A Short Introduction to Adaptive Programming (AP) for Java Programmers

Northeastern Team

Problem addressed

- “To what extent is it possible to construct useful programs without knowing exactly what data types are involved?”

Overview

- DJ introduction
- AspectJ and DJ
- Aspect-oriented Programming in pure Java using the DJ library

AP

- Late binding of data structures
- Programming without accidental data structure details yet handling all those details on demand without program change
- Reducing representational coupling

Concepts needed (DJ classes)

- ***ClassGraph***
- ***Strategy***
- ***Visitor***
- TraversalGraph
- ObjectGraph
- ObjectGraphSlice

important

for advanced programming

Software Design and Development with DJ (very brief)

- Functional decomposition into generic behavior
  - Decomposition into methods
    - Decomposition into strategies
    - Decomposition into visitors
- Adaptation of generic behavior
  - Identify class graph
  - Refine strategies

AOSD: not every concern fits into a component: crosscutting

	CM1	CM2	CM3	CM4	CM5	CM6
CR1	x					
CR2		x				
CR3			x			
CR4	x	x		x	x	

Goal: find new component structures that encapsulate “rich” concerns

Advice applies to all join points in pointcut

Analogy 1

Visitor = multiple advice for multiple pointcuts

AspectJ

- Abstract pointcut
  - set of execution points
  - where to watch
- Advice
  - what to do
- Concrete pointcut
  - set notation (using regular expressions)

DJ

- Abstract object slice
  - set of entry/exit points
  - where to go
- Visitor
  - what to do
- Actual object slice
  - path set notation using traversal strategies

Analogy 2: more useful

AspectJ

- Pointcut
  - where to watch execution
- Advice
  - what to do

DJ

- Visitor signature
  - where to watch traversal execution
- Visitor method body
  - what to do

Analogy 3

AspectJ

- Introduction
  - Introduce one field or method into multiple classes

DJ

- Traversal specification
  - Introduce traversal methods into multiple classes
  - Several related introductions are defined by one traversal specification

a reusable aspect

```
abstract public aspect RemoteExceptionLogging {

  abstract pointcut logPoint();

  after() throwing (RemoteException e): logPoint() {
    log.println("Remote call failed in: " +
                thisJoinPoint.toString()  +
                "(" + e + ").");
  }
}
```

abstract

```
public aspect MyRMILogging extends RemoteExceptionLogging {
  pointcut logPoint():
    call(* RegistryServer.*.*(..)) ||
    call(private * RMIMessageBrokerImpl.*.*(..));
}
```

Aspects are adaptive

```
abstract aspect CapabilityChecking {

  pointcut invocations(Caller c):
    this(c) && call(void Service.doService(String));

  pointcut workPoints(Worker w):
    target(w) && call(void Worker.doTask(Task));

  pointcut perCallerWork(Caller c, Worker w):
    cflow(invocations(c)) && workPoints(w);



  before (Caller c, Worker w): perCallerWork(c, w) {
    w.checkCapabilities(c);
  }
}
```

DJ: Counting Pattern:
Abstract Pointcut

```
class BusRoute {
   int countPersons(TraversalGraph WP) {
      Integer result = (Integer)
      WP.traverse(this, new  Visitor(){ int r ;
       public void before(Person host){ r++; }
      public void start() { r = 0;}
      public Object getReturnValue()
        {return new Integer ( r);}
     }); return result.intValue();}
}
```

DJ: Counting Pattern:
Concrete Pointcut

```
// Prepare the traversal for the current class graph
ClassGraph classGraph = new ClassGraph();
TraversalGraph WPTraversal = new TraversalGraph
   ("from BusRoute via BusStop to Person", classGraph);

int  r = aBusRoute.countPersons(WPTraversal);
```

Example : Count Aspect Pattern

```
collaboration Counting {
    role Source {
      in TraversalGraph getT();
      public int count (){ // traversal/visitor weaving
           getT().traverse(this, new Visitor(){ int r;
             public void before(Target host){ r++; }
             public void start() { r = 0;} …) } }
    role Target {}
}
```

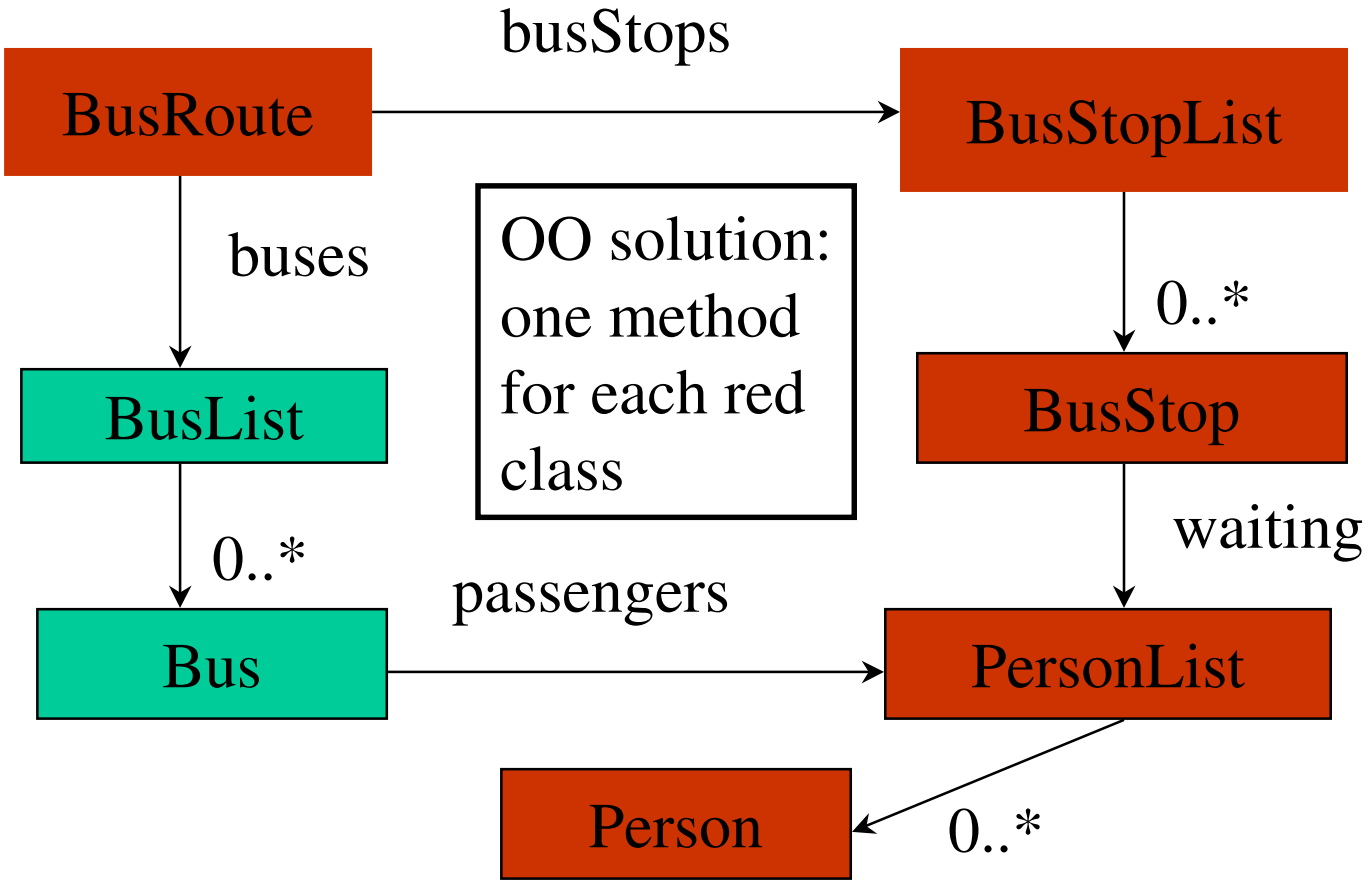
Base:
Meta variable: bold
Keywords: underscore

AP history

- Programming with partial data structures = propagation patterns
- Programming with participant graphs = high-level class graphs
- Programming with object slices
  - partial objects = all the constraints imposed by visitors

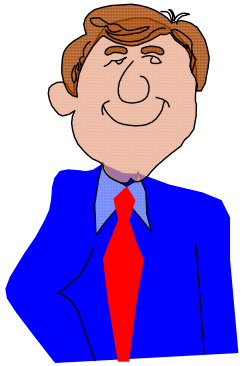
Collaborating Classes

find all persons waiting at any bus stop on a bus route

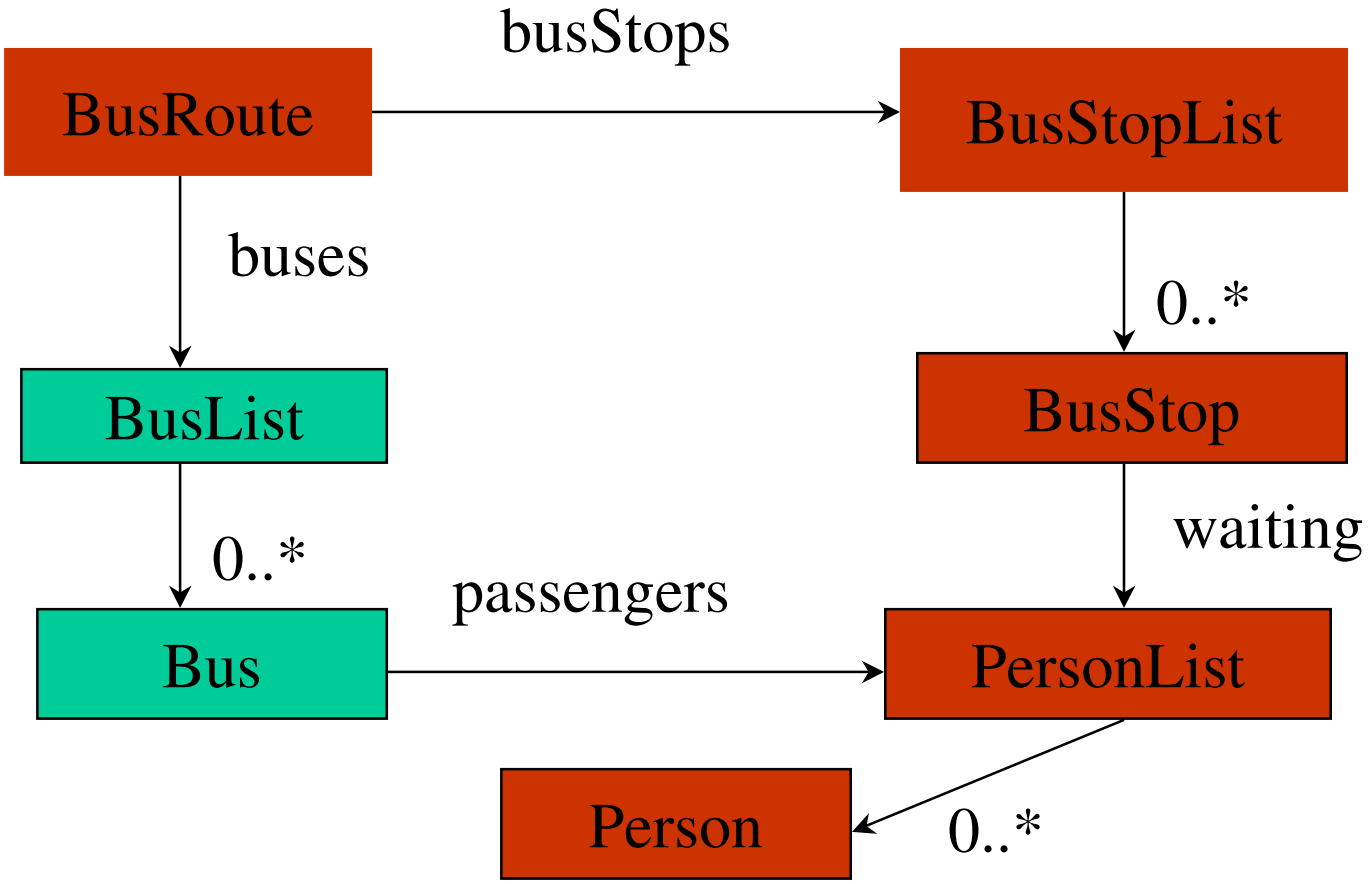


find all persons waiting at any bus stop on a bus route

Traversal Strategy



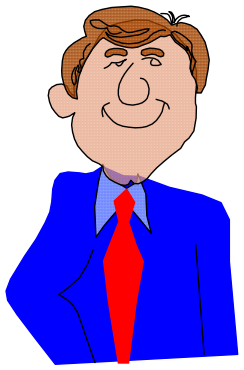
`from` BusRoute `through` BusStop `to` Person

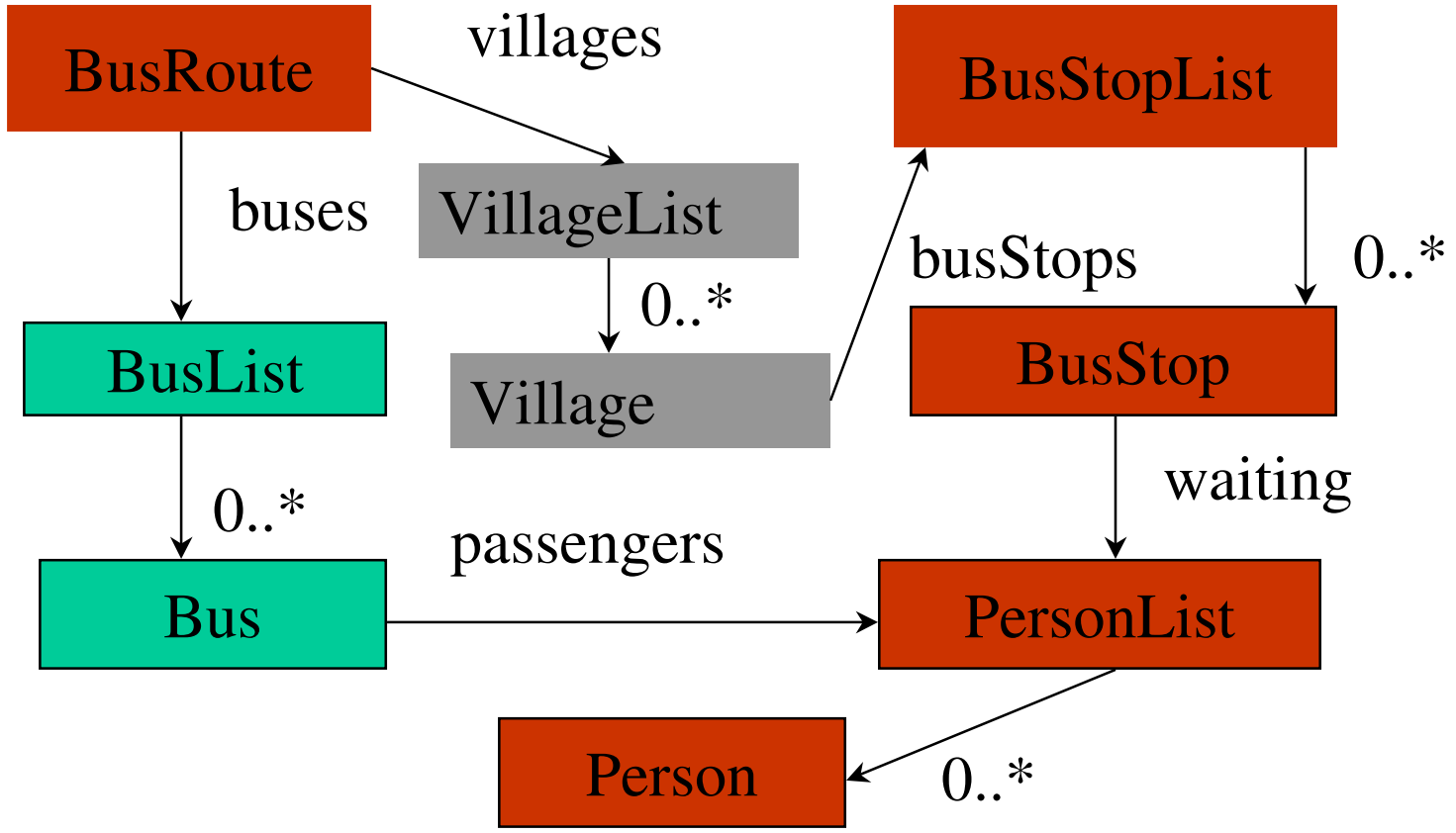


find all persons waiting at any bus stop on a bus route

Robustness of Strategy

`from` BusRoute `through` BusStop `to` Person





Writing Adaptive Programs with Strategies (DJ=pure Java)

String WPStrategy="`from` BusRoute `through` BusStop `to` Person"

```
class BusRoute {
   int countPersons(TraversalGraph WP) {
      Integer result = (Integer)
      WP.traverse(this, new  Visitor(){ int r ;
       public void before(Person host){ r++; }
      public void start() { r = 0;}
      public Object getReturnValue()
        {return new Integer ( r);}
      }); return result.intValue();}
}
```

Writing Adaptive Programs with Strategies (DJ=pure Java)

String WPStrategy="`from` BusRoute `through` BusStop `to` Person"

```
// Prepare the traversal for the current class graph
ClassGraph classGraph = new ClassGraph();
TraversalGraph WPTraversal = new TraversalGraph
   (WPStrategy, classGraph);

int  r = aBusRoute.countPersons(WPTraversal);
```

Writing Adaptive Programs with Strategies (DJ=pure Java)

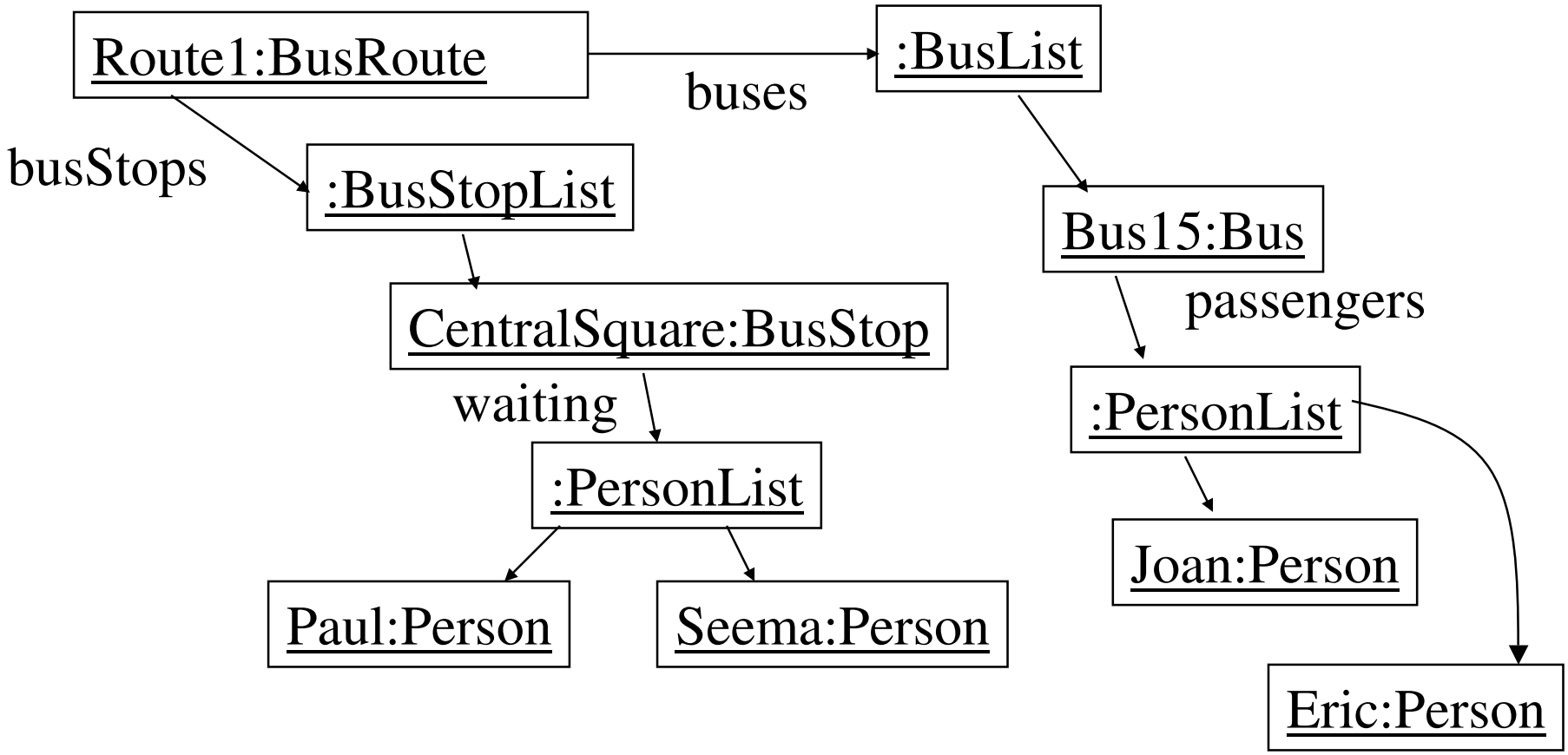
String WPStrategy="`from` BusRoute `through` BusStop `to` Person"

```
class BusRoute {
   int countPersons(TraversalGraph WP) {
      Integer result = (Integer)
      WP.traverse(this, new  Visitor(){...});
   return result.intValue();}
}
```

WP.traverse(this,visitor) <===>

```
ObjectGraph objectGraph =
   new ObjectGraph(this, classGraph);
ObjectGraphSlice objectGraphSlice =
  new ObjectGraphSlice(objectGraph, WP);
objectGraphSlice.traverse(visitor);
```

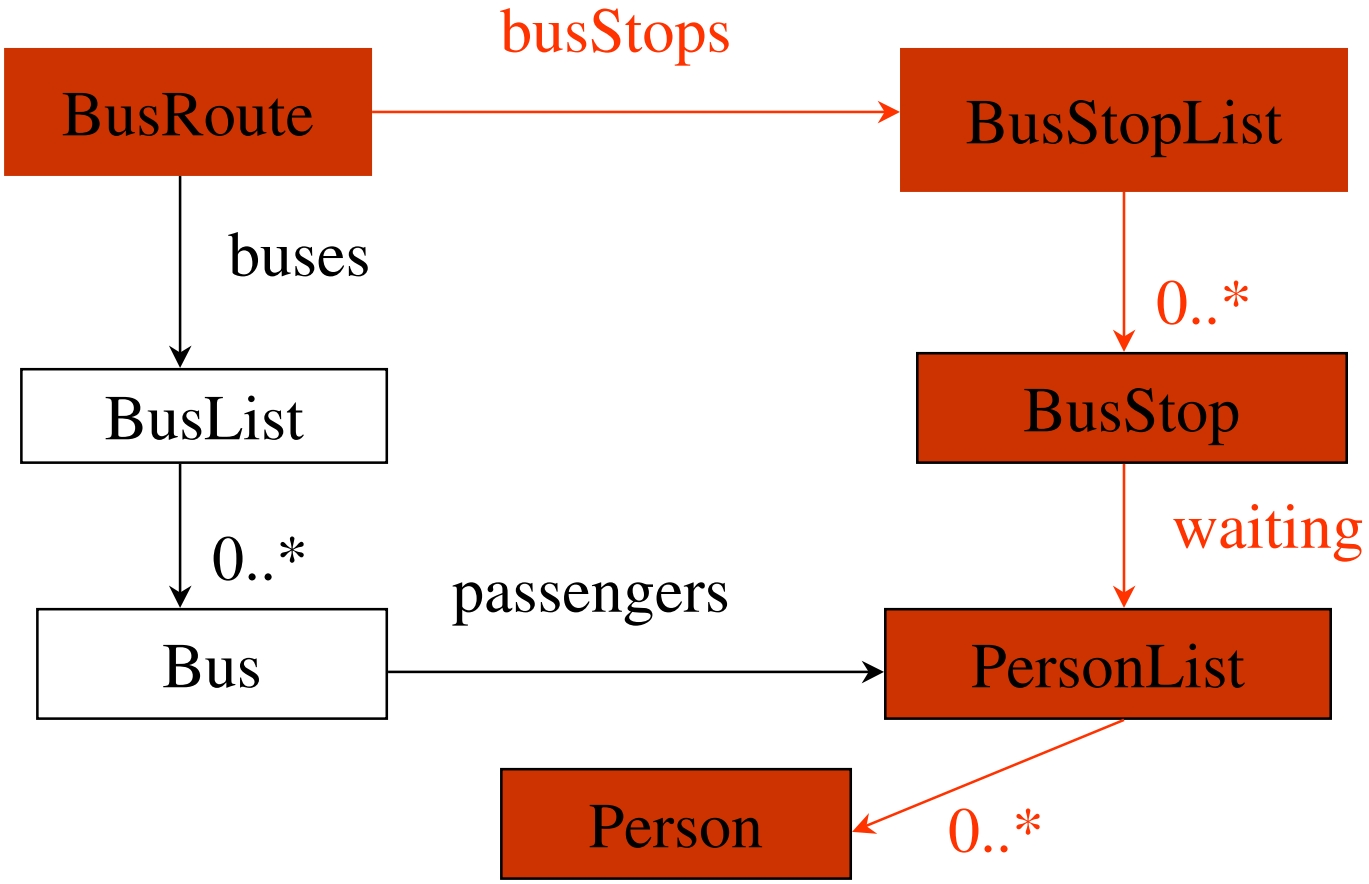
ObjectGraph: in UML notation



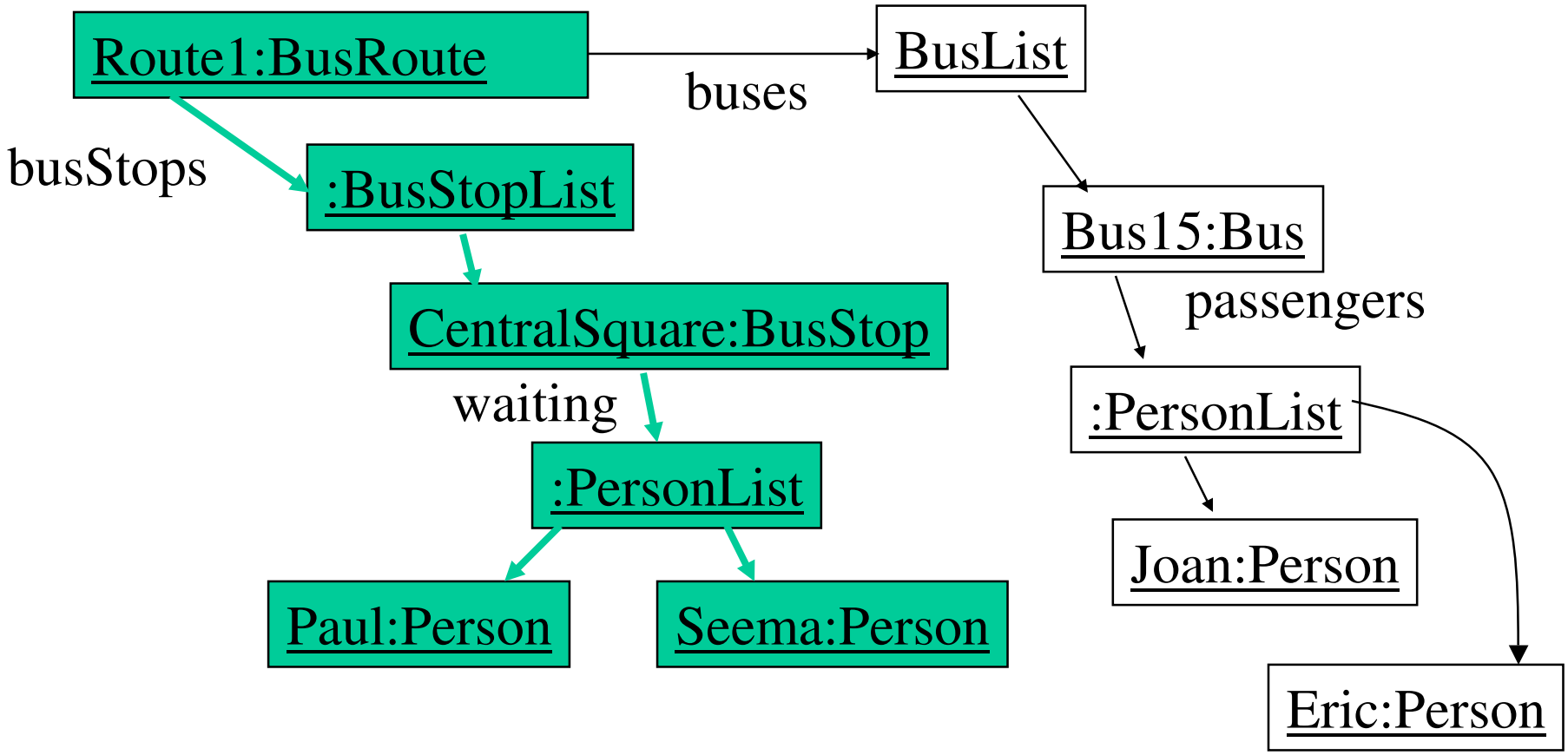
find all persons waiting at any bus stop on a bus route

TraversalGraph

`from` BusRoute `through` BusStop `to` Person



ObjectGraphSlice



Applications of Traversal Strategies

- Program Kinds in DJ
  - $\text{AdaptiveProgram}_{\text{Traditional}}$(ClassGraph)
    - strategies are part of program: DemeterJ, Demeter/C++
  - $\text{AdaptiveProgram}_{\text{Dynamic}}$(Strategies, ClassGraph)
    - strategies are a parameter. Even more adaptive.
  - $\text{AdaptiveProgram}_{\text{TraditionalOptimized}}$ (TraversalGraphs)
    - strategies are a parameter. Reuse traversal graphs.
  - $\text{AdaptiveProgram}_{\text{DJ}}$(ObjectGraphSlices)
    - strategies are a parameter. Reuse object graph slices.

Example

- For data member access:
- C c = (C) Main.cg.fetch(this, “from A via B to C”);

Understanding the meaning of a strategy

- Classes involved: Strategy, ObjectGraph, ObjectGraphSlice, ClassGraph
- We want to define the meaning of a Strategy-object for an ObjectGraph-object as an ObjectGraphSlice-object (a subgraph of the ObjectGraph-object). Minimal attention necessary will be given to ClassGraph-object.

Simple case: from A to B

- See lecture: Navigation in object graphs navig-object-graphs-1205-w02.ppt

Graphs and paths

- Directed graph: *(V,E)*, *V* is a set of nodes, $E \subseteq V \times V$ is a set of edges.
- Directed labeled graph: *(V,E,L)*, *V* is a set of nodes, *L* is a set of labels, $E \subseteq V \times L \times V$ is a set of edges.
- If $e = (u,l,v)$, *u* is source of *e*, *l* is the label of *e* and *v* is the target of *e*.

Graphs and paths

- Given a directed labeled graph: (V,E,L), a node-path is a sequence $p = \langle v_0 v_1 \ldots v_n \rangle$ where $v_i \in V$ and $(v_{i-1}, l_i, v_i) \in E$ for some $l_i \in L$.
- A path is a sequence $\langle v_0\ l_1\ v_1\ l_2\ \ldots\ l_n\ v_n \rangle$, where $\langle v_0 \ldots v_n \rangle$ is a node-path and $(v_{i-1},\ l_i,\ v_i) \in E$.

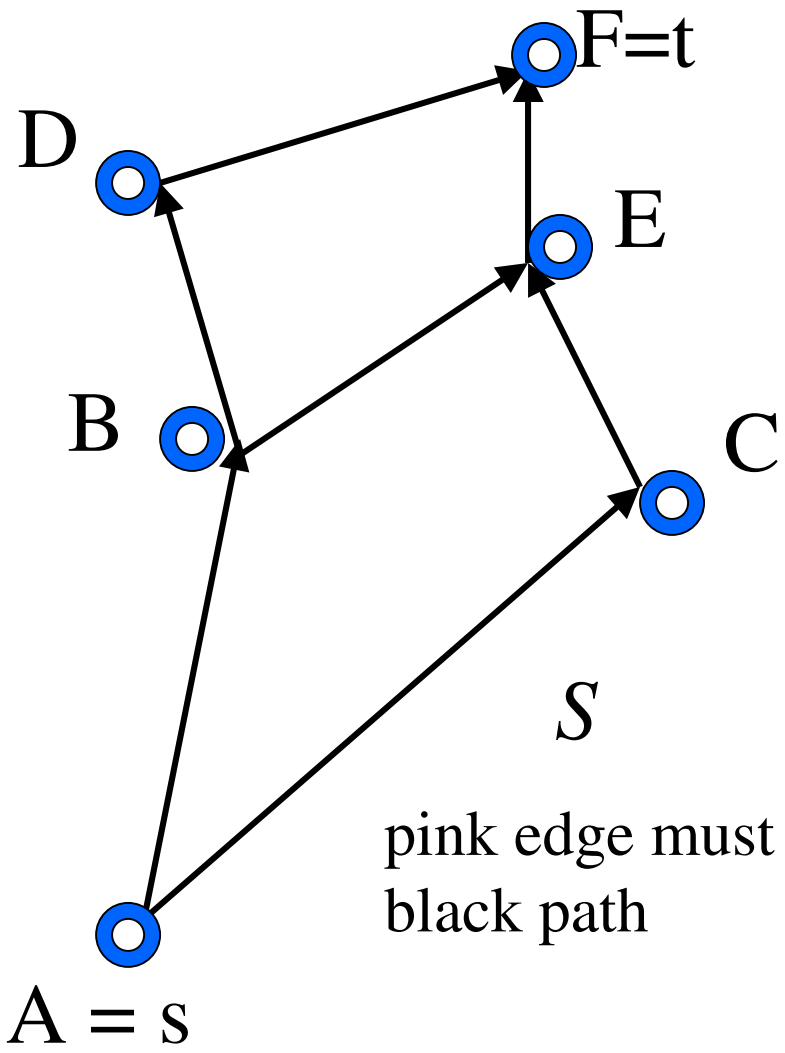
Graphs and paths

- In addition, we allow node-paths and paths of the form $<v_0>$ (called trivial).
- First node of a path or node-path *p* is called the source of *p*, and the last node is called the target of *p*, denoted *Source(p)* and *Target(p)*, respectively. Other nodes: interior.

Strategy definition: embedded, positive strategies

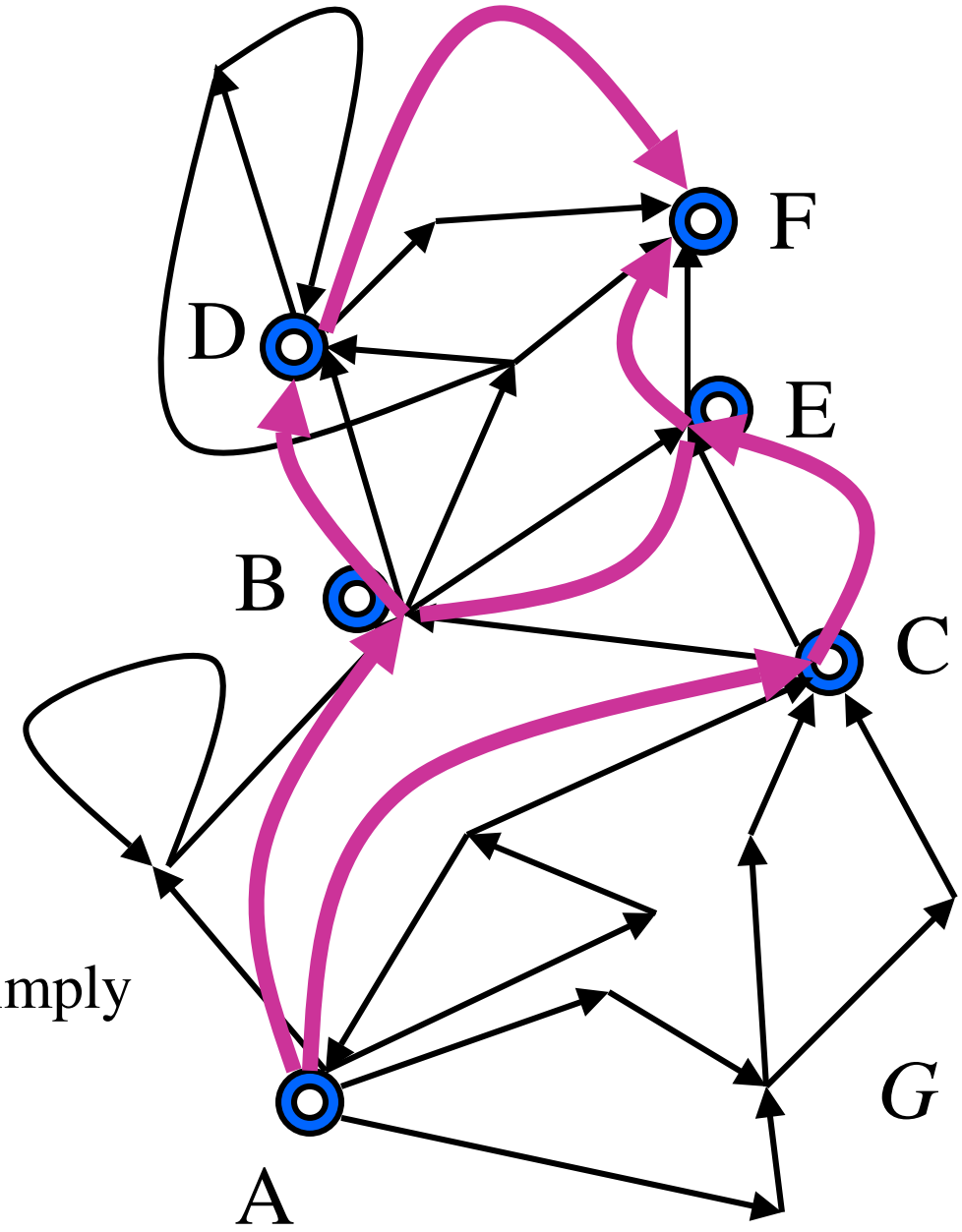
- Given a graph G, a strategy graph S of G is any subgraph of the transitive closure of G. Source s, Target t.
- The transitive closure of G=(V,E) is the graph G*=(V,E*), where E*={(v,w): there is a path from vertex v to vertex w in G}.

S is a strategy for G

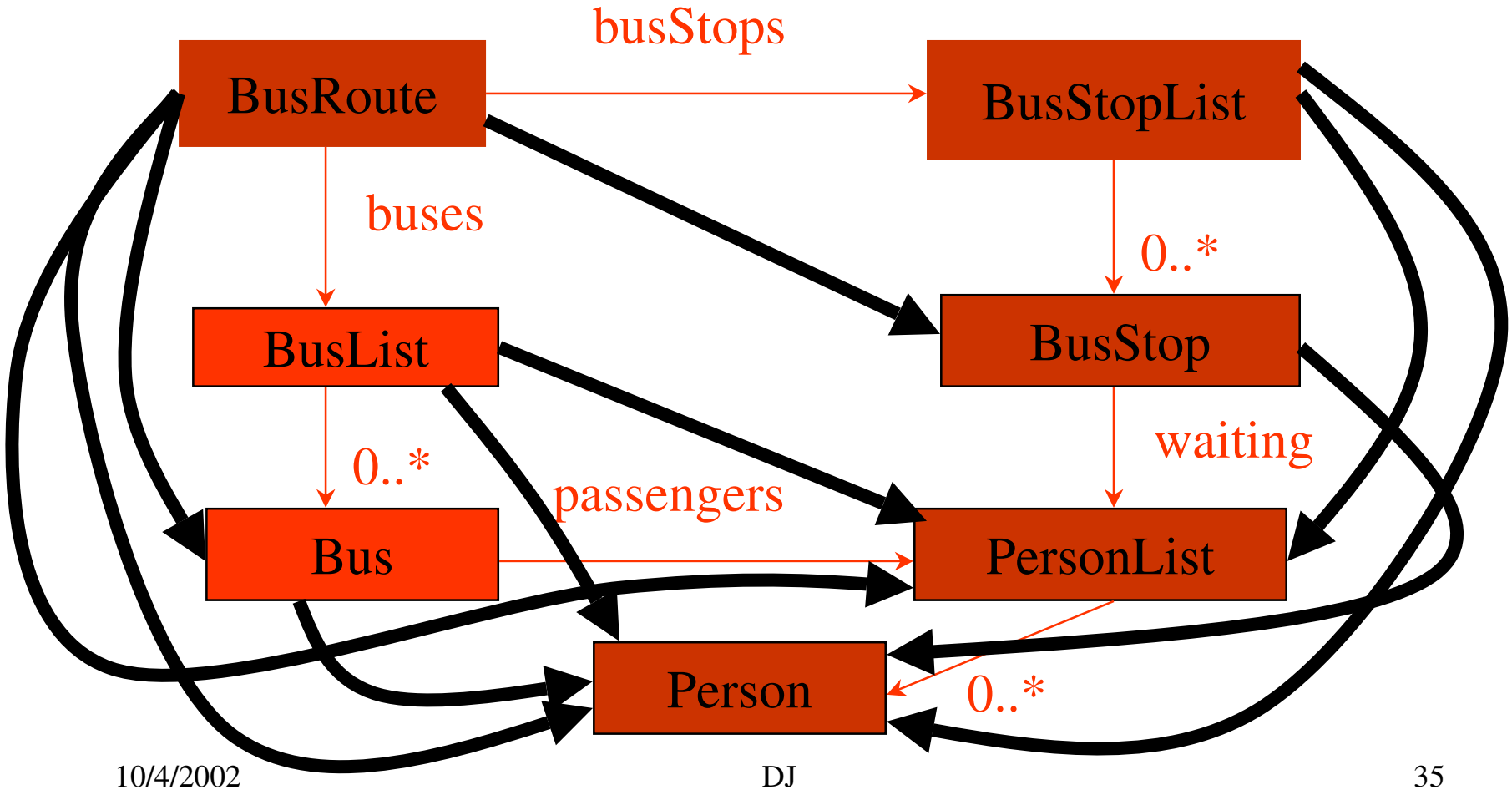


S

pink edge must imply
black path



Transitive Closure



Strategy graph and base graph are directed graphs

Key concepts

- Strategy graph *S* with source *s* and target *t* of a base graph *G*. *Nodes(S)* subset *Nodes(G)* (Embedded strategy graph).
- A path *p* is an ***expansion*** of path *p'* if *p'* can be obtained by deleting some elements from *p*.

A simple view of traversals

- When a traversal reaches a target node in the object graph, the path traversed from the source, with suitable substitution of subclasses by superclasses, must be an expansion of an s-t path in the strategy graph. s is the source and t is the target of the strategy. Each edge in the strategy graph corresponds to at least one edge in the object graph.

A simple view of traversals

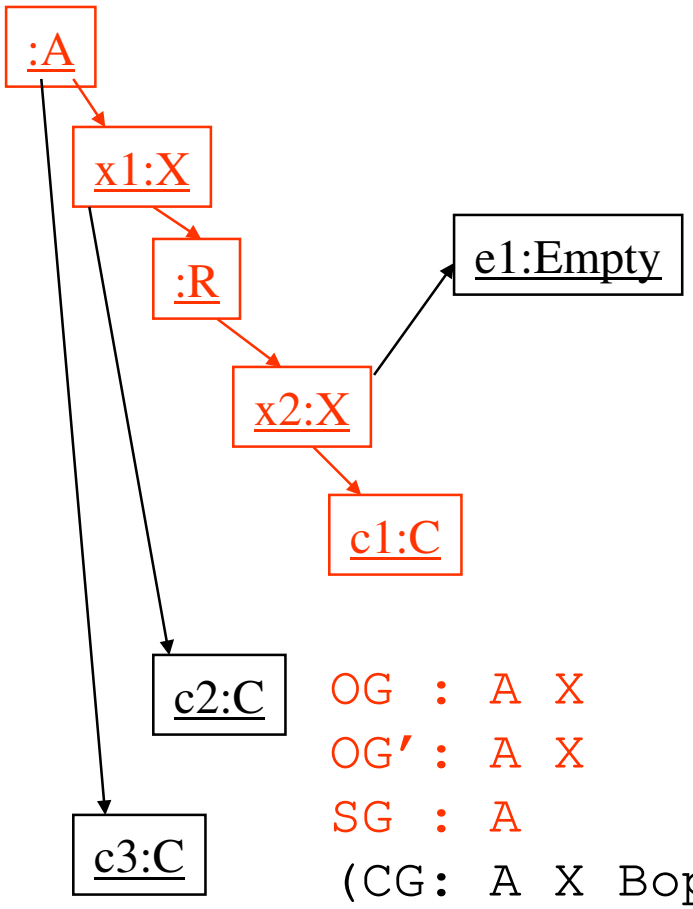
- When a traversal reaches a final node in the object graph without being at a target, the path traversed from the source, with suitable substitution of subclasses by superclasses, must be a prefix of an expansion of an s-t path in the strategy graph. The prefix is the longest prefix such that there is still a possibility of success as determined by the class graph.

Only node paths shown for space reasons

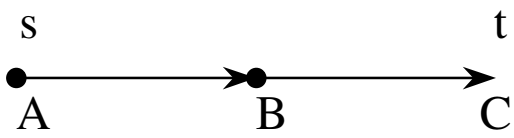
Example 1

```
strategy:
{A -> B
 B -> C}
```

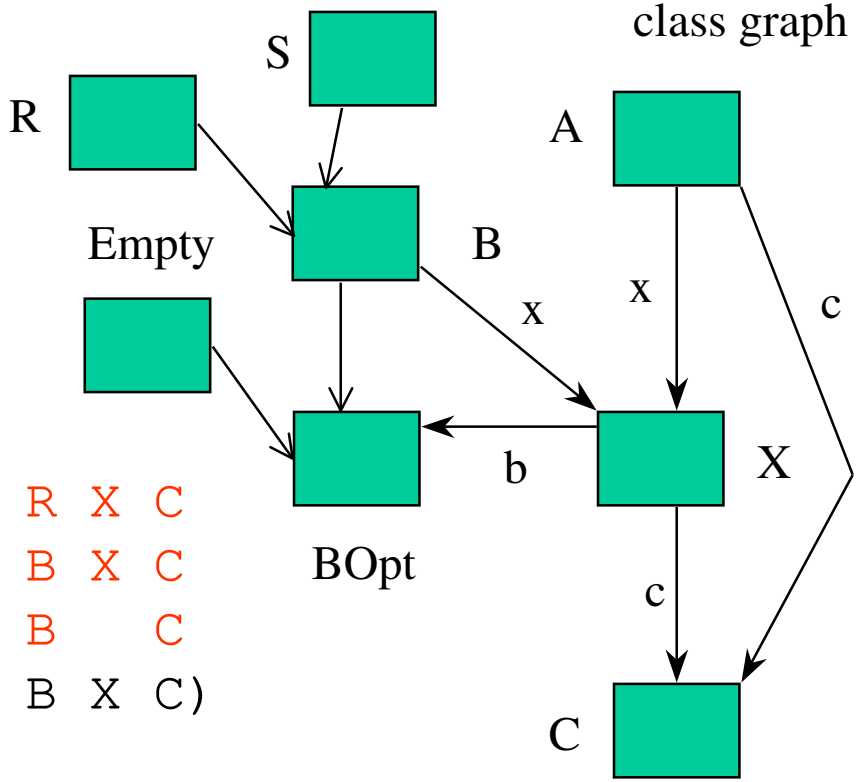
Object graph



Strategy



class graph



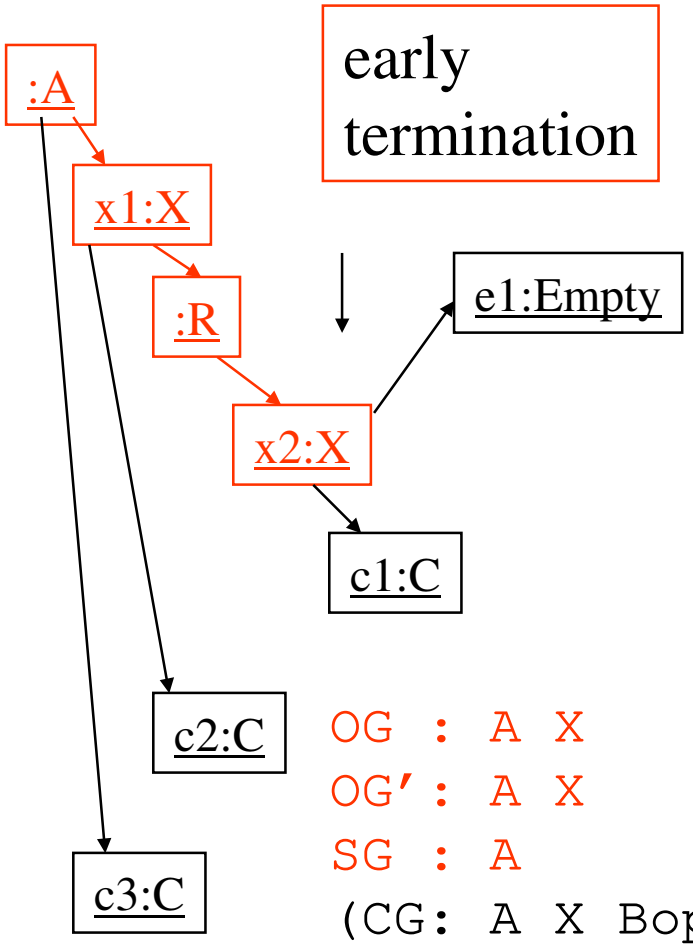

```
OG  : A X      R X C
OG' : A X      B X C
SG  : A        B   C
(CG: A X Bopt B X C)
```

Only node paths shown for space reasons

Example 1A

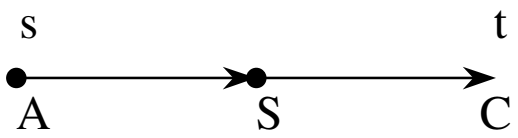
```
strategy:
{A -> S
 S -> C}
```

Object graph

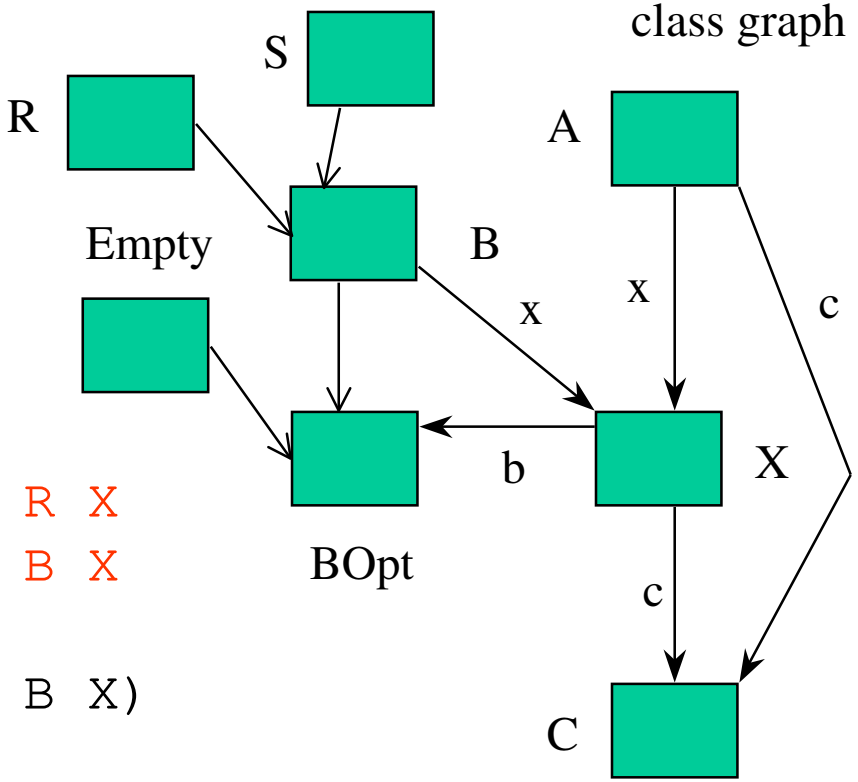


early termination

Strategy



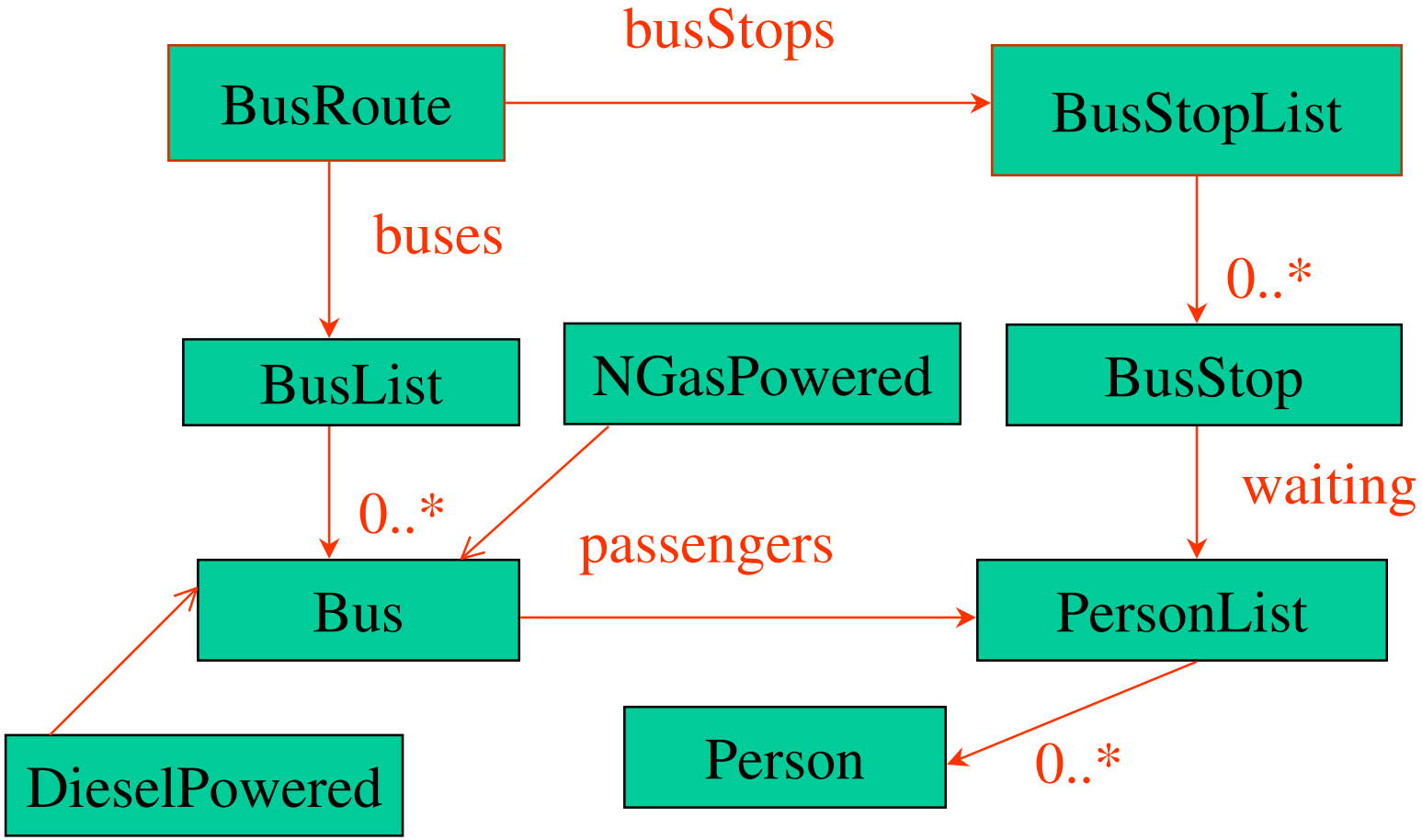
class graph




```
OG  : A X      R X
OG' : A X      B X
SG  : A
(CG: A X Bopt B X)
```

`S = from` BusRoute `through` Bus `to` Person

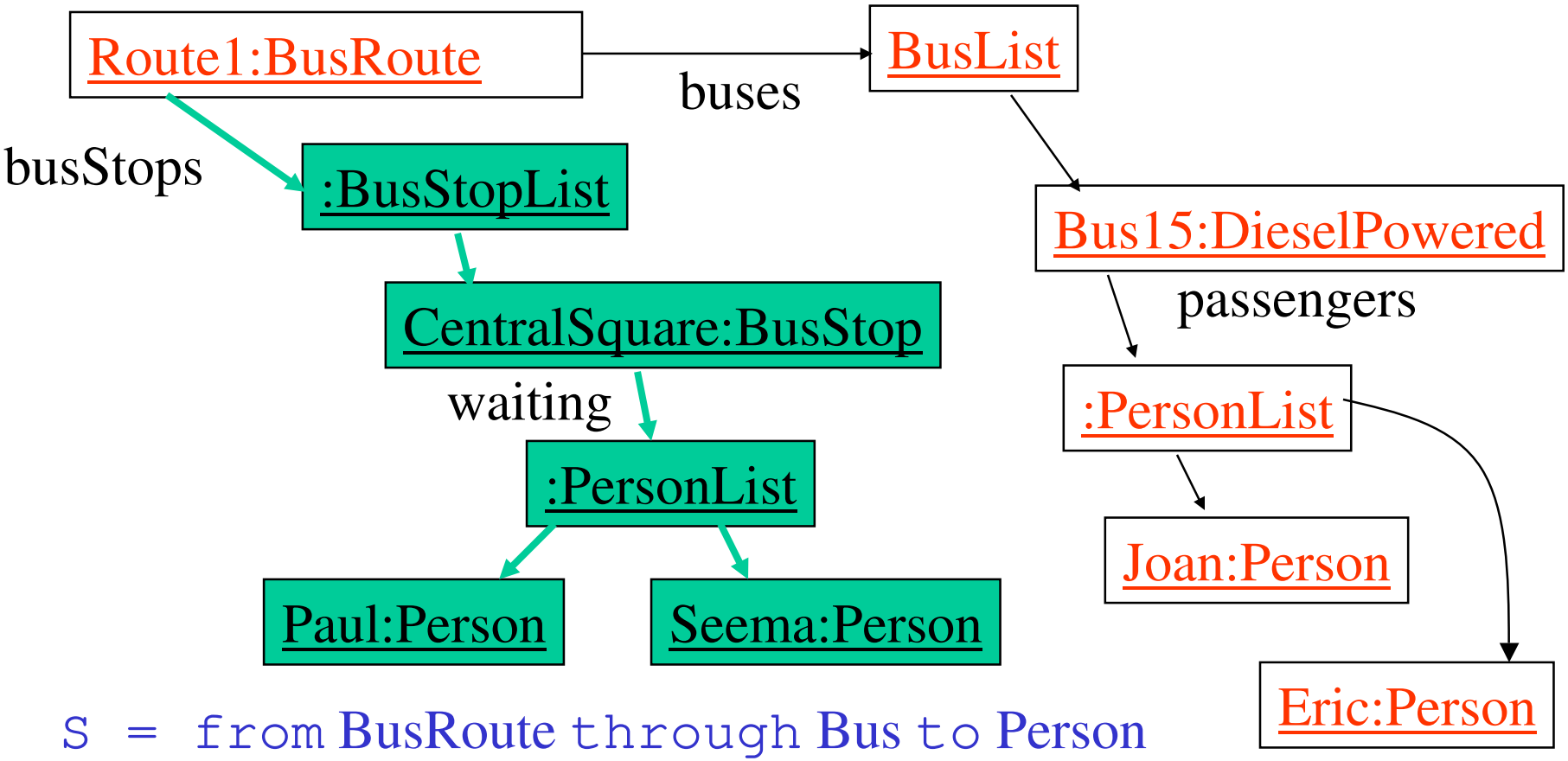
Example 2



```
OG  :  BR  BL  DP  PL  P
OG′ :  BR  BL  B   PL  P
SG  :  BR      B       P
```

Example 2

Only node paths shown for space reasons

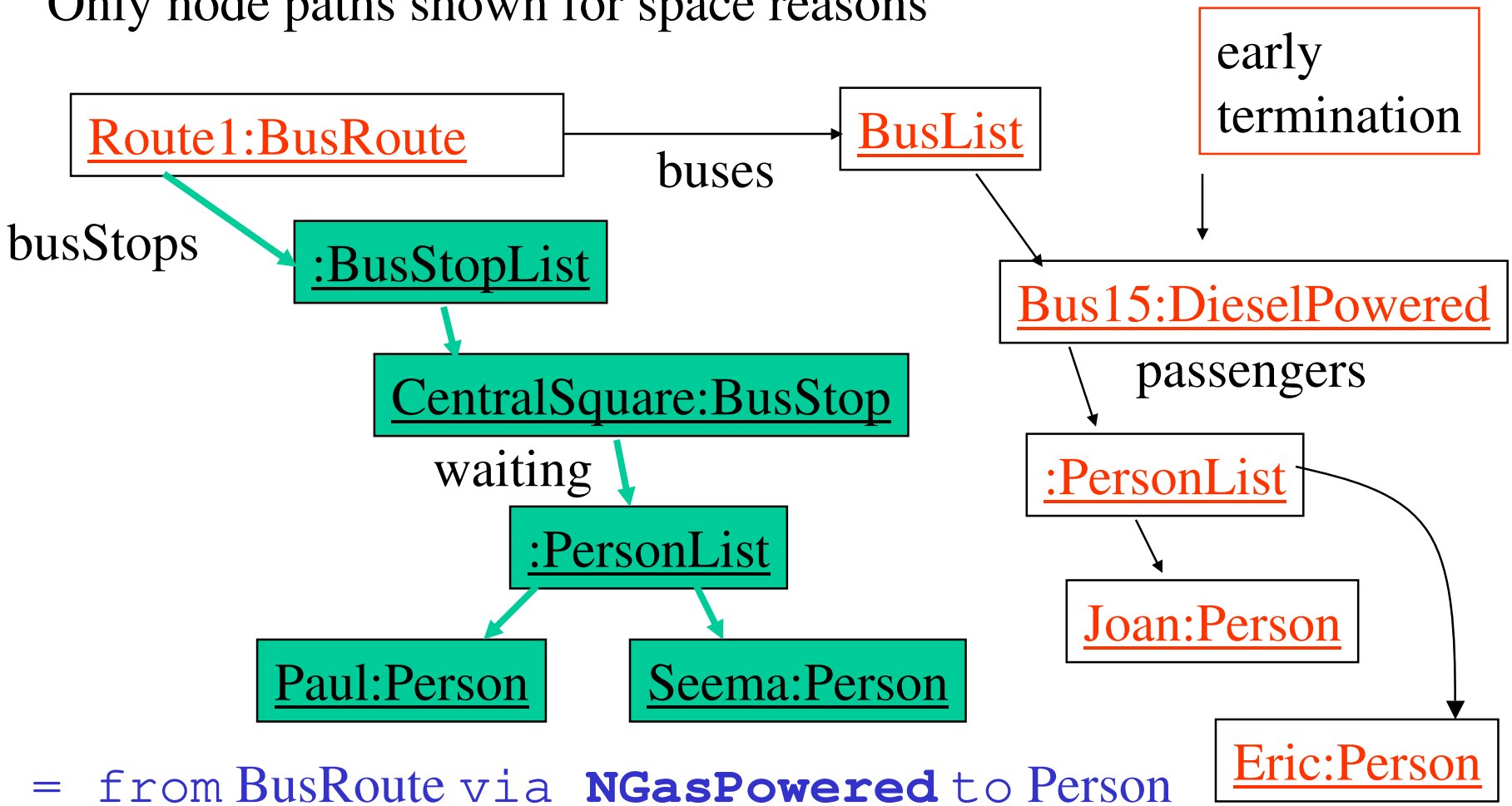


`S = from` BusRoute `through` Bus `to` Person

```
OG  :  BR BL
OG':  BR BL
SG  :  BR
```

Example 3

Only node paths shown for space reasons




```
S = from BusRoute via NGasPowered to Person
```

Allow

- strategy: `{A -> B B -> C}`
- class graph: `A : B. B : C. C = .`
- object graph: `C`

ObjectGraphSlice

- The object graph slice starting with o1 is the slice built by following the edges POSS(Class(o1), t, o1) starting at o1 and continuing until every path terminates (at an object of type t or it terminates prematurely).

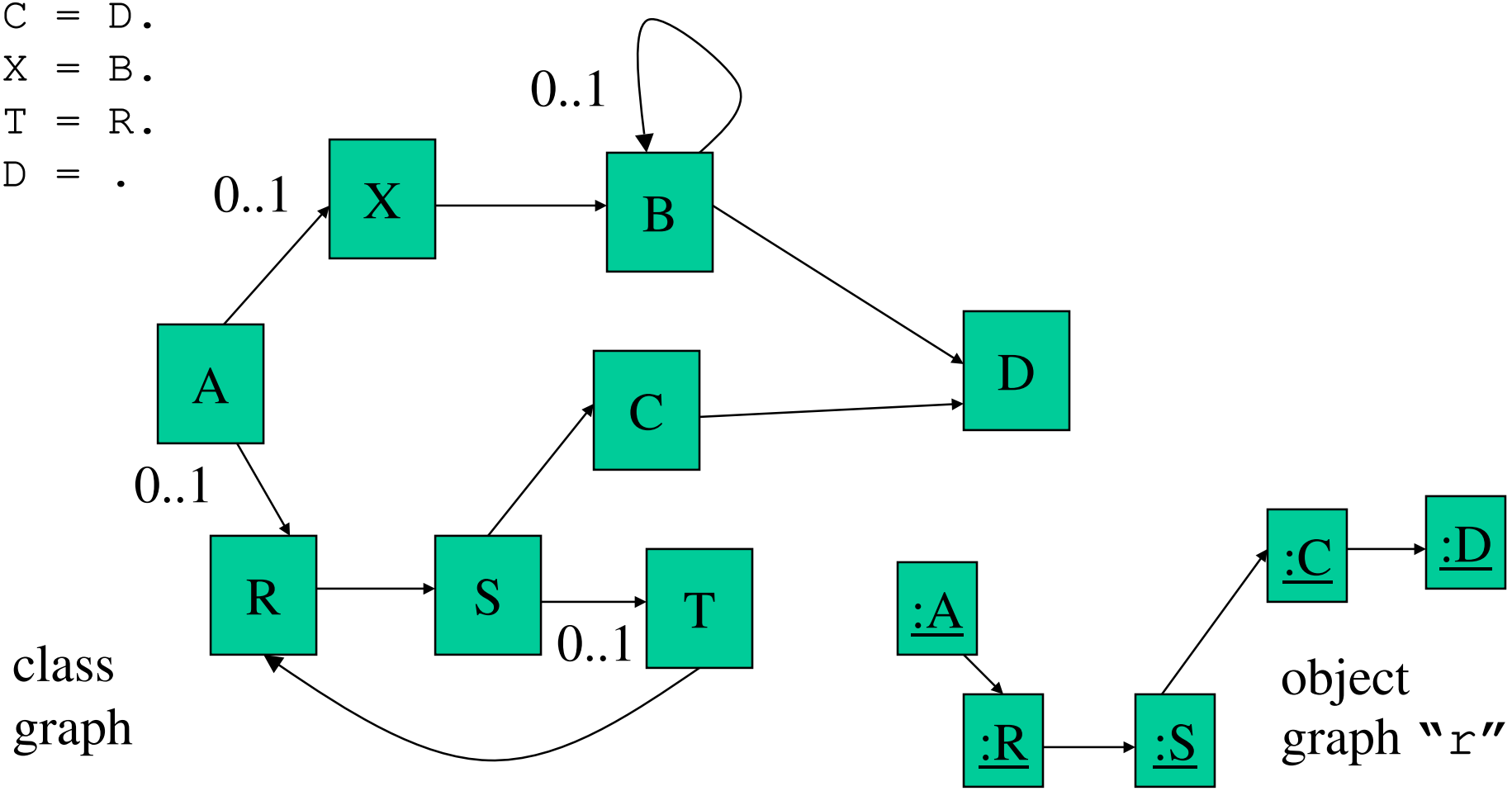
Example

class dictionary

```
A = [“x” X] [“r” R].
B = [“b” B] D.
R = S.
S = [“t” T] C
C = D.
X = B.
T = R.
D = .
```

strategy

```
A -> T
T -> D
```



Example

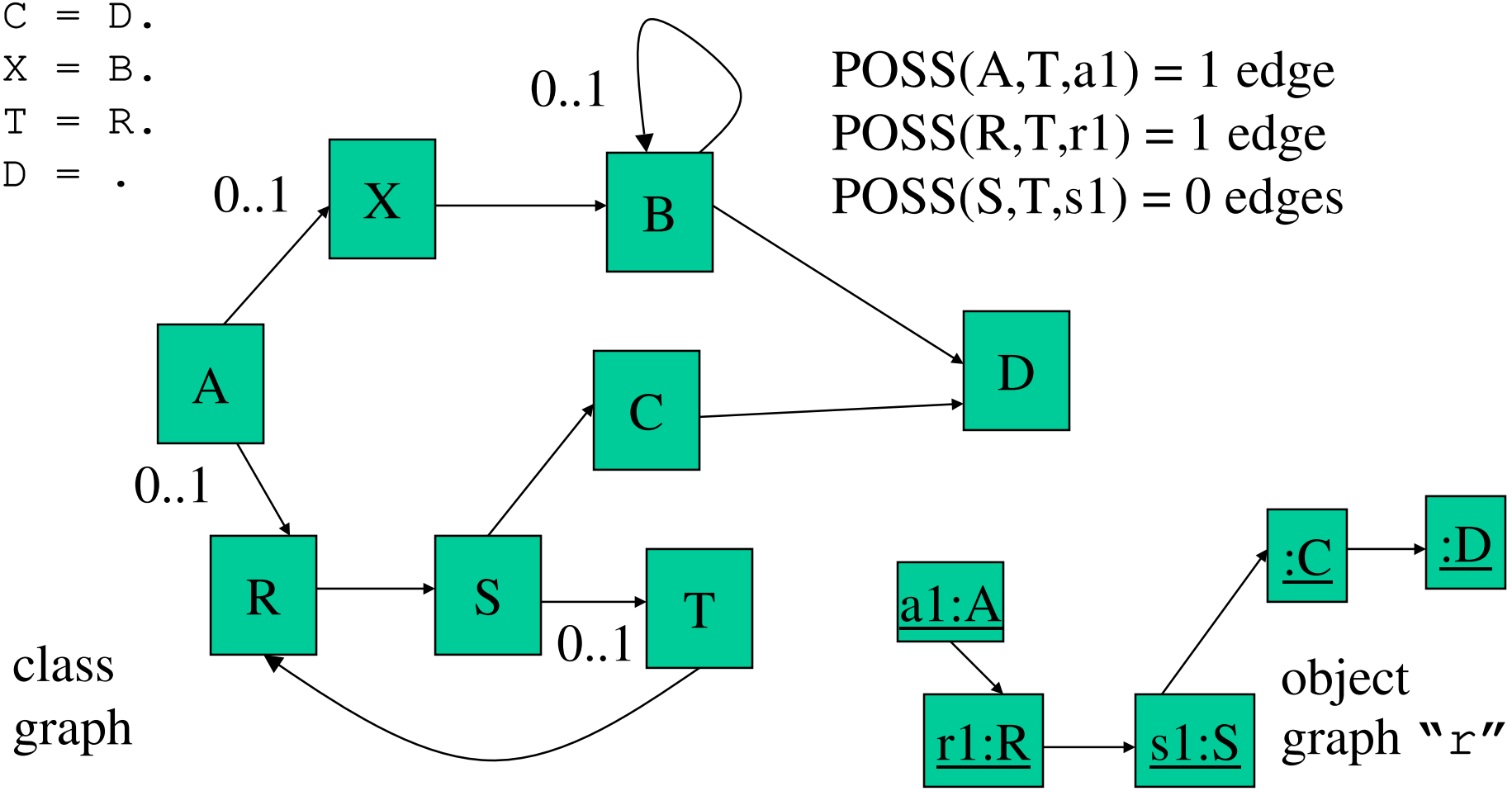
class dictionary

```
A = ["x" X] ["r" R].
B = ["b" B] D.
R = S.
S = ["t" T] C
C = D.
X = B.
T = R.
D = .
```

strategy

```
A -> T
T -> D
```

POSS(A,T,a1) = 1 edge
POSS(R,T,r1) = 1 edge
POSS(S,T,s1) = 0 edges



DJ

- An implementation of AP using only the DJ library (and the Java Collections Framework)
- All programs written in pure Java
- Intended as prototyping tool: makes heavy use of introspection in Java
- Integrates Generic Programming (a la C++ STL) and Adaptive programming

Integration of Generic and Adaptive Programming

- A traversal specification turns an object graph into a list.
- Can invoke generic algorithms on those lists. Examples: contains, containsAll, equals, isEmpty, contains, etc. add, remove, etc. throws operation not supported exception.
- What is gained: genericity not only with respect to data structure implementations but also with respect to class graph

Sample DJ code

```
// Find the user with the specified uid
List libUsers =
  classGraph.asList(library,
     "from Library to User");
ListIterator li =
  libUsers.listIterator();
// iterate through libUsers
```

Methods provided by DJ

- On ClassGraph, ObjectGraph, TraversalGraph, ObjectGraphSlice: `traverse, fetch, gather`
- traverse is the important method; fetch and gather are special cases
- TraversalGraph
  - Object traverse(Object o, Visitor v)
  - Object traverse(Object o, Visitor[] v)

Traverse method: excellent support for Visitor Pattern

```
// class ClassGraph
Object traverse(Object o,
   Strategy s, Visitor v);
```

traverse navigates through Object o following traversal specification s and executing the before and after methods in visitor v

ClassGraph is computed using introspection

Fetch Method

- If you love the Law of Demeter, use fetch as your shovel for digging:
  - Part k1 = (K) classGraph.fetch(a,"from A to K");
- The alternative is (digging by hand):
  - Part k1 = a.b().c().d().e().f().g().h().i().k();
- DJ will tell you if there are multiple paths to the target (but currently only at run-time).

Gather Method

- Returns a list of objects.
- Object ClassGraph.gather(Object o, String s)
  - List ks = classGraph.gather(a,"from A to K"); returns a list of K-objects.

Using DJ

- traverse(…) returns the v[0] return value. Make sure the casting is done right, otherwise you get a run-time error. If "`public Object` getReturnValue()" returns an Integer and traverse(…) casts it to a Real: casting error at run-time.
- Make sure all entries of Visitor[] array are non-null.

Using multiple visitors

```
// establish visitor communication
aV.set_cV(cV);
aV.set_sV(sV);
rV.set_aV(aV);

Float res = (Float) whereToGo.
   traverse(this,
   new Visitor[] {rV, sV, cV, aV});
```

DJ binary construction operations

	cg	s	tg	o	og	ogs
cg	*	tg,cg	*	og	*	*
s		*	*	*	ogs	*
tg			*	*	ogs	*
o				*	*	*
og					*	*
ogs						*

Who has traverse, fetch, gather? (number of arguments of traverse)

	cg(3)	s	tg(2)	o	og(2)	ogs(1)
cg	*	tg,cg	*	og	*	*
s		*	*	*	ogs	*
tg			*	*	ogs	*
o				*	*	*
og					*	*
ogs						*

Methods returning an ObjectGraphSlice

- ClassGraph.slice(Object, Strategy)
- ObjectGraph.slice(Strategy)
- TraversalGraph.slice(Object)
- ObjectGraphSlice(ObjectGraph,Strategy)
- ObjectGraphSlice(ObjectGraph,TraversalGraph)

Blue: constructors

Traverse method arguments

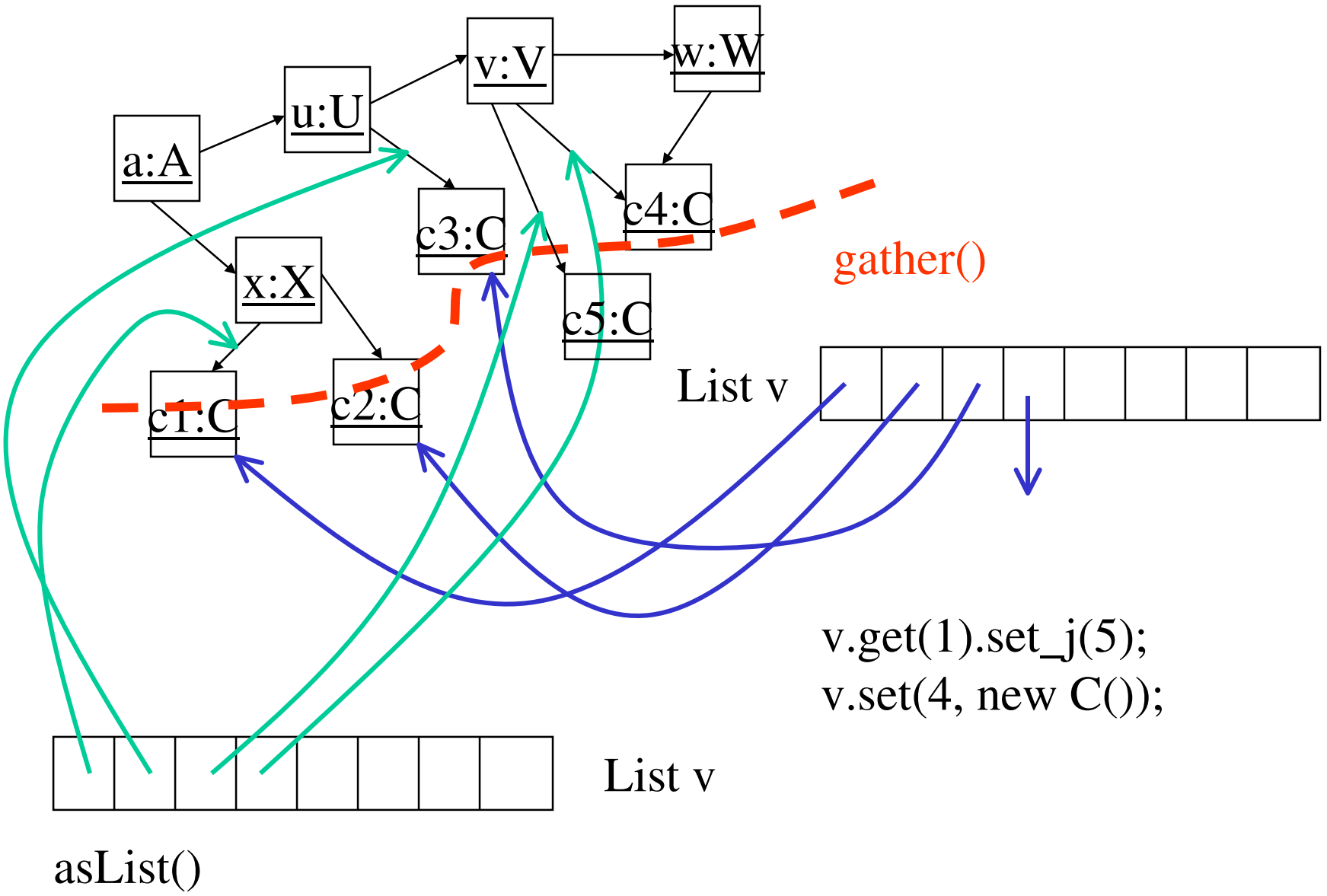
- ClassGraph
  - Object, Strategy, Visitor
- TraversalGraph
  - Object, Visitor
- ObjectGraph
  - Strategy, Visitor
- ObjectGraphSlice
  - Visitor

Traverse method arguments. Where is collection framework used?

- ClassGraph
  - gather(Object, Strategy) / asList(Object, Strategy)
- TraversalGraph
  - gather(Object) / asList(Object)
- ObjectGraph
  - gather(Strategy) / asList(Strategy)
- ObjectGraphSlice
  - gather() / asList()

Where is collection framework used?

- ObjectGraphSlice.asList()
  - a fixed-size List backed by the object graph slice. Is write-through: modifying list will modify object and modifying object will modify list. (Similar to Arrays.asList() in Java.)
- gather copies the pointers to the objects.


a:A
u:U
v:V
w:W
x:X
c1:C
c2:C
c3:C
c4:C
c5:C
gather()
List v
v.get(1).set_j(5);
v.set(4, new C());
List v
asList()

Interfaces

- Interface List
  - ListIterator listIterator()
  - Object set(int index, Object element)
- Interface ListIterator
  - void set(Object o): replaces the last element returned by next or previous with the specified element.

Why is asList useful?

- `from Application to X:` want to change all F-objects to D-objects.
- From Application to "predecessors" of D: put in a new object.
  - This is not structure-shy: all the predecessors of X also need to be mentioned.

Why is asList useful?

- `from Application to X:` want to change all X-objects to D-objects.

```
Application = <es> List(E).
E = X D.
D = X F.
X : F | D.
F = .
D = List(X).
List(S) ~ {S}.
```

Sketch:
from Application to E:
  aE.set_x(new D());
aE.get_d().set_x(new D());
from E to D: update list elements

from Application to X: set(new D())

Why is asList useful?

- From A to B: want to change a B-object that satisfies some property. Does not matter whether it is in a list.

A = B C.

C = List(B).

Some more theory

- Explaining paths in class graphs:
  - strategy *S* for a class graph *G: S* is subgraph of the transitive closure of *G*.
  - *S* defines ***path set*** in *G* as follows: $PathSet_{st}(S,G)$ is the set of all *s*-*t* paths in *G* that are expansions of any *s*-*t* path in *S*.
  - A path *p* is an ***expansion*** of path *p'* if *p'* can be obtained by deleting some elements from *p*.

the following slides explain this view graph

Relational Formulation

From object o of class c1, to get to c2, follow edges in the set

POSS(c1,c2,o)={e | c1 <=.e.=> (<=.C.=>)* <= c2 }

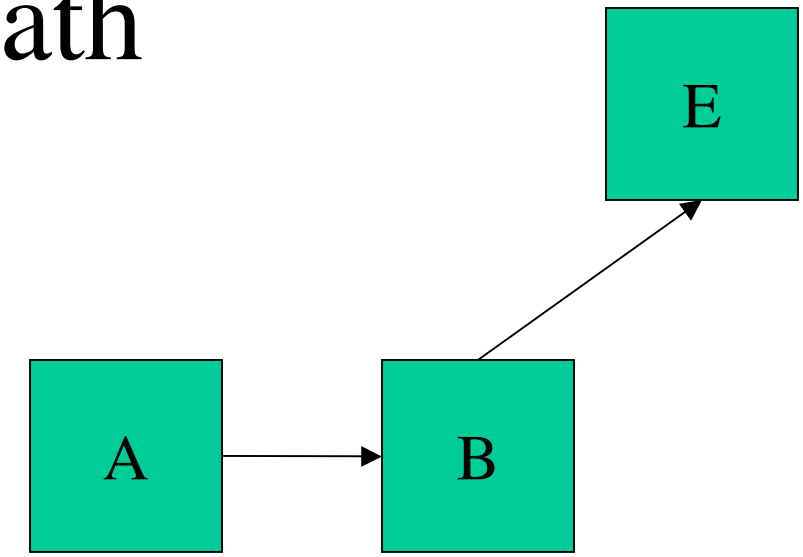
Can easily compute these sets for every c1, c2 via transitive-closure algorithms.
POSS = abbreviation for: following these edges it is still possible to reach a c2-object.

What is a path?

- If we only have concrete classes: no problem.
- Use the standard graph theoretic definition.

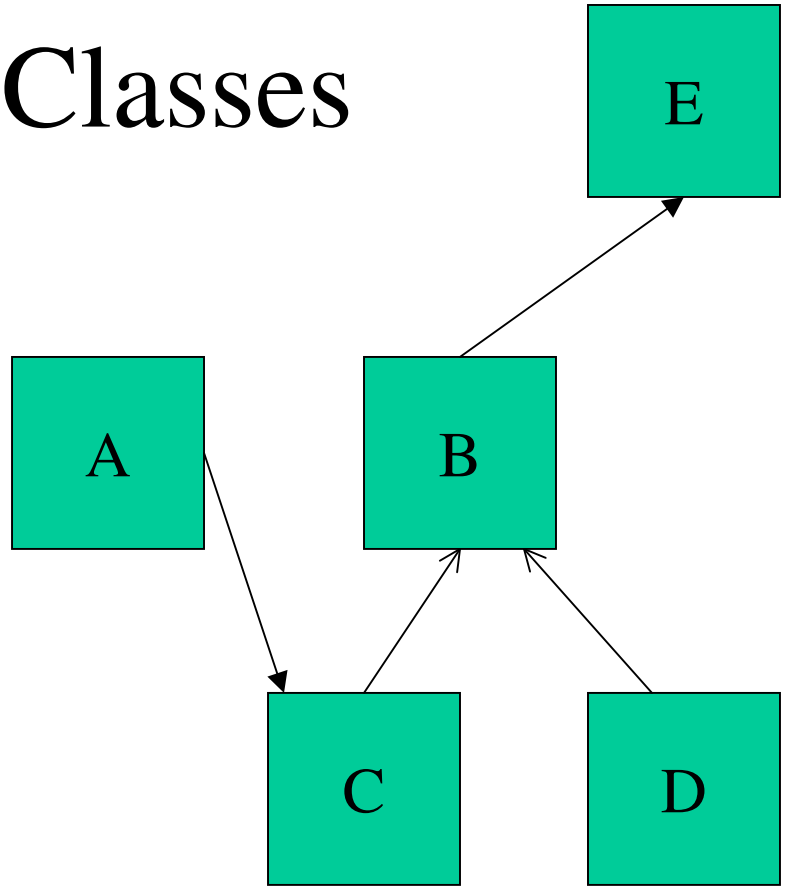
A Path

- (A,B,E)



Traversals with Abstract Classes

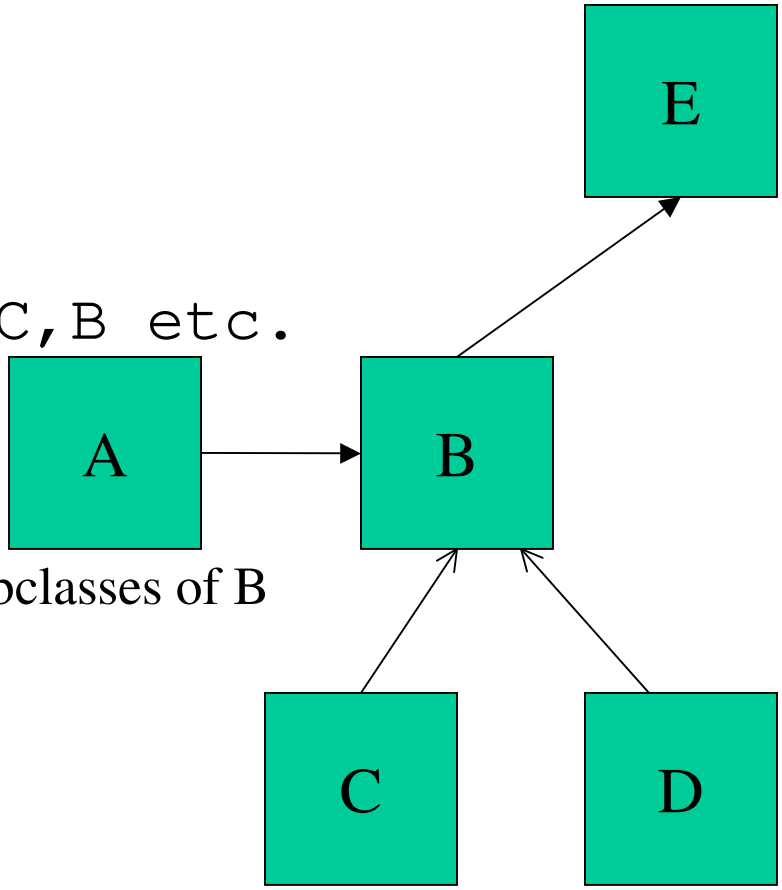
- from A to E
- from A to B
- from A to C
- from A to D



Traversals to Abstract Classes

- `from A to B =`
- `includes =>B,C and :>C,B etc.`

- Motivation:
  - `from A to E` also includes subclasses of B



Path concept

- Path from A to B
  - include construction edges (forward)
  - inheritance edge implies subclass edge in opposite direction.
  - include inheritance edges (backward and forward). Backward inheritance edges are called subclass edges.
  - follow rule: after an inheritance edge, you are not allowed to follow a subclass edge.

Path concept in flat class graphs

- Path from A to B:
- In flat class graph there is never a construction edge following an inheritance edge: (<=.C) = C

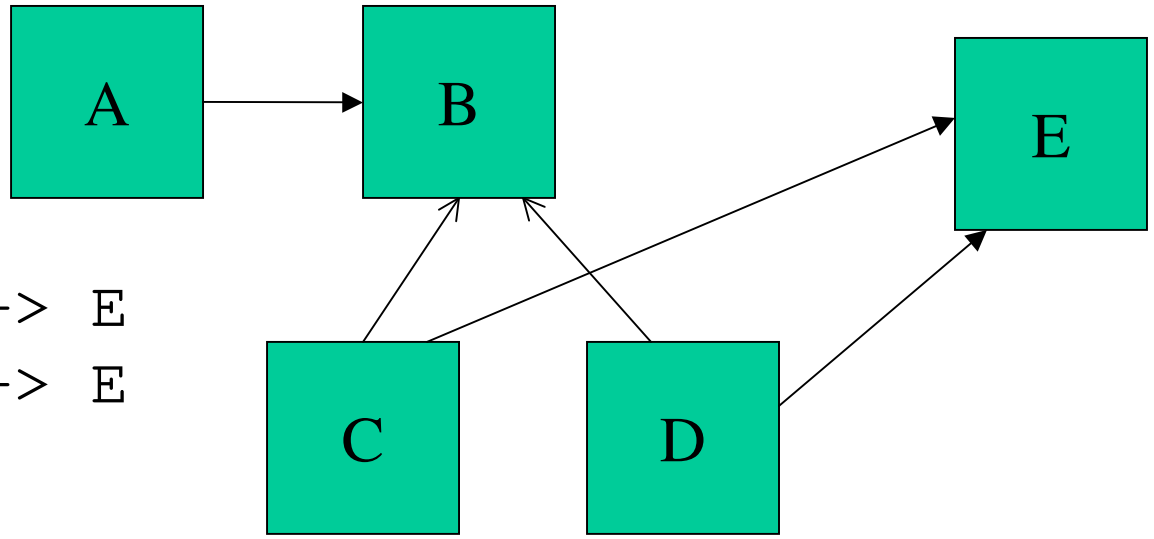
From object o of class c1, to get to c2, follow edges in the set

POSS(c1,c2,o)={e | c1 <=.e.=> (<=.C.=>)* <= c2 }

Requirements: for flat class graphs

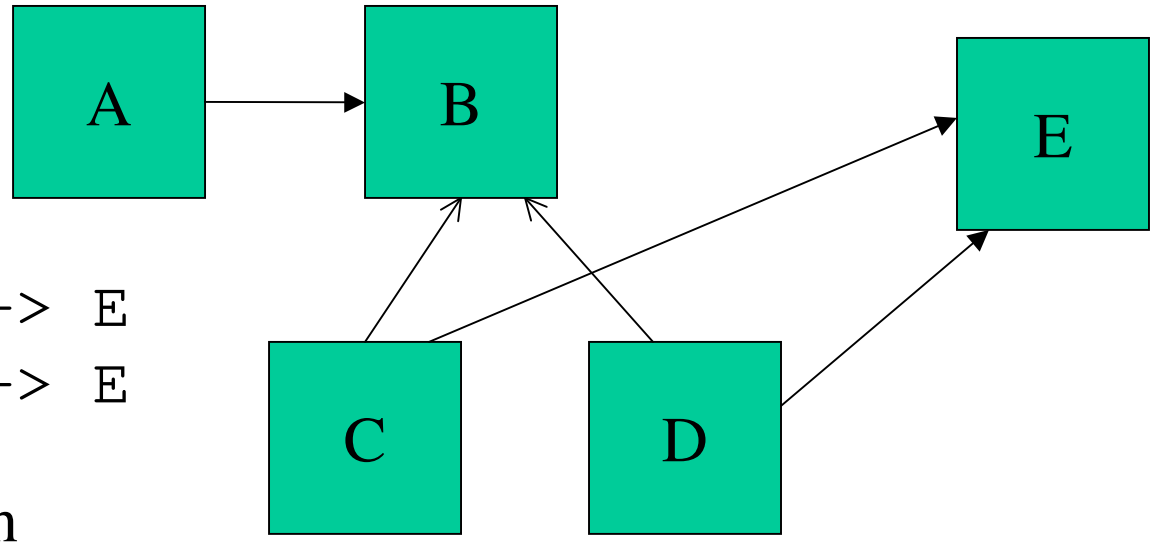
- Paths in class graph turn into paths in object graph by deleting alternation edges and nodes and inheritance edges (Def. of corresponding path).

```
A -> B => C -> E
A ->      C -> E
```



Requirements: for flat class graphs

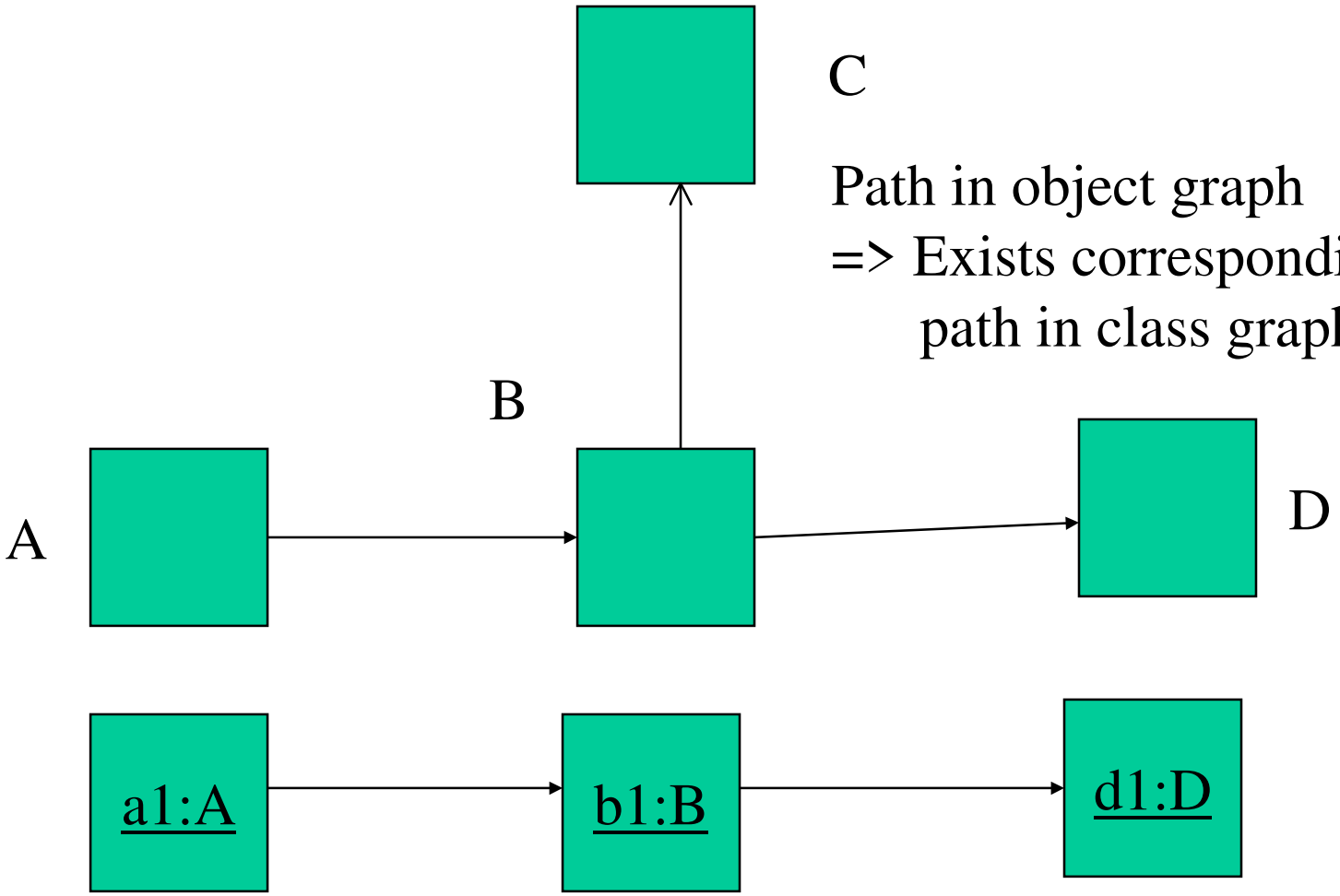
- If there is a path in the class graph then there is a legal object of the class graph that has the same corresponding path.




```
A -> B => C -> E
A ->      C -> E
```

Path in class graph
=> Exists object with path in object graph

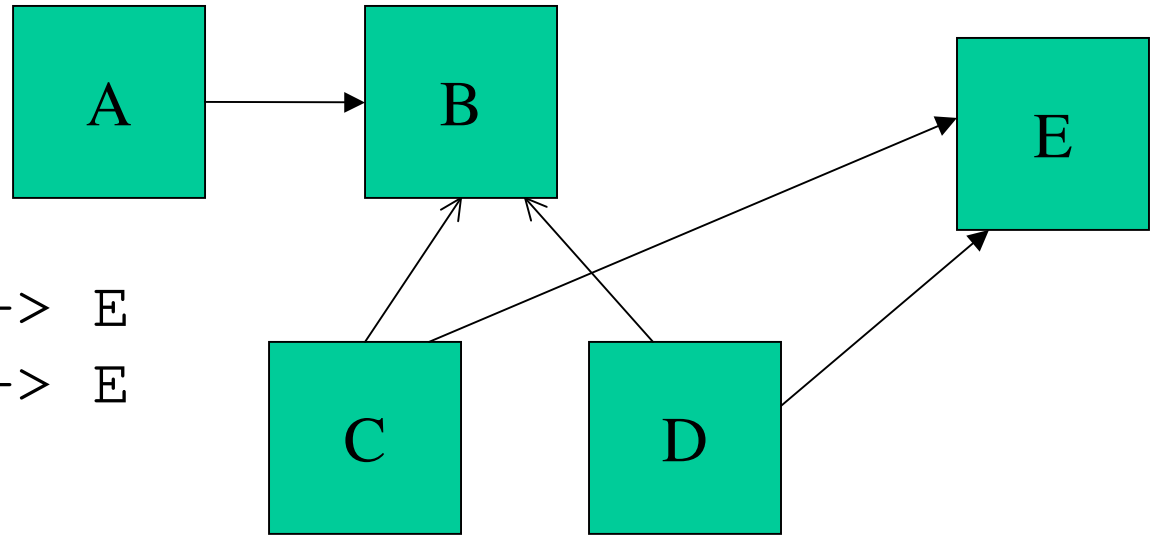
Requirements: for flat class graphs



Requirements: for flat class graphs

- For a class graph G and legal object O, if there is a path p in the object graph then there is a path P in the class graph such that p corresponds to P.

```
A -> B => C -> E
A ->      C -> E
```

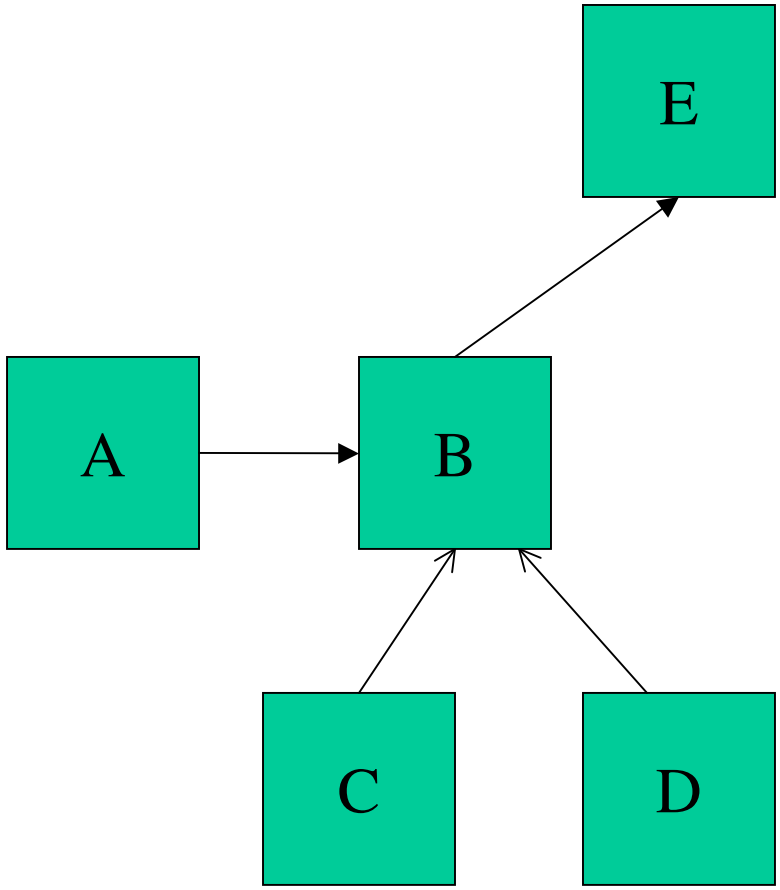


More on semantics of DJ with abstract classes

- What is the meaning of a visitor on an abstract class?

Traversals to Abstract Classes

- `Class graph`



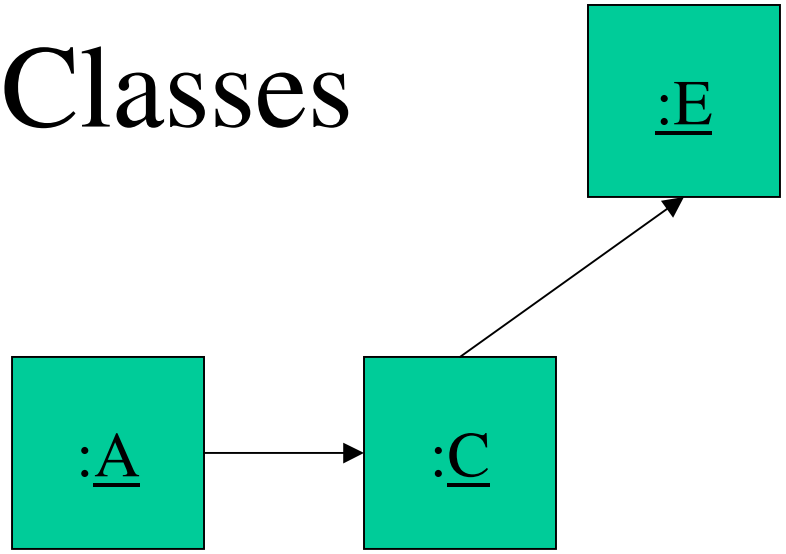
visitor:

before (B){p(“b”);}

before (C){p(“c”);}

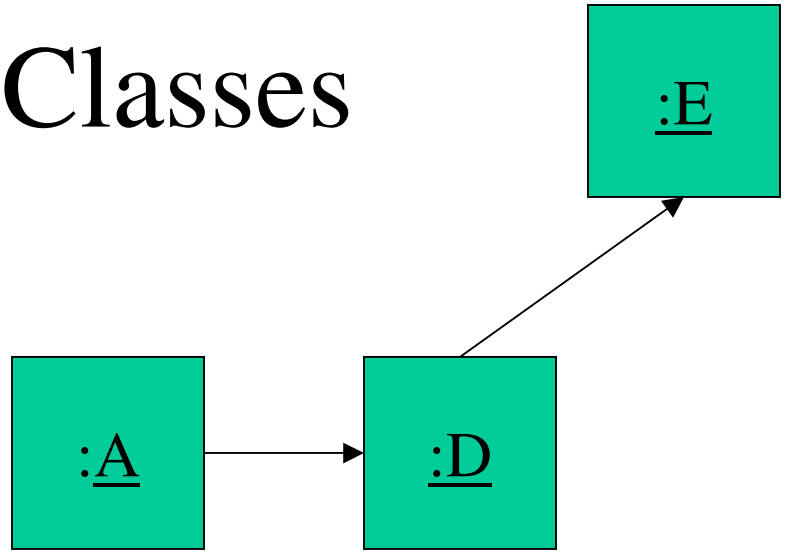
Visitor Methods on Abstract Classes

- from A to E: b, c
- from A to B: b, c
- from A to C: b, c
- visitor:
  - before (B){p("b");}
  - before (C){p("c");}



Visitor Methods on Abstract Classes

- from A to E: b
- from A to B: b
- from A to C:
- visitor:
  - before (B){p("b");}
  - before (C){p("c");}

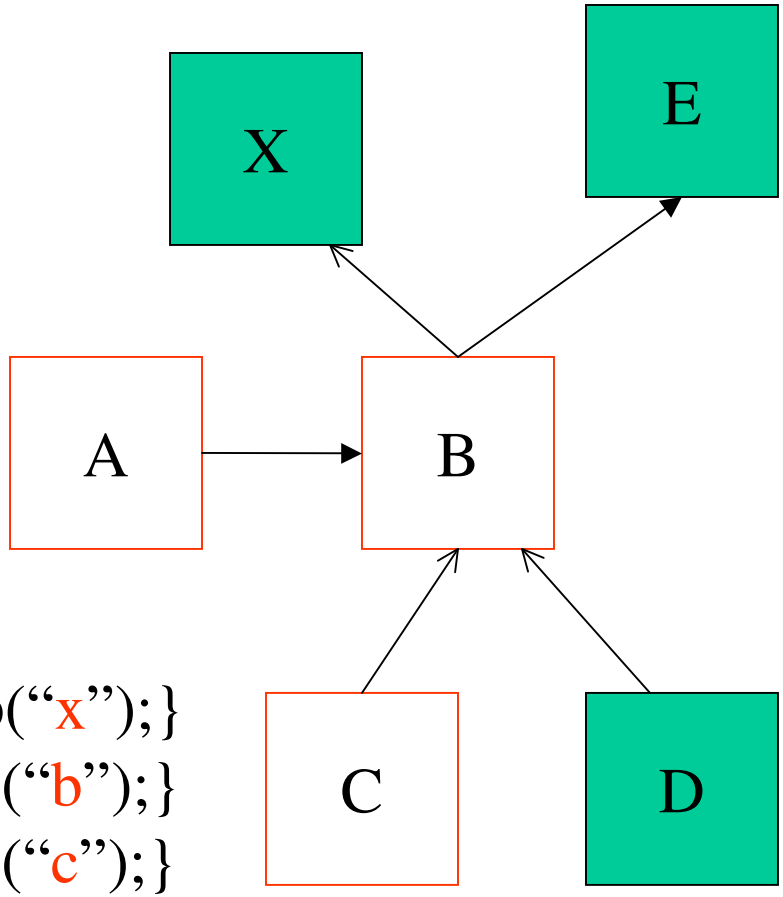


Visitor Rule

- When an object of class X is visited, all visitors of ancestor classes of X will be active.
- The before visitors in the downward order and the after visitors in the upward order.

Traversals to Abstract Classes

- `From A to C`



visitor:

void before (X host){p(“x”);}
void before (B host){p(“b”);}
void before (C host){p(“c”);}

Example in DemeterJ

```
class graph in program.cd:
A = B.
X : B.
B : C | D common E.
C = "c".
D = "d".
E = .
```

Behavior basically in DJ

```
program.beh:
Main { {{ // all Java code
  public static void main(Sring args[] … {
  A c = A.parse(“c”); A d = A.parse(“d”);
  ClassGraph cg = new ClassGraph(true,false);
  Visitor v = new Visitor() {
    void before (X host) {System.out.println(“x”);}
    void before (B host) {System.out.println(“b”);}
    void before (C host) {System.out.println(“c”);} };
  System.out.println(“C-object:”);
  cg.traverse(c,”from A to C”,v);
  System.out.println(“D-object:”);
  cg.traverse(d,”from A to C”,v); }
  System.out.println(“Done.”); }} // end all Java code

}
```

Output

```
C-object:
x
b
c
D-object:
Done.
```

Alternative Visitor Rule: not what programmers want

- When an object of class X is visited, all visitors of ancestor classes of X ~~***and in the path set of the current traversal***~~ will be active.
- The before visitors in the downward order and the after visitors in the upward order.

Guidelines

```
IF you use the combination of the following pairs and triples
   for multiple traversals, fetch or gather, introduce the
   following computation saving objects:
(cg,s,o)->ogs
(cg,s)->tg
(cg,o)->og
(tg,o)->ogs
```

In principle can express programs only with ClassGraph and Strategy and Visitor:

cg.traverse(o,s,v);
cg.fetch(o,s);
cg.gather(o,s);
cg.asList(o,s);

cg	class graph
s	strategy
tg	traversal graph
o	object
og	object graph
ogs	object graph slice
v	visitor

Abbreviations

DJ unary construction operations

- Class graph from Strategy
  - ClassGraph(Strategy): make a class graph with just the classes and edges in traversal graph determined by strategy. Interpret path set as a graph. Maintain several class graphs cg1, cg2, cg3 that are suitable for expressing what you need.
- Class graph from all classes in package

ClassGraph construction

- make a class graph from all classes in default package
  - ClassGraph()
    - include all fields and non-void no-argument methods. Static members are not included.
  - ClassGraph(boolean f, boolean m)
    - If f is true, include all fields; if m is true, include all non-void no-argument methods.

Dynamic features of DJ ClassGraph construction

- When a class is defined dynamically from a byte array (e.g., from network) ClassGraph.addClass(Class cl) has to be called explicitly. Class cl is returned by class loader.
- ClassGraph() constructor examines class file names in default package and uses them to create class graph.

Dynamic features of DJ ClassGraph construction

- ClassGraph.addPackage(String p)
  - adds the classes of package p to the class graph. The package is searched for in the CLASSPATH. How can we control (f,m) options? Uses the same rule as used for the original class graph construction.
- Java has no reflection for packages. Motivates above solution.

Adding Nodes and Edges to ClassGraph

- addClass(Class cl)
  - add cl and all its members to the class graph, if it hasn't already been added.
- addClass(Class cl, boolean aF, boolean aM)
  - add cl to the class graph. If aF, add all its non-static fields as construction edges. If aM, add all its non-static non-void methods with no arguments as derived construction edges.

Adding Nodes and Edges to ClassGraph

- Part addConstructionEdge(Field f)
  - add f as a construction edge.
- Part addConstructionEdge(Method m)
  - add a no-args method as a construction edge.
- addConstructionEdge may have in addition a String argument called source. For Impl.
- And also a Class argument called target. Also for Impl. Should not be public.

Add other repetition edges

- void ClassGraph.addRepetitionEdge(String source, String target)
  - add a repetition edge from source to target
- Questions
  - what about subclass and inheritance edges
  - what happens if class graph contains edges not in program. Error will occur.

Design and Implementation

- Until summer 1999: Josh Marshall
- Since then: Doug Orleans
- Available on the Web from DJ home page
- Quite complex
- Viewing an object as a list is done through coroutines to simulate continuation

Problem with DJ

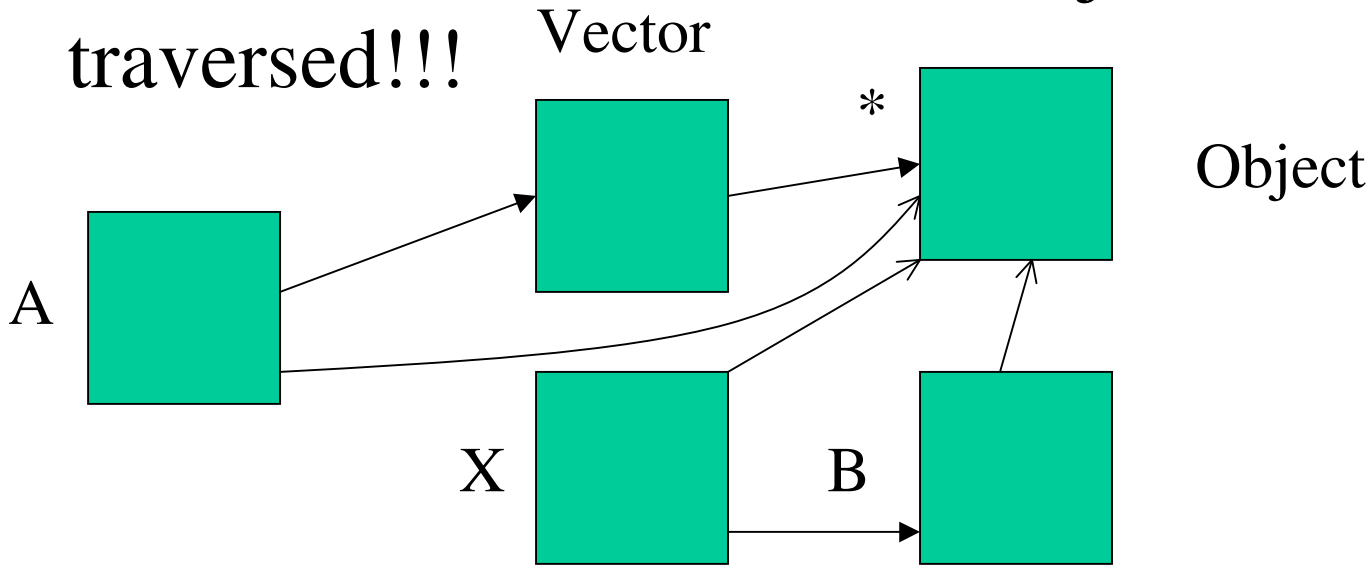
- What is coming is not about a problem of DJ but about a problem with Java: the lack of parameterized classes.
- The lack of parameterized classes forces the use of class Object which, as the mother of all classes, is too well connected.
- This leads to unnecessary traversals and traversal graphs that are too big.

Lack of parameterized classes in Java makes DJ harder to use

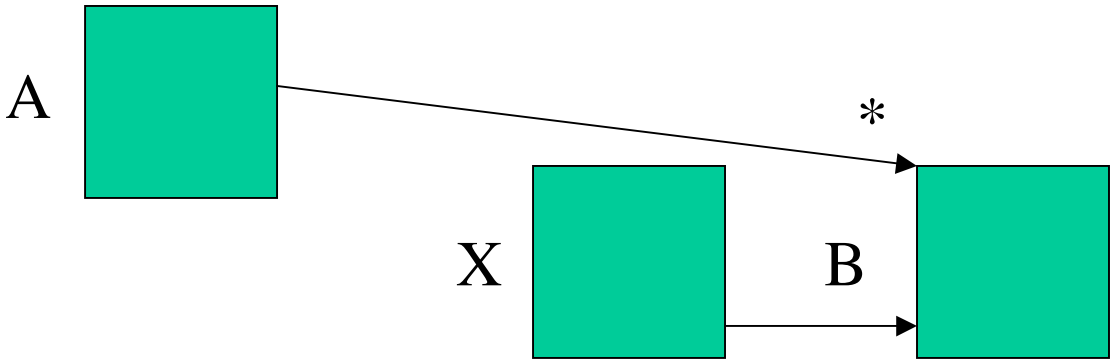
- Consider the traversal: from A to B
- Let's assume that in the class graph between A and B there is a Java collection class. The intent is: A = List(B) which we cannot express in Java. Instead we have: A = Vector(Object). Object : A | B. Let's assume we also have a class X=B.

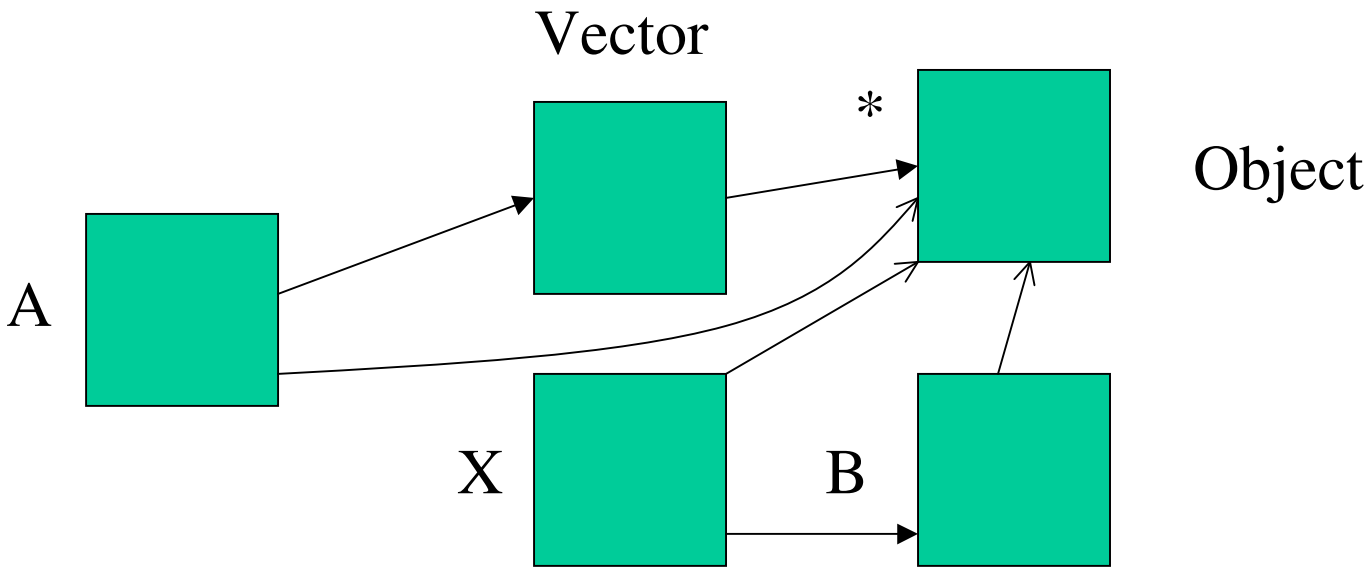
Lack of parameterized classes in Java makes DJ harder to use

- We have: A = Vector(Object). Object : A | B | X. X = B.
- If the vector contains an X object it will be traversed!!!



No X-object is allowed
to be in vector





Moral of the story

- If the Collection objects contain only the objects advertised in the nice class graph of the application the traversal done by DJ will be correct. But unecessary traversals still happen.
- However, if the Collection objects contain additional objects (like an X-object) they will be traversed accidentally.

Moral of the story

- Java should have parameterized classes.
- Workaround: Use a JSR (Java Specification Request) 31 approach: use a schema notation with parameterization to express class graph and generate Java code from schema. For traversal computation, the schema will be used.

Size of traversal graph

- DJ might create big traversal graphs when collection classes are involved. DJ will plan for all possibilities even though only a small subset will be realized during execution.
- To reduce the size of the traversal graph, you need to use bypassing. In the example: from A bypassing {A,X} to B.

Technical Details

- Using DJ and DemeterJ

Combining DJ and DemeterJ

- DJ is a 100% Java solution for adaptive programming.
- DemeterJ has
  - XML style data binding facilities: code generation from schema (class dictionary).
  - Its own adaptive programming language.
- We attempt an optimal integration giving us the strong advantages of both and only few small disadvantages.

Optimal DJ and DemeterJ Integration

- Take all of DJ
- Take all of DemeterJ class dictionary notation
- Take a very tiny bit of DemeterJ adaptive programming language (basically only part that allows us to weave methods).

Combining DJ and DemeterJ

- Pros (advantages)
  - Java class generation from class dictionary (getters, setters, constructors).
  - Parser generation.
  - Better packaging of Java code into different files.
  - MUCH MORE POWERFUL.
- Cons (disadvantages)
  - No longer pure Java solution.
  - need to learn Demeter notation for class dictionaries (similar to XML DTD notation).
  - need to learn how to call DemeterJ and how to use project files.

Combining DJ and DemeterJ

- What do we have to learn about DemeterJ?
  - Class dictionaries: `*.cd` files
  - Behavior files: `*.beh` files. Very SIMPLE!
    - `A { {{ ... }} }` defines methods ... of class A
  - Project files: `*.prj`
    - list behavior files `*.beh` that you are using
  - Commands:
    - `demeterj new, demeterj test, demeterj clean`

Combining DJ and DemeterJ

- What you might forget in class dictionaries that are used with DJ:
  - `import edu.neu.ccs.demeter.dj.*;`
  - visitors need to inherit from `Visitor`
  - parts of visitors need to be defined in class dictionary

Combining DJ and DemeterJ

- Structuring your files
  - put reusable visitors into separate behavior files.
  - put each new behavior into a separate behavior file. Visitors that are not planned for reuse should also go into same behavior file. Update the class dictionary with required structural information for behavior to work.
  - List all `*.beh` files in `.prj` file.

End