Compositional Pointer and Escape Analysis for Java Programs

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Presented by Chen Fu
Rutgers

Points-to Analysis

- Flow Sensitive
  - Intraprocedural
    - Do “kill”
    - “Summary” points-to graph for each method.
      - “Outside” nodes/edges to represent interprocedural/unknown points-to relation.
  - Interprocedural
    - Merge the caller/callee points-to graph at call sites.
    - How to get initial call graph?
- Context Sensitive?
  - Maybe
- Emphasis on escape analysis.

Inside Nodes/Edges

- Inside nodes/edges
  - Just like those in Anderson's points-to

Outside Nodes/Edges

- Outside Nodes:
  - One of more (static) objects
  - Created outside the current scope.
  - Referenced in the current scope
    - Parameter
    - Global
    - Field Load
    - Return ??
- Outside edges
  - Edges established outside the current scope.
  - Discovered in the current scope.

Algorithm

- Introduce each outside node for
  - Each reference parameter (inside edge),
  - Static field accessed (outside edge).
- Run analysis similar in Anderson's points-to except:
  - Do kill, need iterate,
  - Difference in field load.
- At call sites
  - Merge callee's summary with current points-to graph.

Escape

- An object escape a method if reachable from:
  - A parameter
  - A static field
  - A thread object
  - An actual parameter of an not-yet-known method.

Figure 1

```
class complex{
  double x,y;
  complex(double a, double b) { x = a; y = b; }

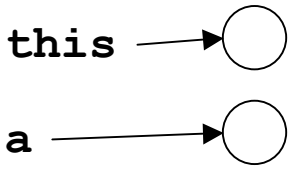
  complex multiply(complex a) {
    complex product = new complex(x*a.x - y*a.y, x*a.y + y*a.x);
    return product;
  }

  complex multiply(complex a){
    complex sum = new complex(x+a.x, y+a.y);
    return sum;
  }

  complex multiplyAdd(complex a, complex b) {
    complex product = a.multiply(b);
    complex sum = this.add(product);
    return sum;
  }
}
```

Figure 1 – Cont.

```
complex multiply(complex a) {
    complex product = new();
    return product;
}
```



Graph Initialization

Figure 1 – Cont.

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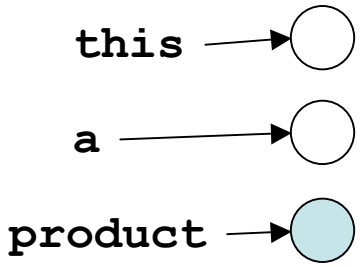

Graph Initialization
New Object

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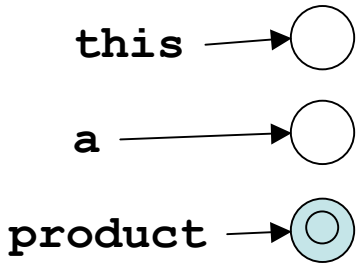
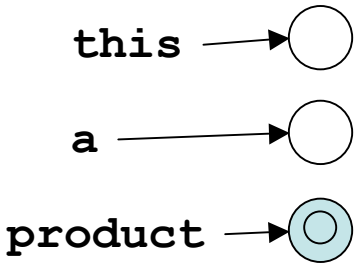


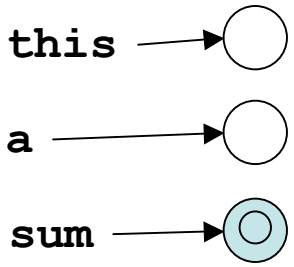
Graph Initialization
New Object
Return

Figure 1 – Cont.

```
complex multiply(complex a) {
    complex product = new();
    return product;
}
```

```
complex add(complex a){
  complex sum = new complex();
  return sum;
}
```





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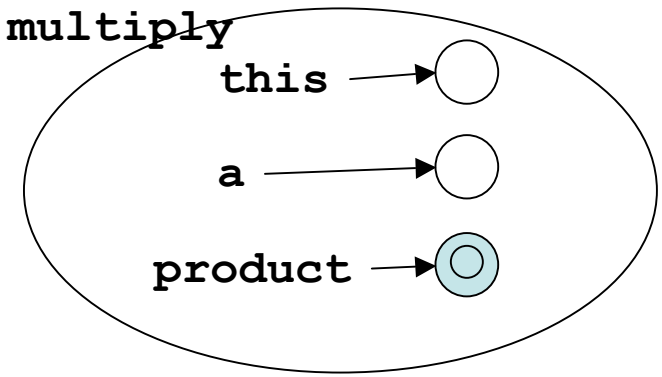

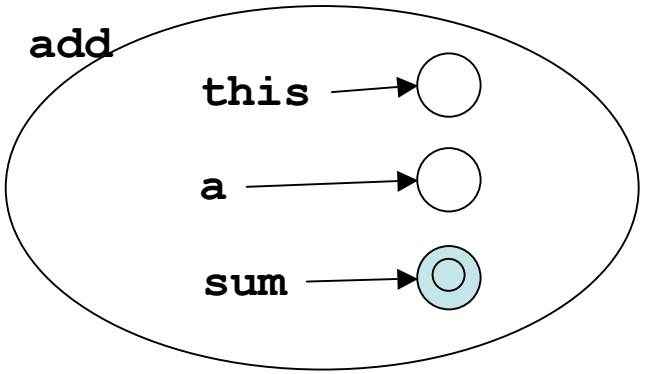


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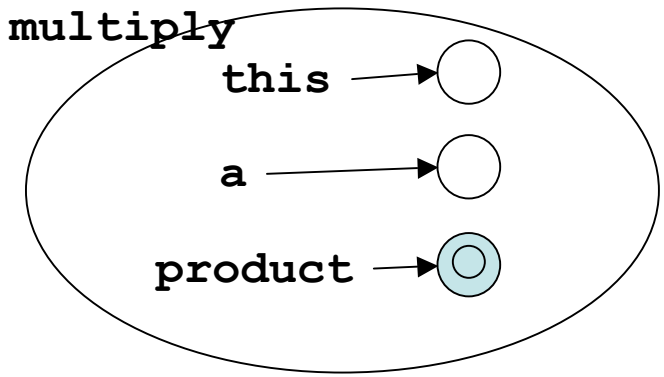
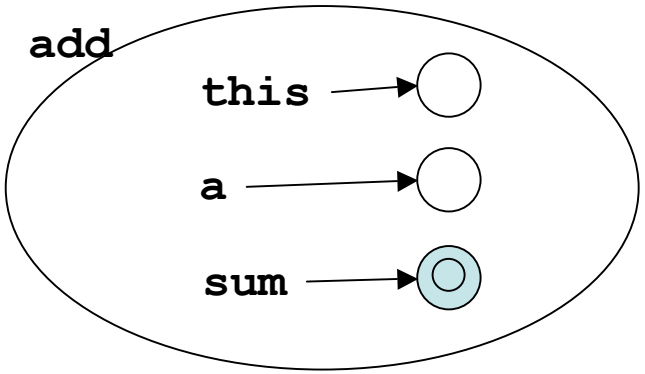
Graph merging at call site



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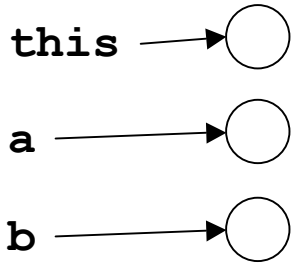

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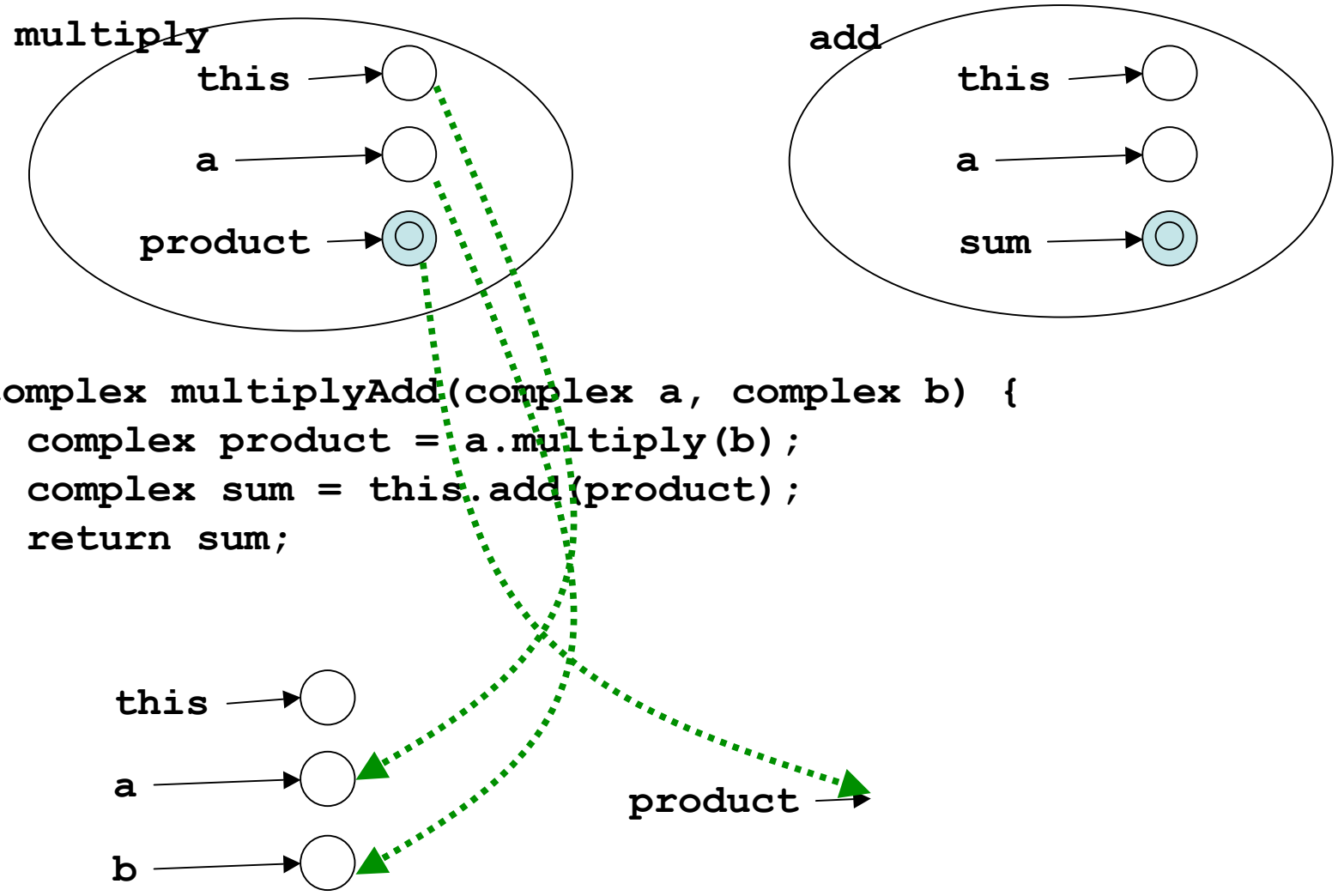

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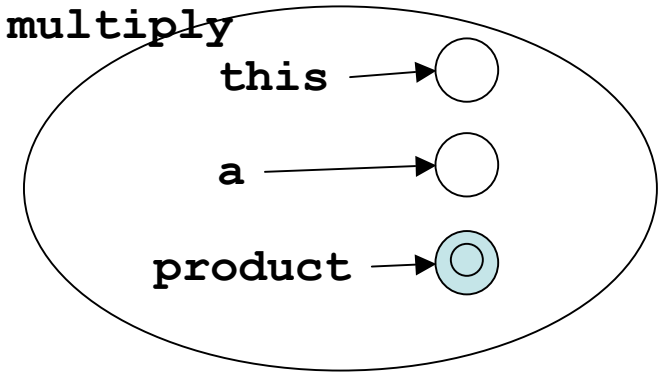

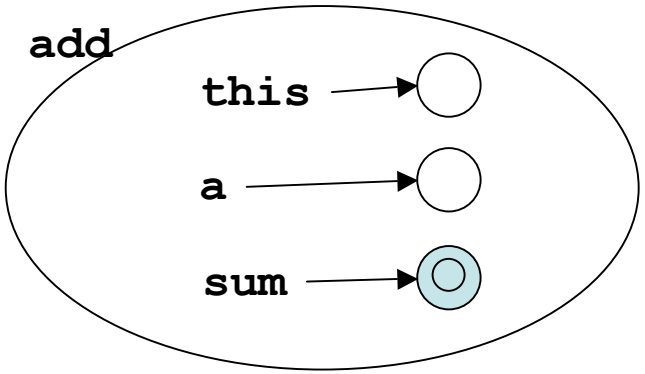


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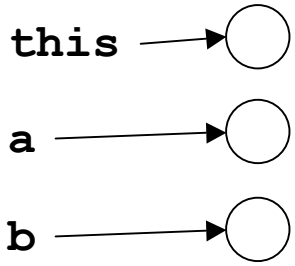

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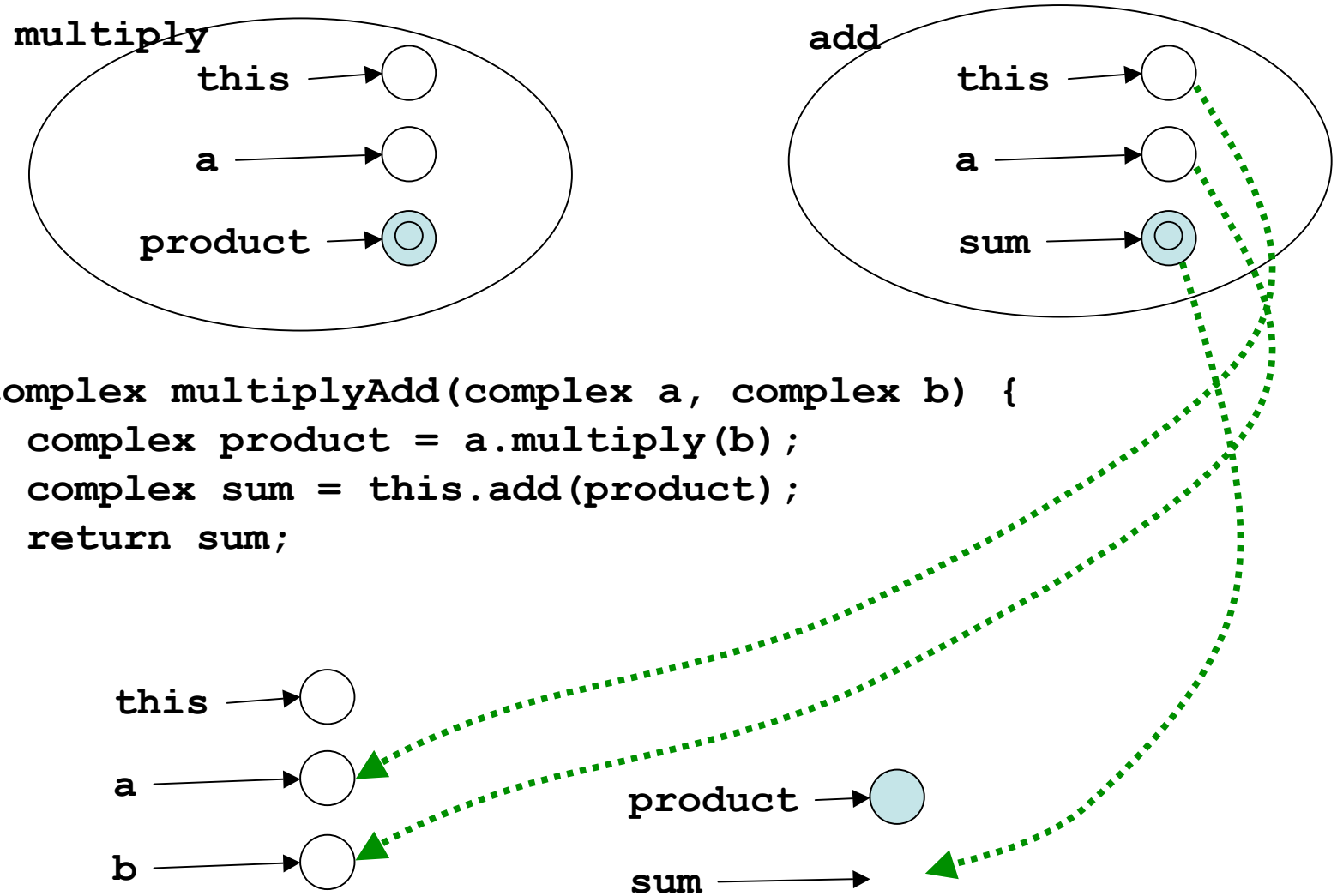

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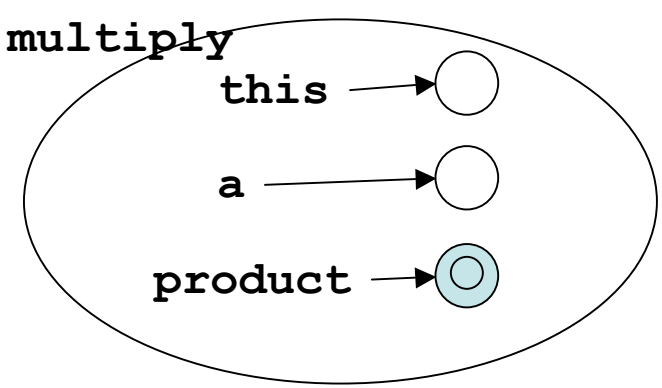

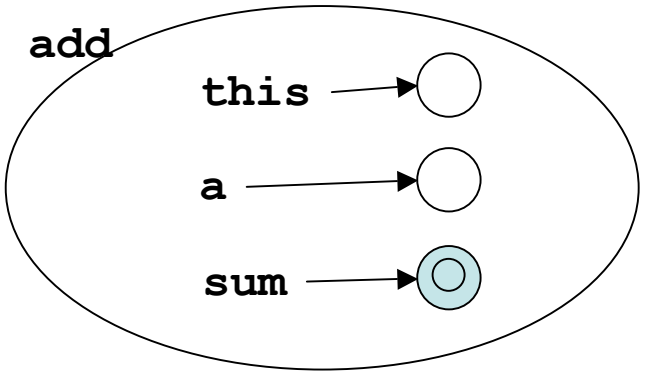


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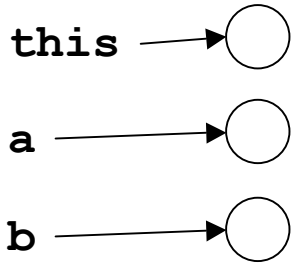

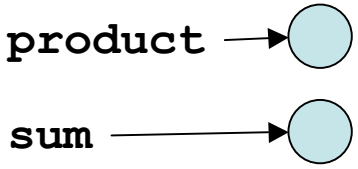

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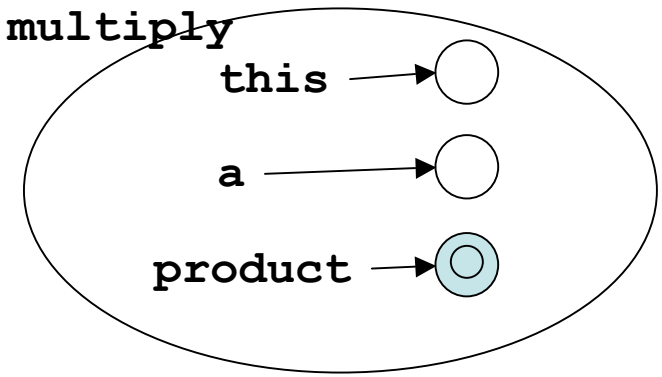

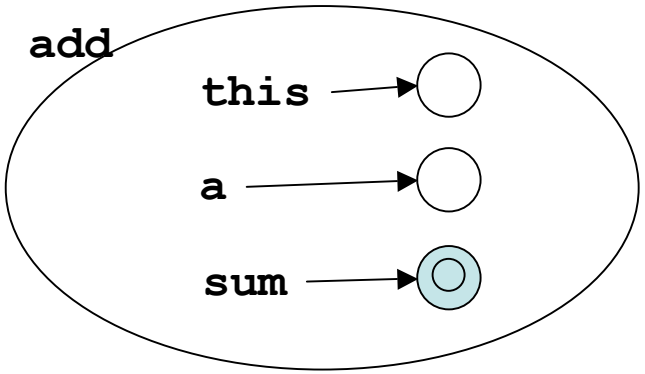


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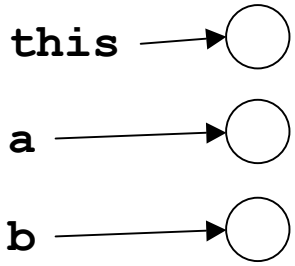

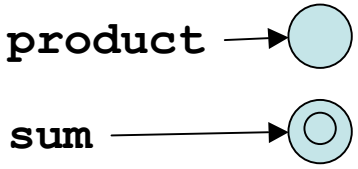

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Figure 4

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  this.element = e;
  this.next = n;
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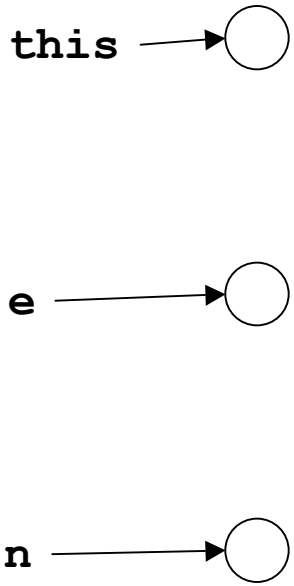

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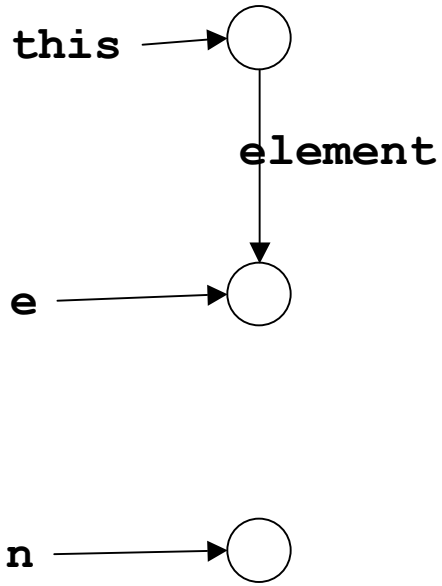

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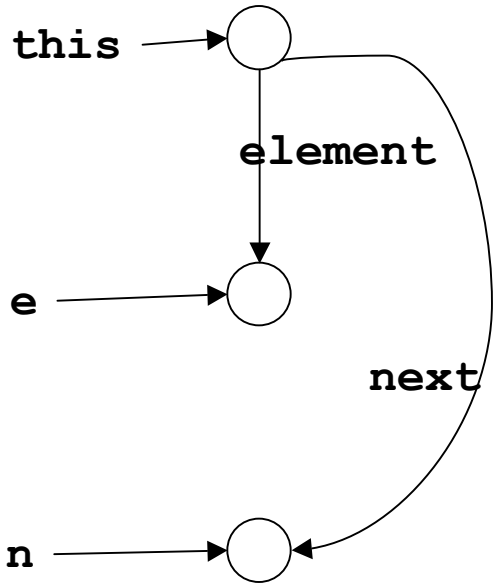
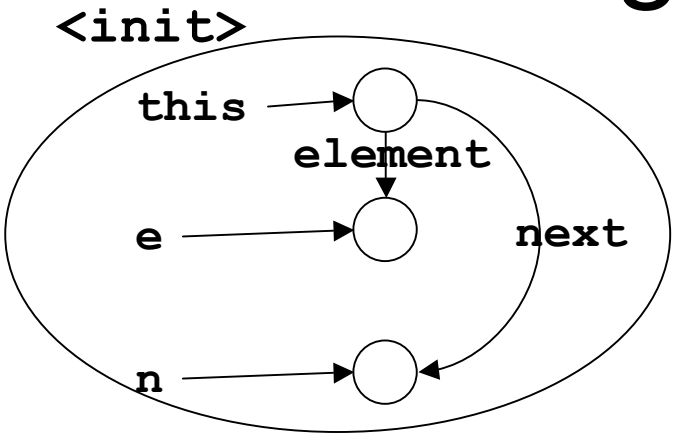
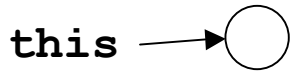
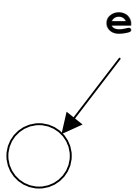


Figure 4 – cont.





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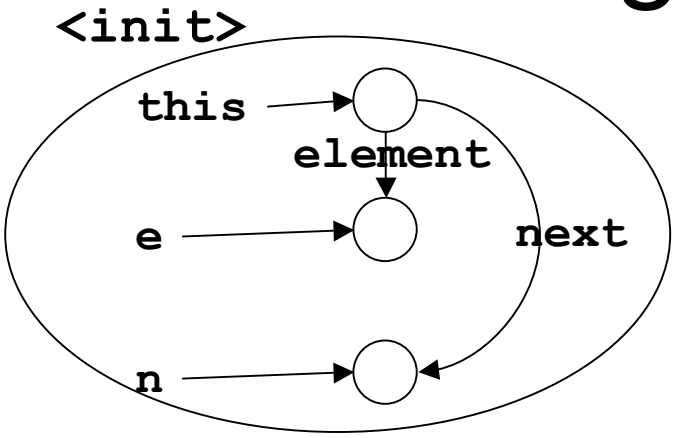
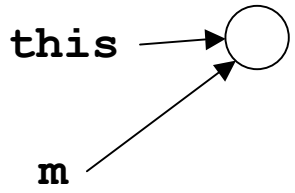
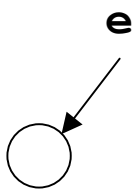
multisetElement insert(Object e){
  multisetElement m = this
  while (..) {
    if (..) return this;
    m = m.next;
  }
  return new multisetElement(e, this);
}
```

Figure 4 – cont.





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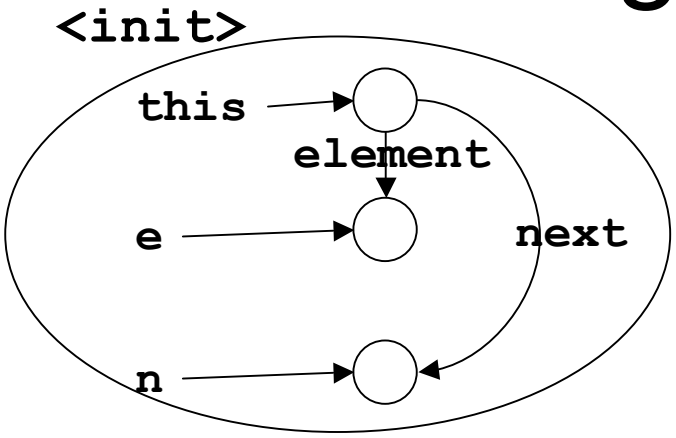

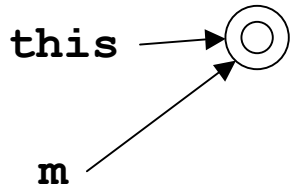

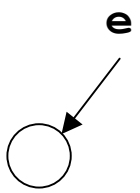


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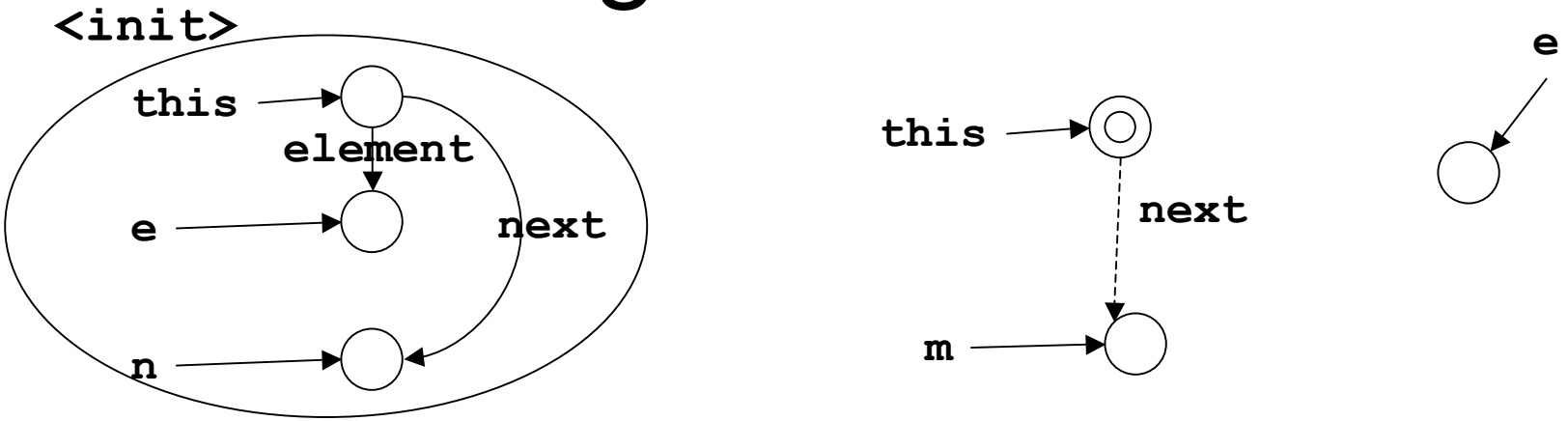


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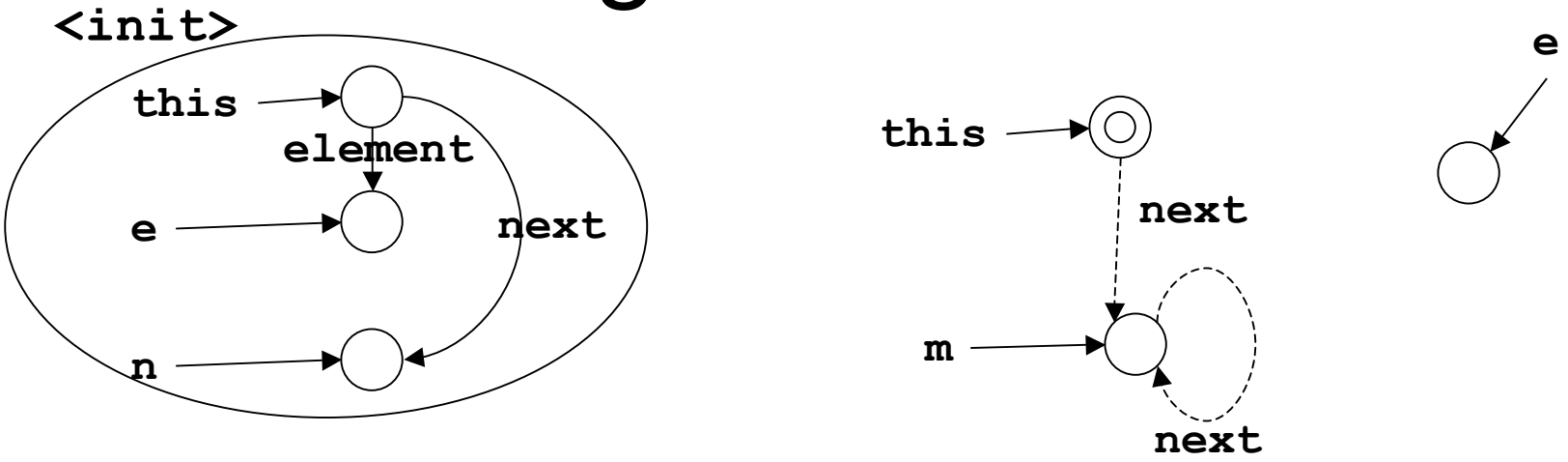


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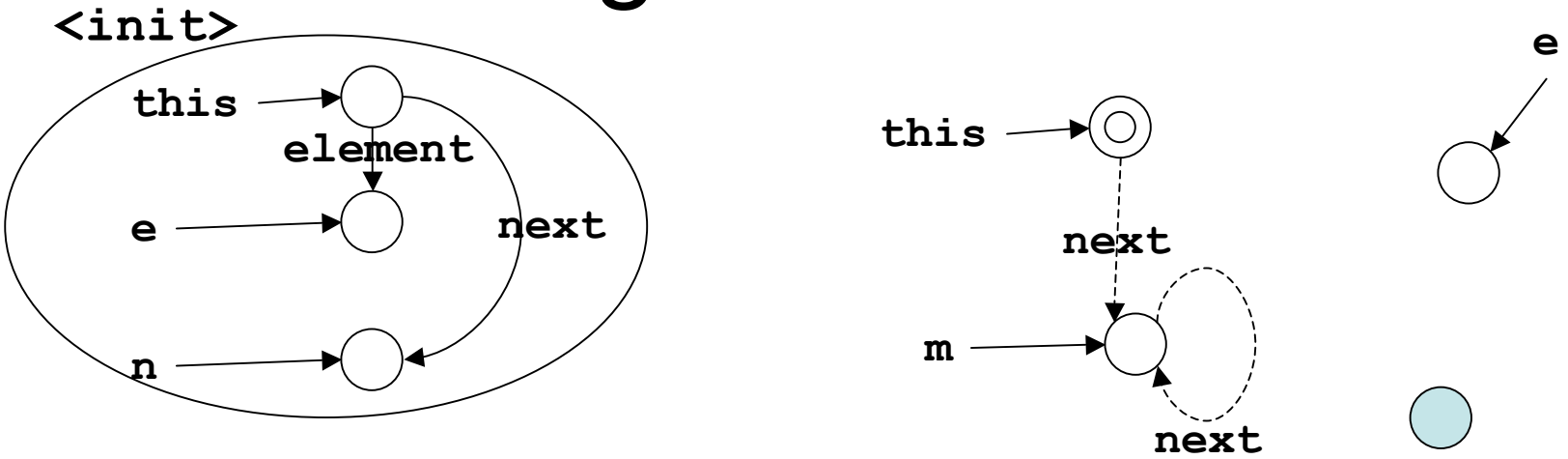


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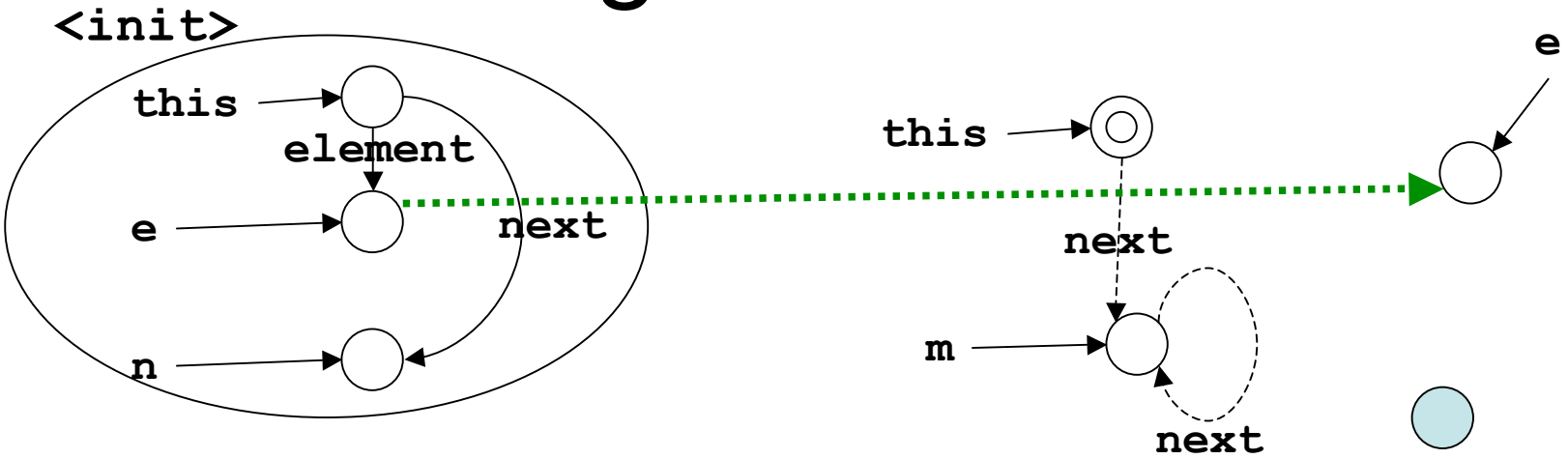


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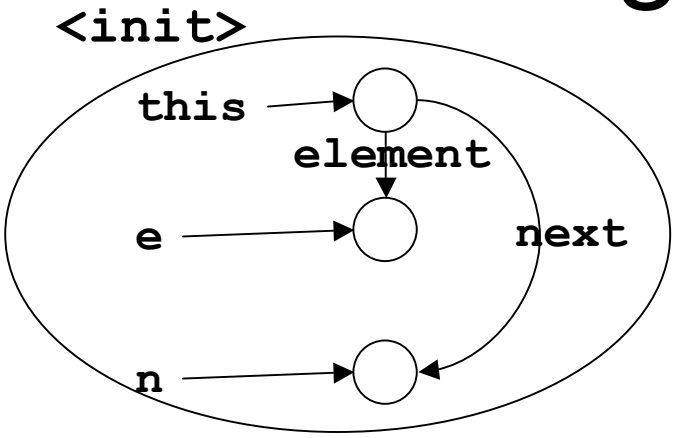

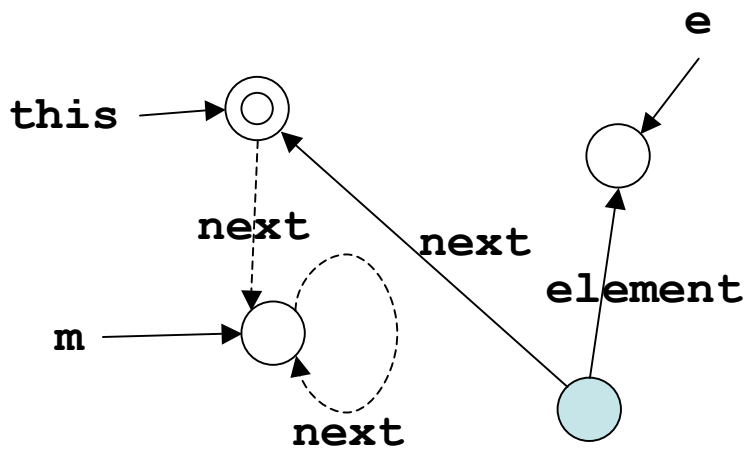


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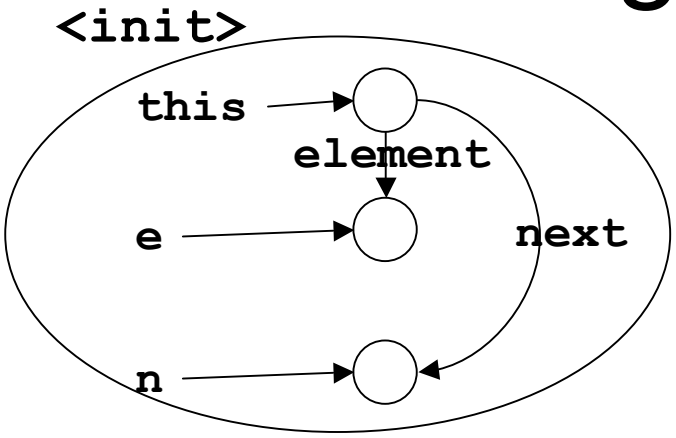

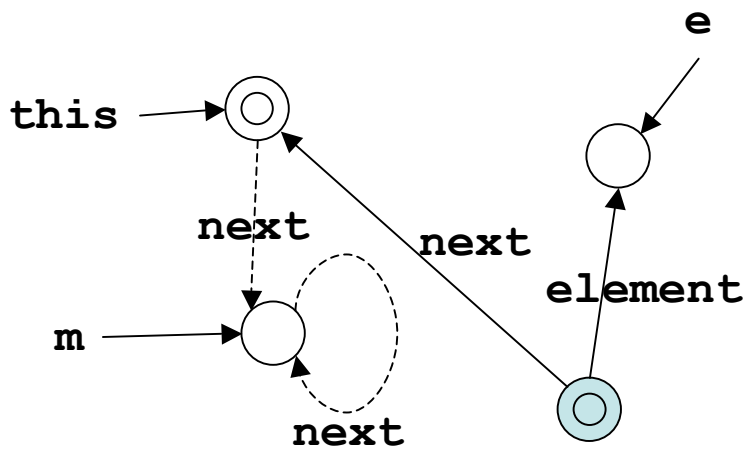


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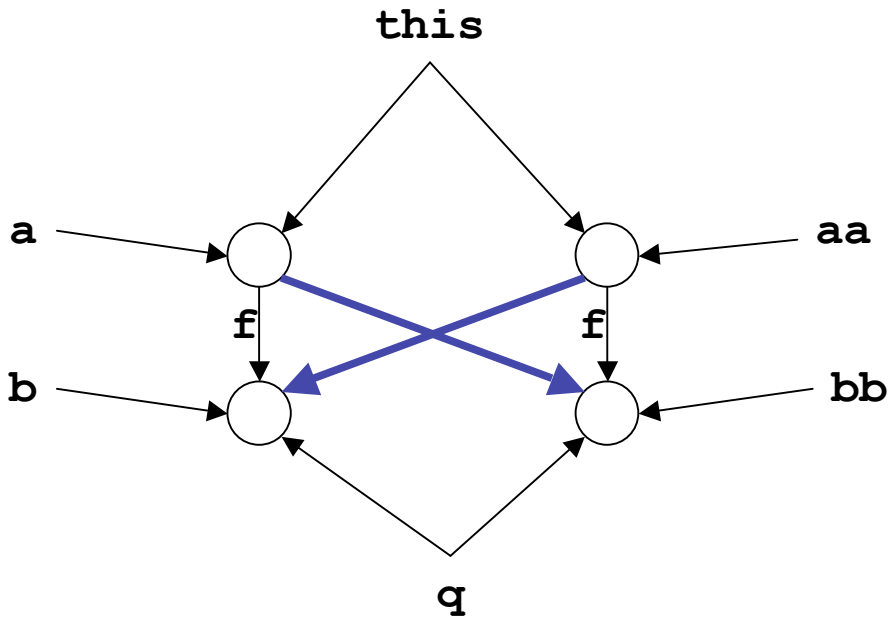
Context Sensitive?

```
class A{
    X f;
    void m(X q){
        this.f = q;
    }
}
. . .
    A a = new A(); //o1
    b = new X();   //o2
    a.m(b);

. . .
    A aa = new A();//o3
    bb = new X();  //o4
    aa.m(bb);
```



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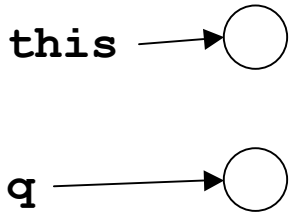


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    X f;
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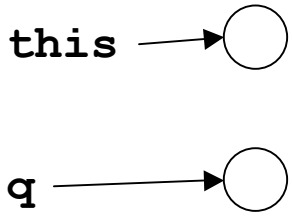


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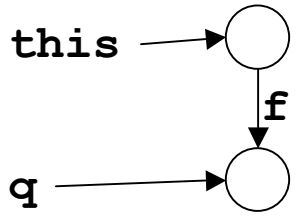


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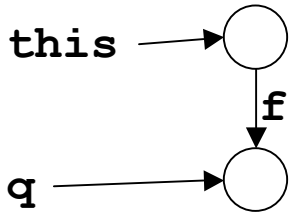


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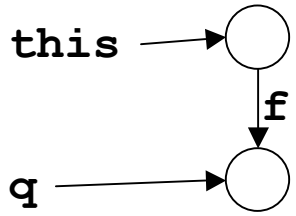


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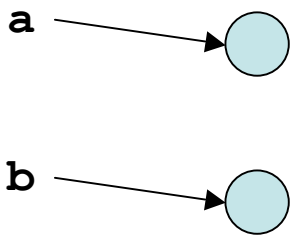


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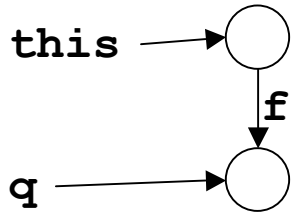


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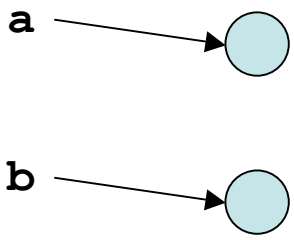


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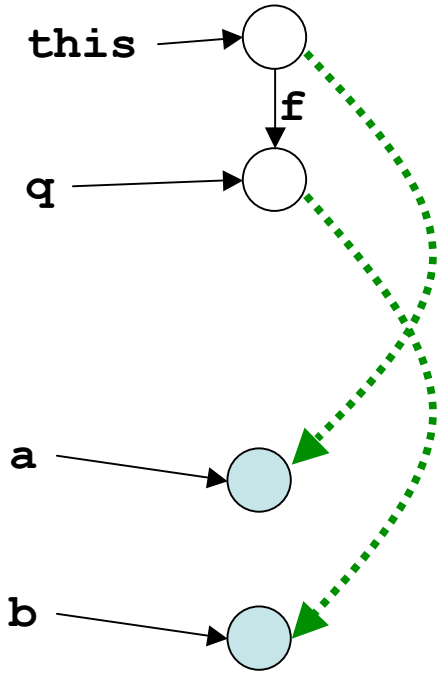

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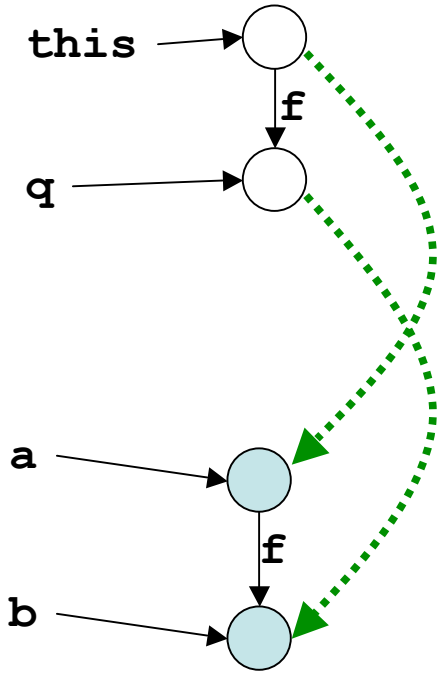

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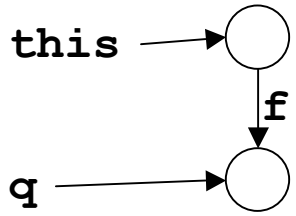


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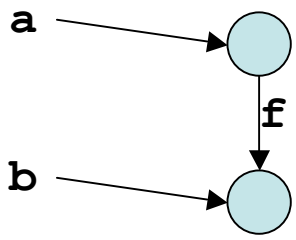


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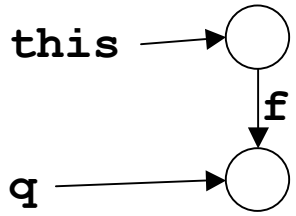


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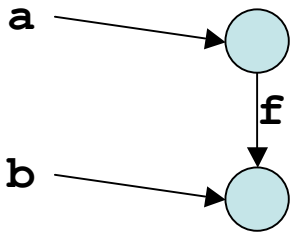

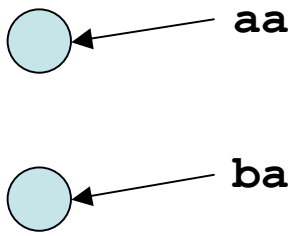


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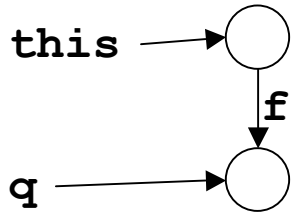


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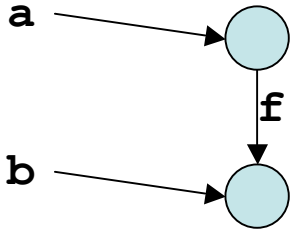

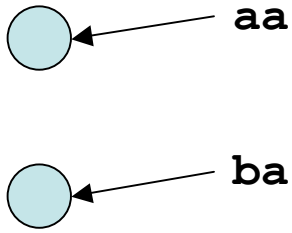


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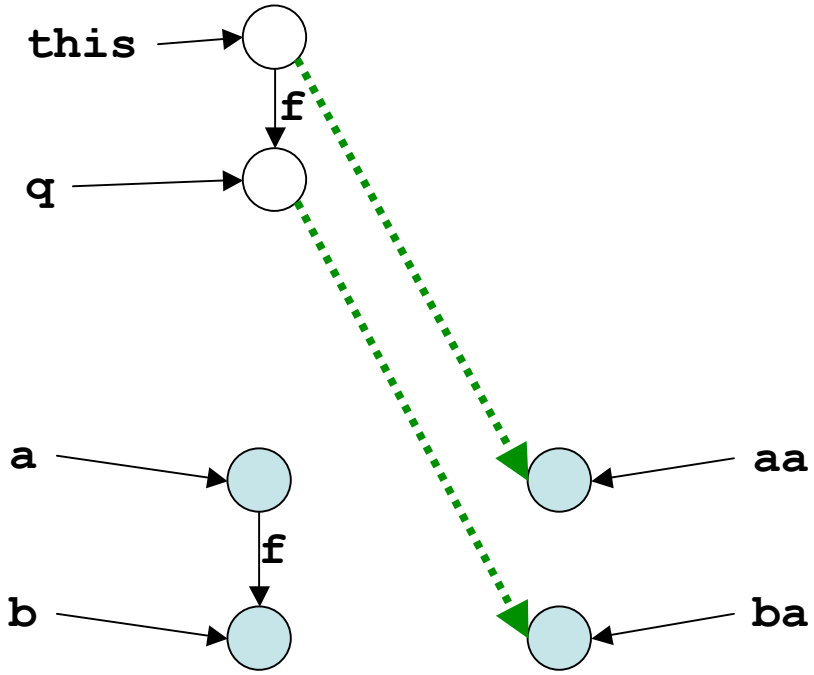

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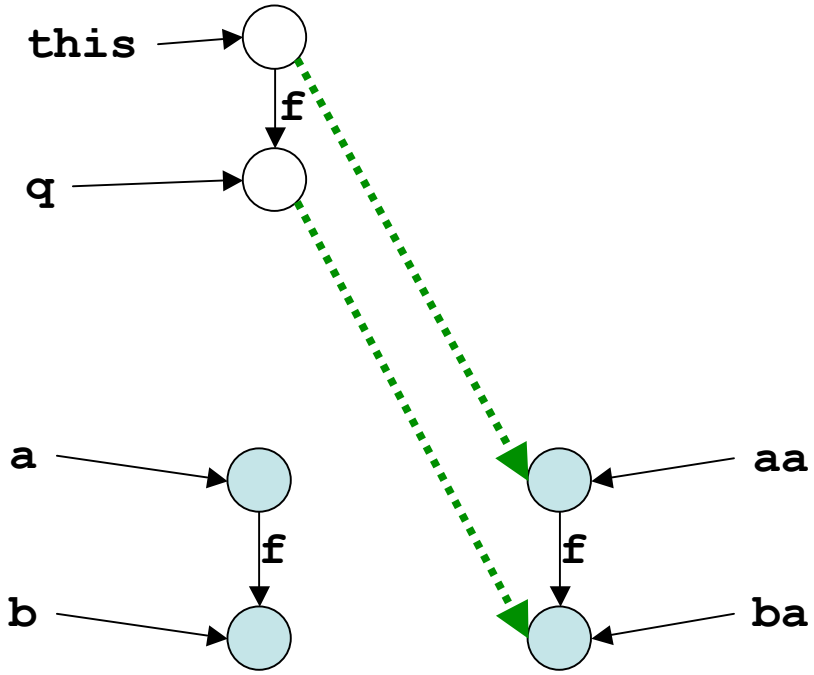

Contribution

- An idea to summarize the points-to effect of any partial program including:
  - Algorithm of summarizing
  - Algorithm of merging.
  - Usage Example.

Questions

- Why flow sensitive?
  - No comparison in the experiment section.
- What's wrong with Jikes RVM in the benchmark?
- Complexity?