```java
public class Puzzle4 {

    public static void main(String[] args) {
        System.out.print("iexplore:");
        http://www.google.com;
        System.out.println(":maximize");
    }

}
```

A Thought Experiment - Given the following program what graph(s) could we produce?

```
public class MyClass {
    public static void A() {
        B();
    }
    public static void B() {
        C();
    }
    public static void C() {
        B();
        D();
    }
    public static void D() {
        G();
        E();
    }
    public static void E() {}
    public static void F() {}
    public static void G() {}
}
```

Control Flow (summary)

A *calls* B

B *calls* C

C *calls* B

C *calls* D

D *calls* G

D *calls* E

Structure

MyProject *contains* mypackage

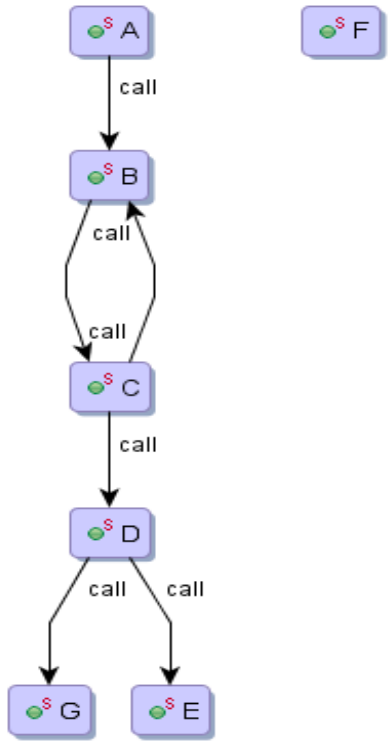
mypackage *contains* MyClass

MyClass *contains* methods: A, B, C, D, E, F, G

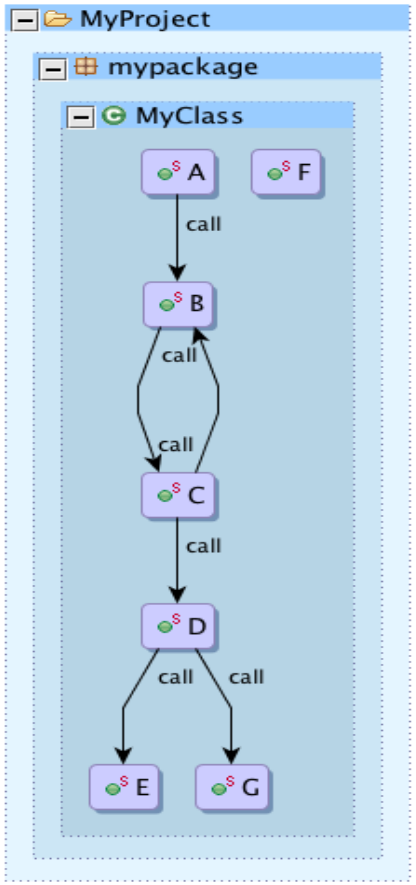
Data Flow?

No data in this program.

Call



Call and Structure



Basic Queries

- Map the Workspace project “*MyProject*”
- Execute the following queries on the Atlas Shell

  (We will discuss what they mean later)

```
var containsEdges = universe.edgesTaggedWithAny(XCSG.Contains)
var app = containsEdges.forward(universe.project(”MyProject"))
var appMethods = app.nodesTaggedWithAny(XCSG.Method)
var initializers = app.methods("<init>”).union(app.methods("<clinit>"))
var constructors = app.nodesTaggedWithAny(XCSG.Constructor)
var callEdges = universe.edgesTaggedWithAny(XCSG.Call)
var q = (appMethods.difference(initializers.union(constructors))).induce(callEdges)
show(q)
```

Java - HelloWorld/src/com/example/MyClass.java - Eclipse

File Edit Source Refactor Navigate Search Project Atlas Run Window Help

Quick Access | Java

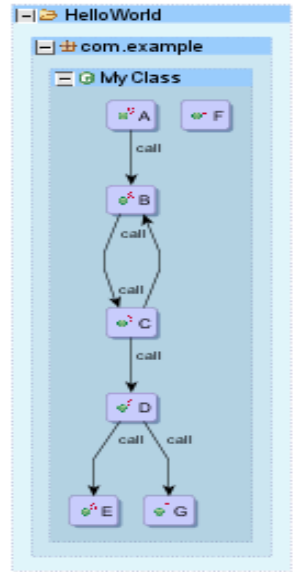
Package Expl...

- HelloWorld [LearningAtl
  - src
    - com.example
      - MyClass.java
  - JRE System Library [Ja
- toolbox.analysis [Starter-
- toolbox.shell [Starter-To

MyClass.java

```
package com.example;

public class MyClass {

    public static void A() {
        B();
    }

    public static void B() {
        C();
    }

    public static void C() {
        B();
        D();
    }

    public static void D() {
        G();
        E();
    }

    public static void E() {
```

Graph 1



Problems @ Javadoc Declaration Console Progress Atlas Shell (toolbox.shell)

Atlas Shell (Project: toolbox.shell)

```
var callEdges = universe.edgesTaggedWithAny(Edge.CALL).retainEdges()
callEdges: com.ensoftcorp.atlas.core.query.Q = <Atlas query expression>

var graph = (methods difference (initializers union constructors)).induce(callEdges)
graph: com.ensoftcorp.atlas.core.query.Q = <Atlas query expression>

show(graph)
```

Evaluate: <type an expression or enter ":help" for more information>

atlas

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Basic Queries

var A = app.methods("A")
var B = app.methods("B")
var C = app.methods("C")
var D = app.methods("D")
var E = app.methods("E")
var F = app.methods("F")
var G = app.methods("G")

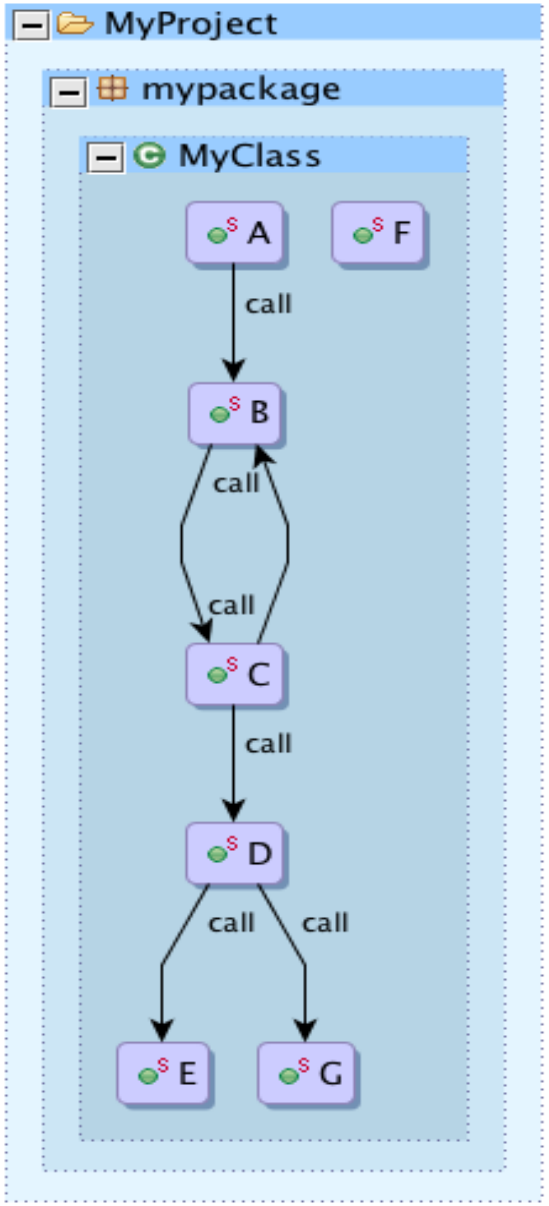
…alternatively…

var A = selected
var B = selected

Note: In the following examples you will need to pass the result to the “show” method on the Atlas Shell to view the results.

Example: show(q.forward(D))

Forward Traversals



q.forward(origin)

Selects the graph reachable from the given nodes using the forward transitive traversal. Includes the origin in the resulting graph query.

q.forward(D) outputs the graph D→E and D→G.

q.forward(C) outputs the graph C→B→C, C→D→E and C→D→G.

q.forwardStep(origin)

Selects the graph reachable from the given nodes along forward paths of length one. Includes the origin in the resulting graph query.

q.forwardStep(D) outputs the graph D→E and D→G.

q.forwardStep(C) outputs the graph C→B and C→D.

q.forwardStep(F) outputs the graph only F.

q.successors(origin)

Selects the immediate successors reachable from the given nodes Does not include the origin unless it succeeds itself. The result does not includes edges.

q.successors(C) outputs: {D, B}

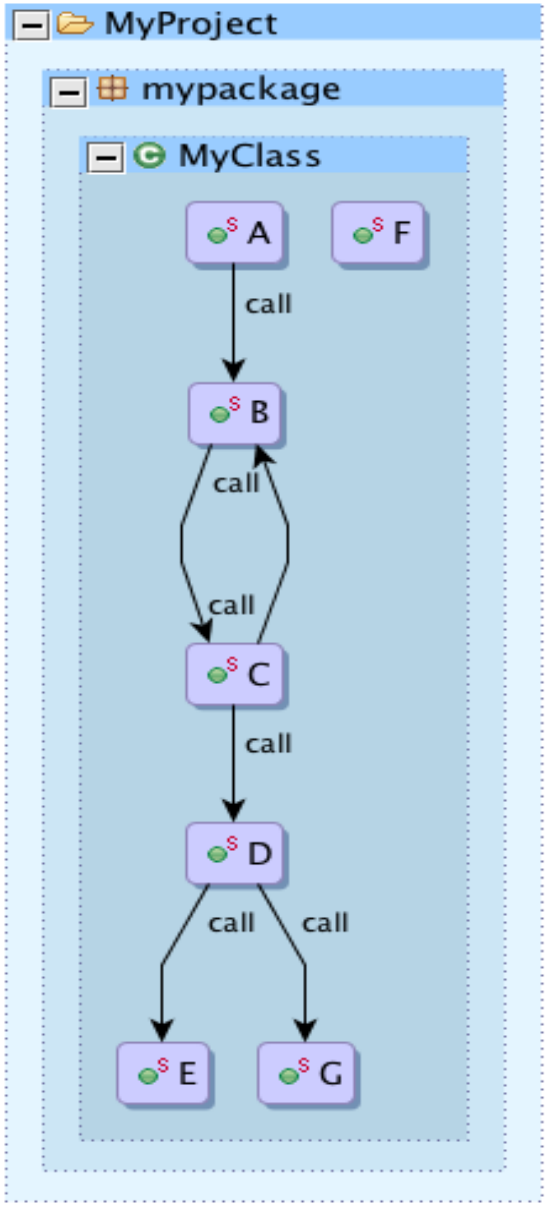
q.successors(F) outputs: Empty graph

Reverse Traversals

q.reverse(origin)
Selects the graph reachable from the given nodes using the reverse transitive traversal. Includes the origin in the resulting graph query.
q.reverse(D) outputs the graph D←C←B←A and D←C←B←C.
q.reverse(C) outputs the graph C←B←A and C←B←C.

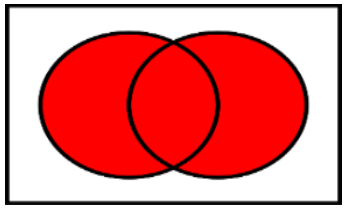
q.reverseStep(origin)
Selects the graph reachable from the given nodes along reverse paths of length one. Includes the origin in the resulting graph query.
q.reverseStep(D) outputs the graph D←C.
q.reverseStep(C) outputs the graph C←B.

q.predecessors(origin)
Selects the immediate predecessors reachable from the given nodes. Does not include the origin unless it precedes itself. The result does not include edge.
q.predecessors(C) outputs: {B}
q.predecessors(F) output: Empty graph.

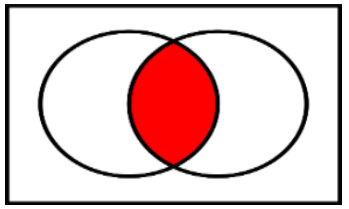


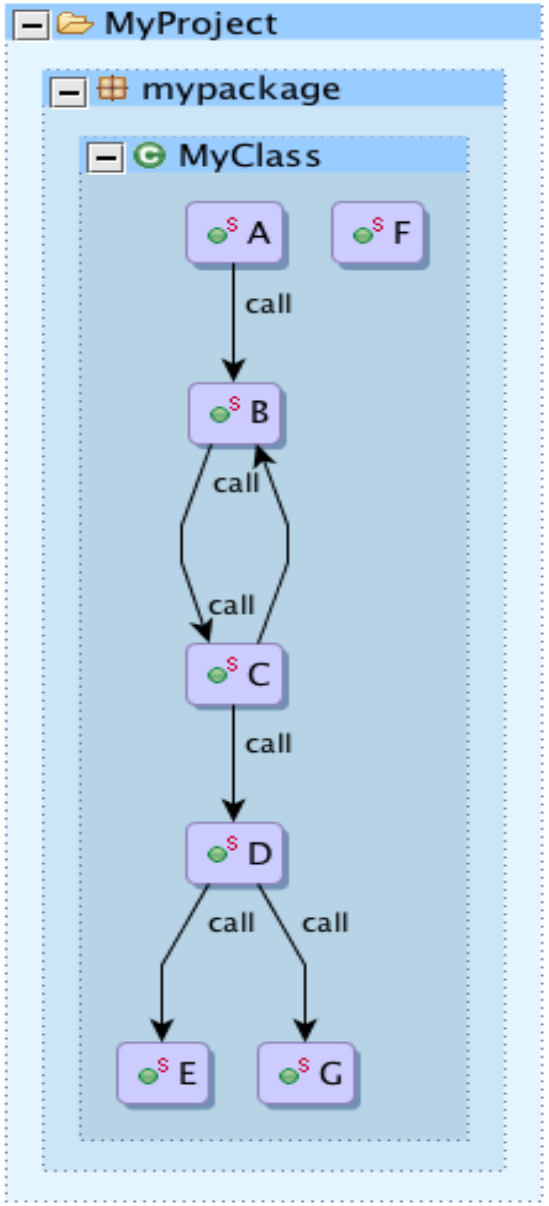
Set Operations (1)

q.union(q2...)
Yields the union of nodes and edges of *this* graph and the *other* graphs.
B.union(C) outputs a graph with nodes B and C.
A.union(B, C) outputs a graph with nodes A, B, and C.
q.union(C) outputs the entire graph.



q.intersection(q2...)
Yields the intersection of nodes and edges of *this* graph and the *other* graphs.
A.intersection(B) outputs an empty graph.
q.intersection(C) outputs a graph with only the node C.

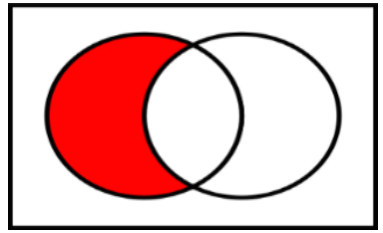




Set Operations (2)

q.difference(q2...)

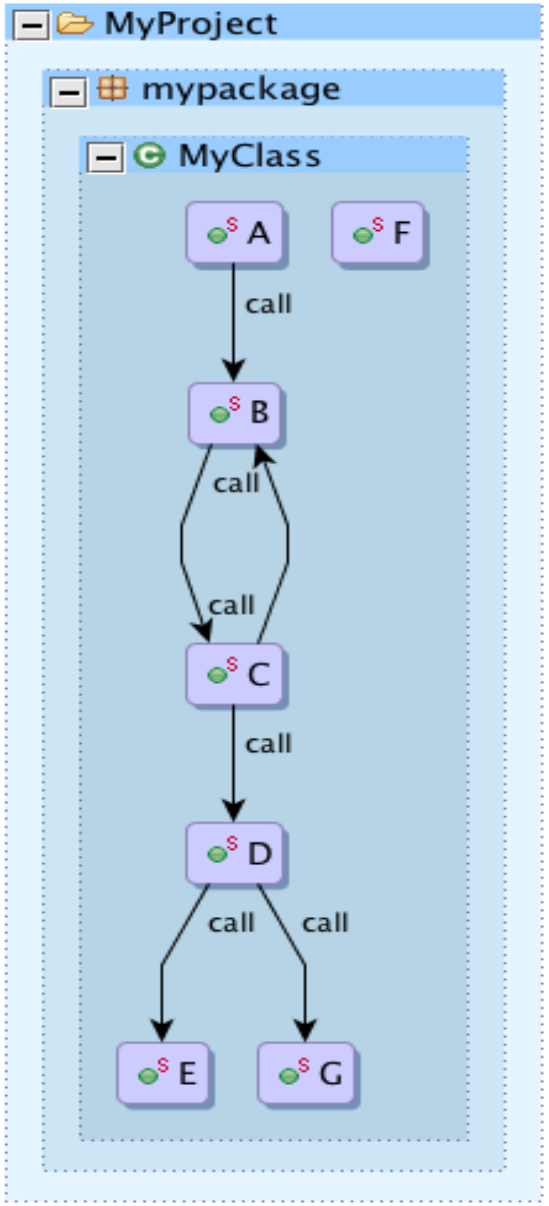
Selects *q*, excluding nodes and edges in q2. Removing an edge necessarily removes the nodes it connects. Removing a node remove the connecting edge as well.



B.difference(C) outputs a graph with only the node B.
B.difference(A, B) outputs an empty graph.
q.difference(C) outputs the shown graph without the node C and any edges entering or leaving node C.

q.differenceEdges(q2...)

Selects q, excluding the edges from q2.
q.differenceEdges(q) outputs only the nodes A,B,C,D,E,F,G.
q.differenceEdges(q.forwardStep(B)) outputs the graph A→B, C→B, C→D, D→E, D→G, and F (the edge B→C is removed from the original graph).

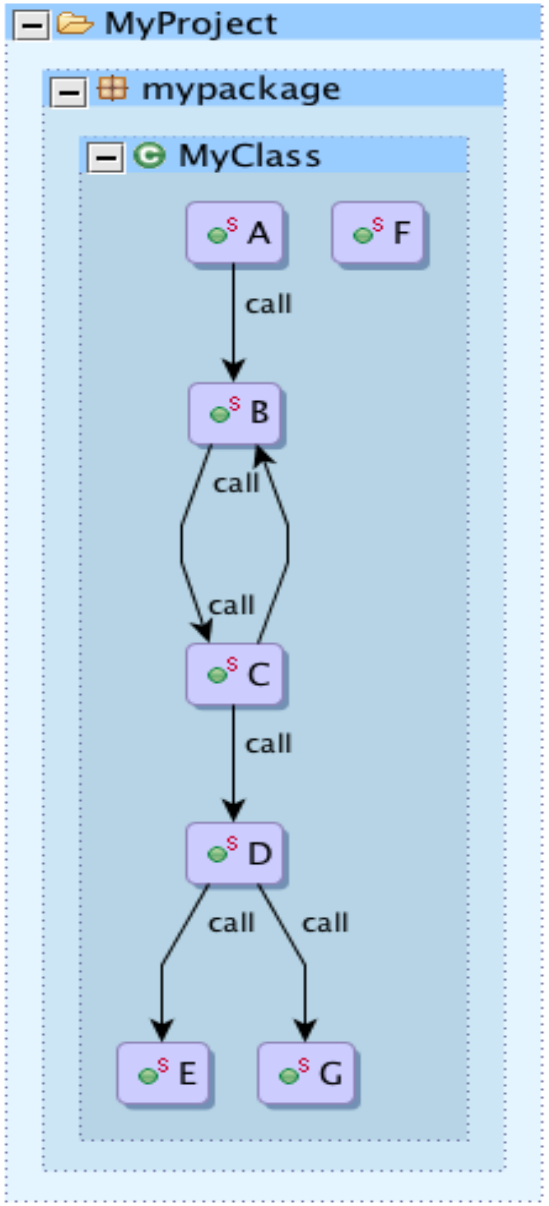


Between Traversals

q.between(fromX, toY)
Selects the subgraph containing all paths starting from a set X to a set Y.
q.between(C, A) outputs Empty graph.
q.between(C, E) outputs the graph C→D→E, C→B→C.

q.betweenStep(fromX, toY)
Selects the subgraph containing all paths of length one starting from a set X to a set Y.
q.betweenStep(C, D) outputs the graph C→D.
q.betweenStep(D, C) outputs Empty graph.
q.betweenStep(C, E) outputs Empty graph.

Note: A possible implementation of betweenStep could be:
q.forwardStep(fromX).intersection(q.reverseStep(toY))



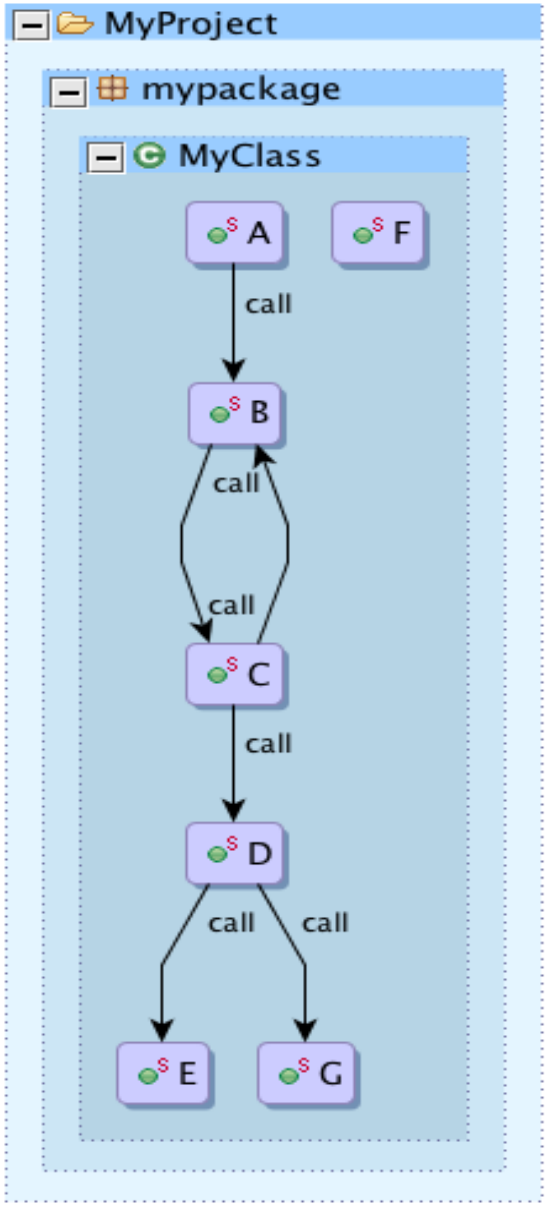
Graph Operations (1)

q.leaves()
Selects the nodes from the given graph with no successors.
q.leaves() outputs {E, F, G}.

q.roots()
Selects the nodes from the given graph with no predecessors.
q.roots() outputs {A, F}.

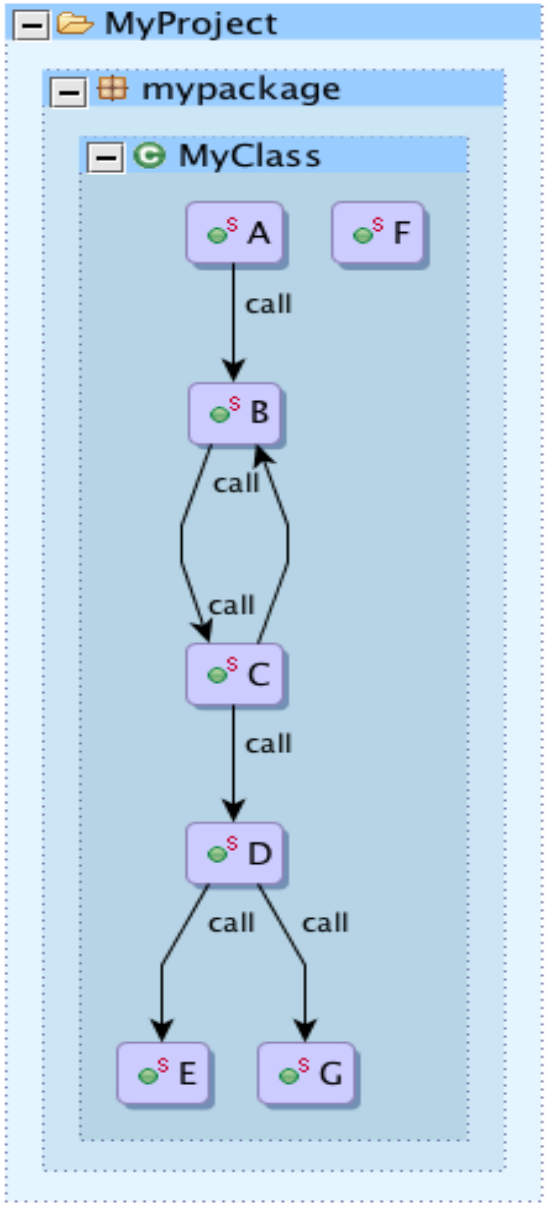
q.retainNodes()
Selects all nodes from the graph, ignoring edges.
q.retainNodes() outputs {A,B,C,D,E,F,G}.

q.retainEdges()
Retain only edges and nodes connected to edges.
q.retainEdges() outputs the shown graph without F



Graph Operations (2)

q2.induce(q)
Adds edges from the given graph query *q2* to *q*.
var q2 = B.union(C)
q2.induce(q) outputs the graph B→C→B.



Graph Elements

- In Atlas a *Q* (query) object can be thought of as a recipe to a *constraint satisfaction problem* (CSP). Building and chaining together *Q*'s costs you almost nothing, but when you ask to see what is in the *Q* (by showing or evaluating the *Q*) Atlas must evaluate the query and execute the graph traversals.
- The evaluated result is a *Graph*. A *Graph* is a set of *GraphElement* objects. In Atlas both a *Node* and an *Edge* are *GraphElement* objects.

```
Graph graph = q.eval();
AtlasSet<Node> graphNodes = graph.nodes();
AtlasSet<Edge> graphEdges = graph.edges();
```

GraphElement Attributes

- A *GraphElement* (Node/Edge) can have attributes
- An attribute is a key that corresponds to a value in the *GraphElement* attribute map.
  - An attribute that is common to almost all nodes and edges is *XCSG.name*.

```
for(Node graphNode : graphNodes){
  String name = (String) graphNode.attr().get(XCSG.name);
}
```

  - Another common attribute is the source correspondence that stores the file and character offset of the source code corresponding to the node or edge. Double clicking on a node or edge takes us to the corresponding source code!

Selecting GraphElements on Attributes

- Attributes can be used to select *GraphElement*s (nodes/edges) out of a graph.
  - For example from the graph we can select all method nodes with the attribute key XCSG.name that have the value "main".

    Q mainMethods = q.selectNode(XCSG.name, "main");

  - We could also select all array's with 3 dimensions.

    Q 3DimArrays = q.selectNode(XCSG.arrayDimension, 3);

Tags: A Special Kind of Attribute

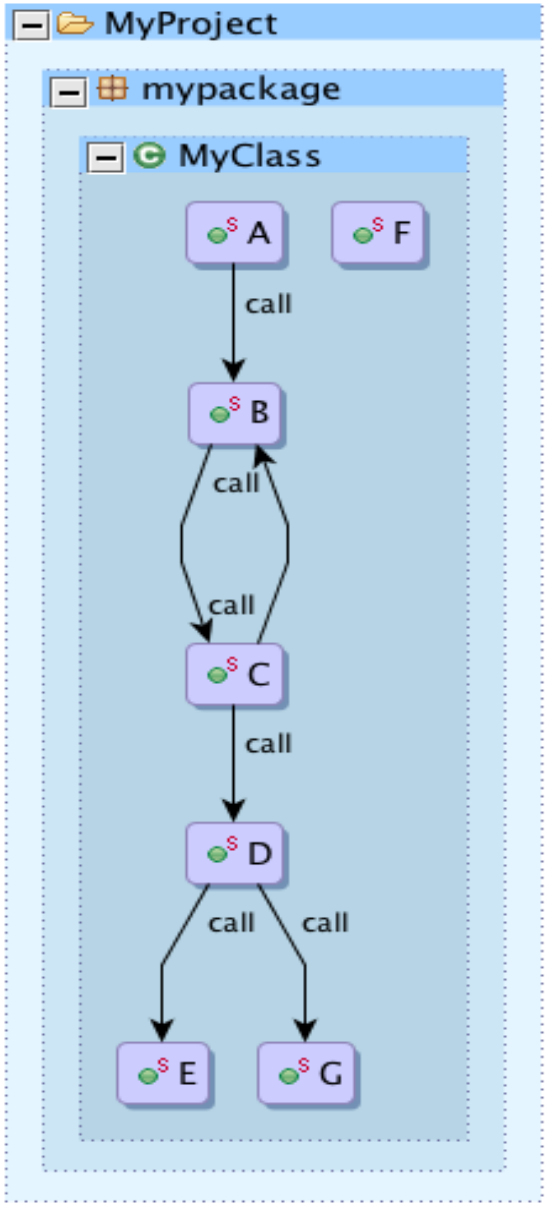
- A Tag is an attribute whose value is TRUE (T)
- The presence of a tag denotes that a *Node* or *Edge* is a member of a set.
  - For example, all method nodes are tagged with *XCSG.Method*.
- Atlas provides several default tags such as *XCSG.Method* that should be used to make code cleaner (and safer from possible schema changes in the future!).

Selecting GraphElements by Tags (1)

q.nodesTaggedWithAny(...)
Selects the nodes tagged with at least one of the given tags.
q.nodesTaggedWithAny(XCSG.Method) outputs: {A,B,C,D,E,F,G}.
q.nodesTaggedWithAny(XCSG.Class) outputs: empty graph.
q.nodesTaggedWithAny(XCSG.Method, XCSG.Class) outputs: {A,B,C,D,E,F,G}.

q.nodesTaggedWithAll(...)
Selects the nodes tagged with all of the given tags.
q.nodesTaggedWithAll(XCSG.Method) outputs: {A,B,C,D,E,F,G}.
q.nodesTaggedWithAll(XCSG.Class) outputs: empty graph.
q.nodesTaggedWithAll(XCSG.Method, XCSG.Class) outputs: empty graph.

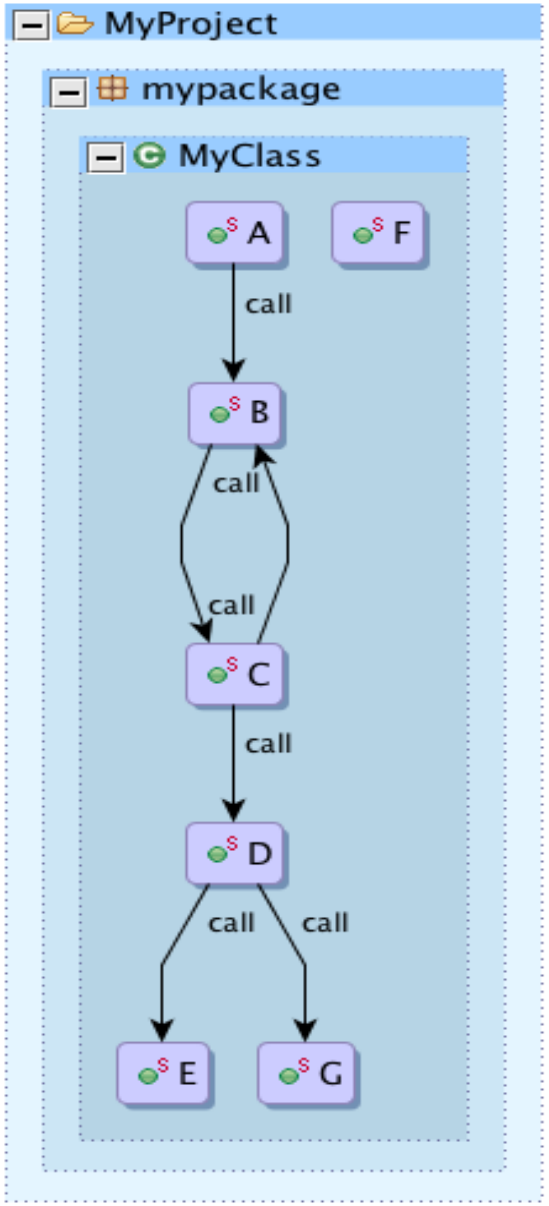
NOTE: The output contains only the nodes.



Selecting GraphElements by Tags (2)

q.edgesTaggedWithAny(...)
Selects edges tagged with at least one of tags. Includes all nodes.
q.edgesTaggedWithAny(XCSG.Call) outputs: the shown graph.

q.edgesTaggedWithAll(...)
Selects edges tagged with all of the given tags. Includes all nodes.
q.edgesTaggedWithAll(XCSG.Call) outputs: the shown q.



Chaining Queries (1)

- We can chain queries to form more complex queries
- Q objects may contain multiple nodes and edges (so an origin can include multiple starting points).
- A second look at the queries we started the example with:

1. First create a subgraph (called containsEdges) of the universe that only contains nodes and edges connected by a *contains* relationship. The Atlas map is heterogeneous, meaning there are many edge and node types. Here we are specifying that we want edges that represent a *contains* relationship from a parent node to a child node.

var containsEdges = universe.edgesTaggedWithAny(XCSG.Contains)

Chaining Queries (2)

2. We then define yet another subgraph (called *app*) which contains nodes and edges declared under the MyProject project.

var app = containsEdges.forward(universe.project(”MyProject"))

3. From the app subgraph we select all nodes that are methods.

var appMethods = app.nodesTaggedWithAny(XCSG.Method)

4. From the subgraph *app* we select all method nodes named "<init>" (instance initializer methods) or "<clinit>" (static initializer methods). We are using a query method called methods(String methodName) that selects methods that have a name that matches the given string. We will explore more query methods later.

var initializers = app.methods("<init>”).union(app.methods("<clinit>"))

Chaining Queries (3)

5. From the app subgraph we select all nodes that are constructors.

var constructors = app.nodesTaggedWithAny(XCSG.Constructor)

6. From the universe create a subgraph (called callEdges) that only contains nodes and edges connected by a call relationship.

var callEdges = universe.edgesTaggedWithAny(XCSG.Call)

7. Define graph to be the methods in the app ignoring initializers and constructors with call edges added in where they exist.

var q = (appMethods difference (initializers.union(constructors))).induce(callEdges)

8. Evaluate and display the graph query.

show(q)

Atlas Schema

- To become proficient in wielding Atlas, you should have:
  - Firm understanding of Extensible Common Software Graph (XCSG) schema
  - Firm understanding of the language you are analyzing (Java source, Jimple, C)
- Examples:
  - How do we detect an inner class with XCSG?
  - No tag for inner class, inner class is defined by a contains relationship.
    - *containsEdges = universe.edgesTaggedWithAny(XCSG.Contains)*
    - *topLevelClasses = containsEdges.successors(universe.nodesTaggedWithAny(XCSG.Package))*
    - *innerClasses = containsEdges.forward(topLevelClasses).difference(topLevelClasses)*
  - What about Java vs. Jimple (Java Bytecode)?
    - No concept of inner classes in bytecode

Atlas Schema Resources

- http://ensoftatlas.com/wiki/Extensible_Common_Software_Graph
- Eclipse → Show Views → Other… → Atlas → Element Detail View
- Atlas Shell (test out queries on the fly!)
- Atlas Smart Views (interactive graphs)

Practice Problems

- Is a java.util.Map a java.util.Collection?
- Let methods B and F be sensitive methods. Return the subset of the sensitive methods that are called by an application.
- Find all calls within the app to custom collection type constructors. Define a custom collection type to be a class that inherits from java.util.Collection and is defined within the app (your project).