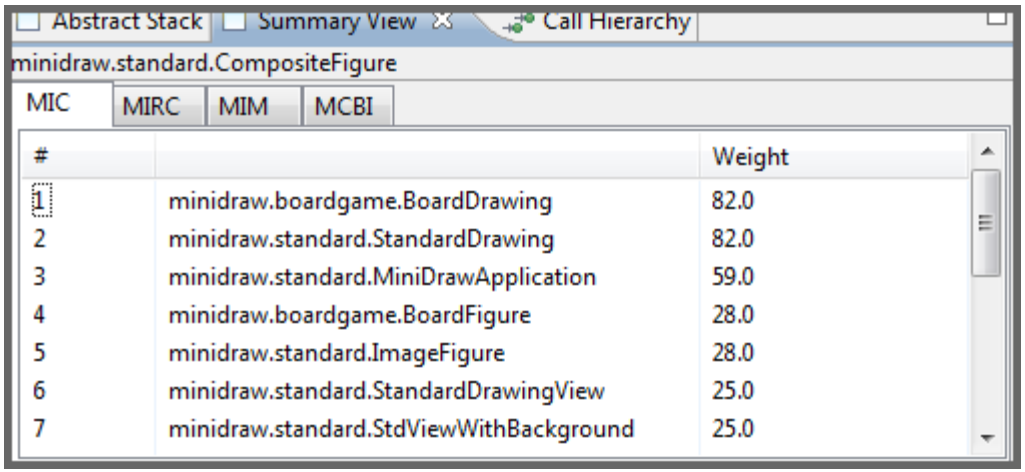
Javadoc

- Documentation from source code comments generated to HTML.
- Limitations: Shows packages, classes, and methods listed alphabetically; no ranking by relevance



Summary View

- Shows a ranked list of :
- **MIC** - Most Important Classes
- Given C a fully qualified name of a class
  - **MIRC**(C): Most Important Related Classes to C
  - **MIM**(C) - Most Important Methods of C
  - **MCBI**(C) - Most Important Classes Behind an Interface



Summary View Usefulness

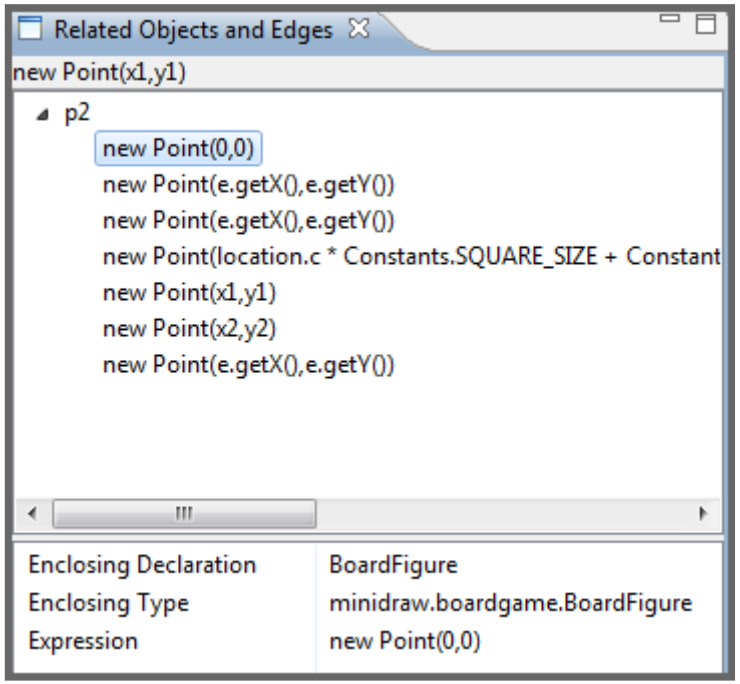
- Summary View gives developer a ranked list of classes and methods.
  - Rankings gathered from multiple strategies that traverse the abstract graph
  - Unlike Package Explorer or Javadoc, where packages, classes and methods organized alphabetically

Demo

- Switch to Runtime Perspective
- Select class: GameStub
- Look at MIRCs, MIMs
- Select a class from the list
- See the Summary View update.

Related Objects and Edges

- Find related places in the code related to this line of code
- See all objects and edges related to the currently selected ASTNode



Related Objects and Edges Usefulness

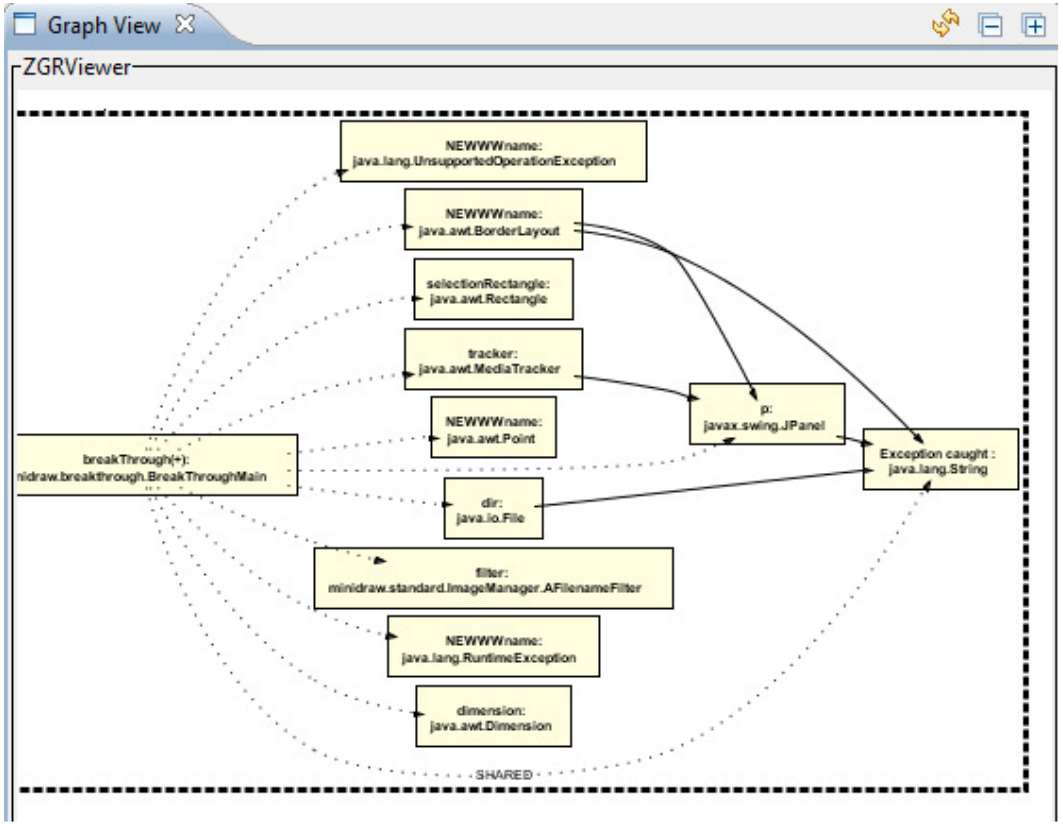
- Usefulness: identify all the code elements that map to the same abstract object or the same abstract edge
  - Similar to notion of "impact analysis"
- Unlike Summary View, does not lift information back to types
  - Traverse graph of abstract objects and edges

Demo

- Switch to Runtime Perspective
- Select class: BoardDrawing
- Select figureMap.put() method invocation in the editor
- Look at the related edges
- Trace to code to another related edge

Graph View

- Displays a partial runtime graph
- Using MIRCs: show related nodes and edges from the class that the developer is working on



Graph View Usefulness

- Graphical representation
  - Can get cluttered
  - Most useful for top-level objects
- Can expand/collapse objects on demand
- Can hide/show objects on demand
  - Objects NOT deleted; just hidden from graph

Demo

- Switch to Runtime Perspective
- Show all objects in the shared domain
  - Root object
- Hide object in shared
- Expand main object

Outline

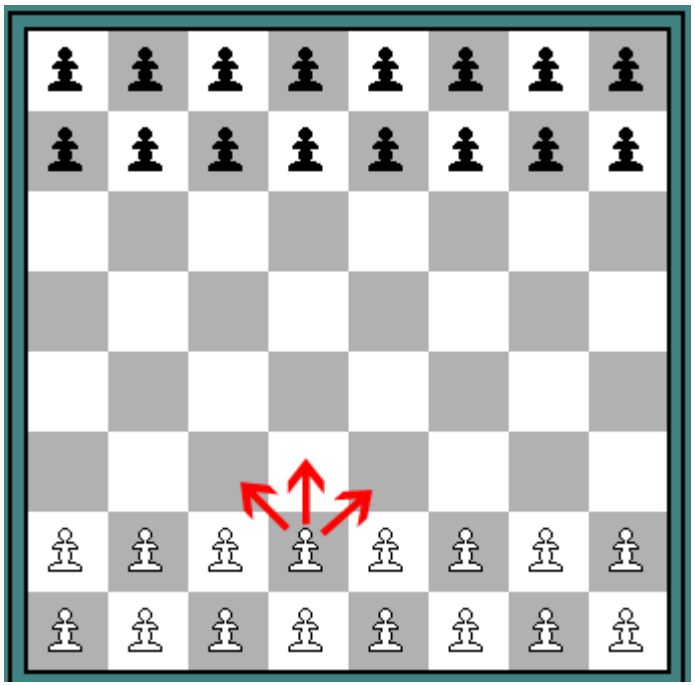
- Motivation
- For each feature in the Runtime Perspective, discuss:
  - closely related Eclipse views
  - new features
- Demonstration
  - Pick tasks to implement
  - Use features from the Runtime Perspective

Subject System

- MiniDraw framework (1400 LOC)
  - Pedagogical object-oriented framework
  - Support development of board games
  - Uses many design patterns
- Breakthrough: game created using framework
  - Game similar to chess or checkers
  - Objective of game: reach the opponents home row

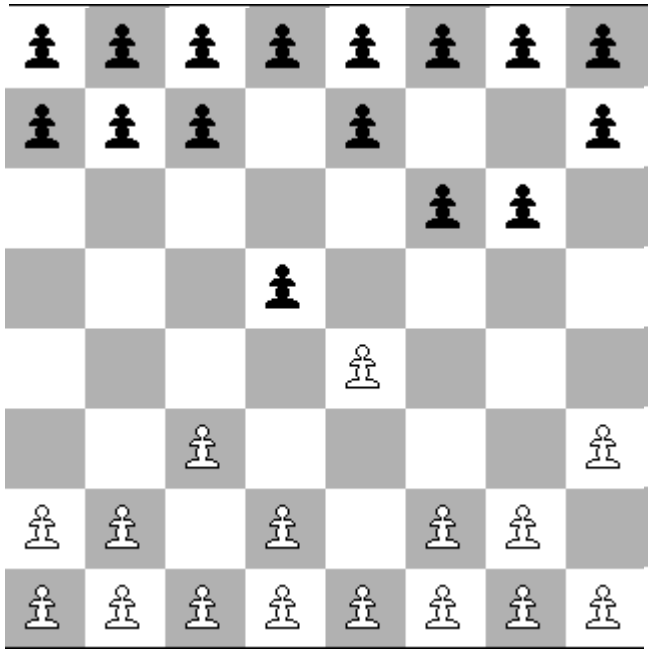
Task #1

- Validate piece movement
- Board Piece can move one square straight or diagonally towards the opponents home row.



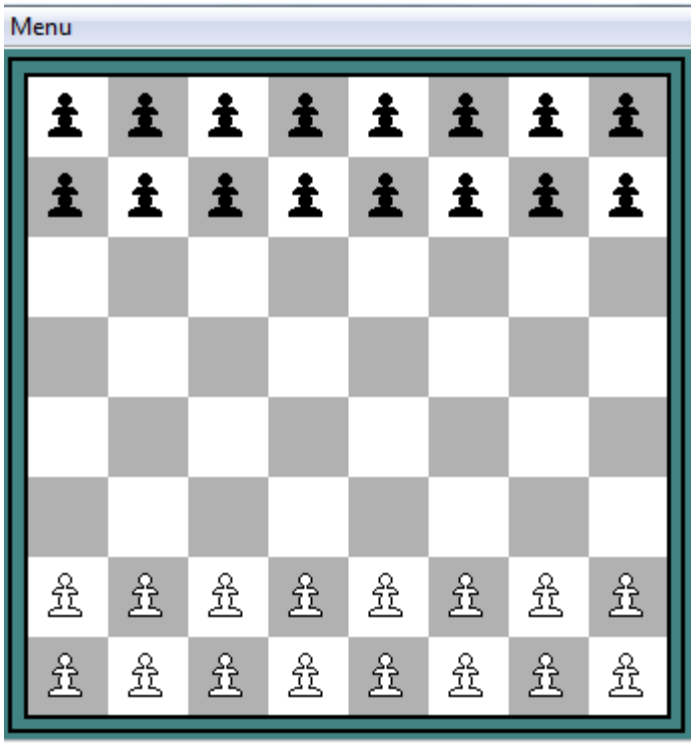
Task #2

- Implement the capture of a board piece
- A board piece can only capture another board piece on a diagonal move.
- Piece takes position of the captured piece



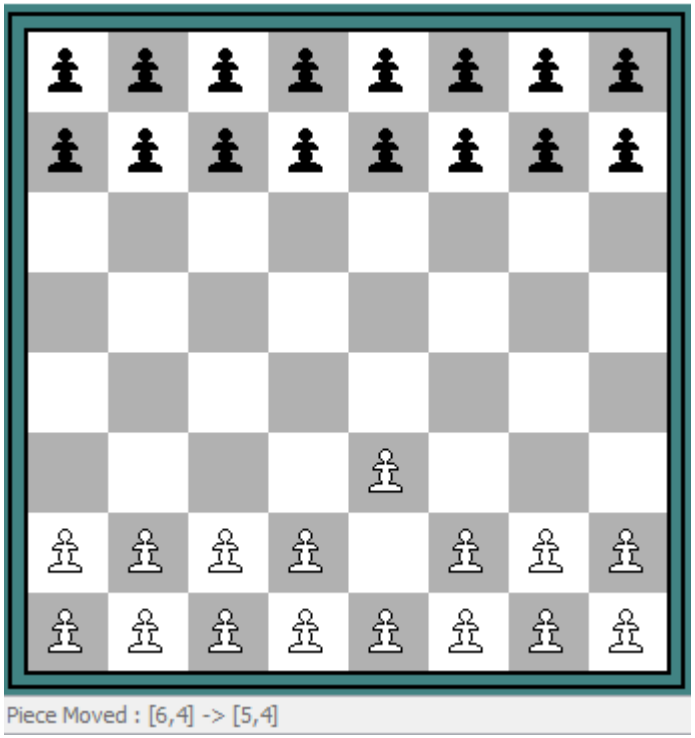
Task #3

- Implement an undo feature
- Menu item "Undo move"



Task #4

- Implement a status bar
- Status bar is built into the framework
- Update status bar on piece movements



How ranking classes works

Computing MICs, MIMs, MIRCs

- Most Important Classes: MIC
- Use the hierarchy of objects
  - All top-level abstract objects are included
  - One strategy: rank classes of those objects based on number of incoming/outgoing edges to abstract object of that type
- Most Important Methods: MIM(C)
- For all method declarations of a given class
  - Rank methods by the number of edges due to method invocations in the abstract graph

Computing MICs, MIMs, MIRCs

- Most Important Related Classes: MIRC(C)
- From a given Class C
  - Traverses the set of edges filtered by edge type (dataflow, points-to, etc)
  - Collect the union of edges having a source or destination that is an object of type C or a subtype of C
- Other strategies are possible

Computing MCBIs

- Most Important Classes Behind an Interface: MCBI(C)
  - Find reachable domains from that location
  (i.e., actual domains bound to formal domain parameters)
  - Find all classes in those domains
  - For all classes that implement the interface, rank these classes using strategy similar to MIRCs

Related Tools

- Code exploration tools:
  - Focus on code structure, not runtime structure
  - Jadeite [Stylos et al., VL/HCC'09]: ranks element in JavaDoc by relevance from a web query (search popularity)
- Heap exploration tools:
  - Backwards/reversible debugging
  - Mine concrete heaps
  - Notion of time (missing here)
- Abstract heap tools [Marron et al., TSE'13]
  - Tradeoffs of static vs. dynamic analysis

Future Work

- Evaluate the tool in user studies
  - Replicate results from previous experiment [Ammar and Abi-Antoun, WCRE'12]
- Use the tool in educational setting
  - Beginners learning design patterns, etc.
  - Use in laboratory component of course
- Use metrics to identify when runtime structure really different from code structure

Conclusion

- Runtime Perspective complementary to:
  - Java Code Perspective and
  - Debugging Perspective
- Mine information from an abstract runtime structure into several views
  - Abstract object tree
  - Abstract stack
  - Summary view
  - Related objects and edges