Software Method Level Speculation for Java

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School of Computer Science
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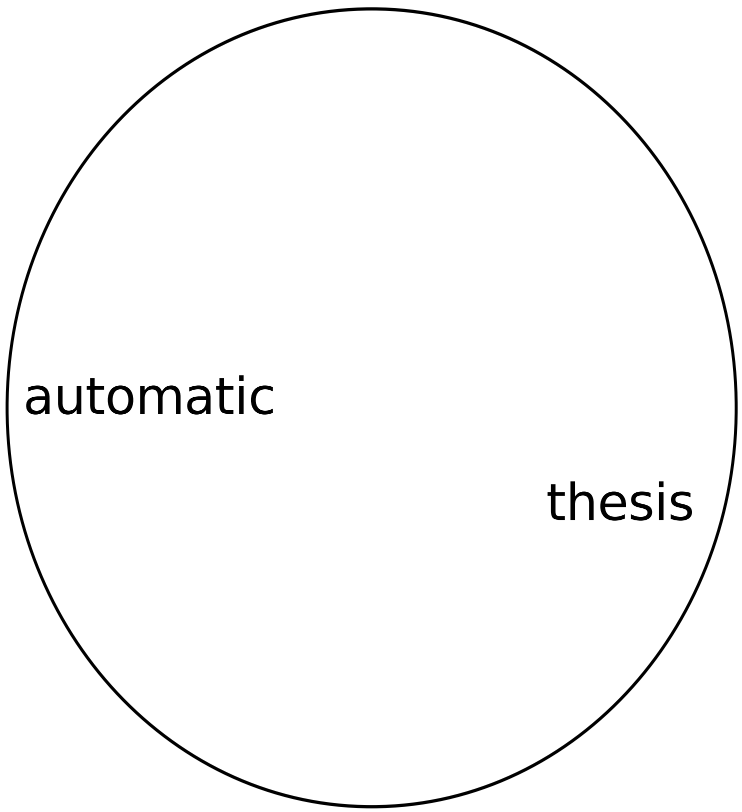
Ph.D. Oral Defense

Parallelization

Parallelization

thesis

Parallelization



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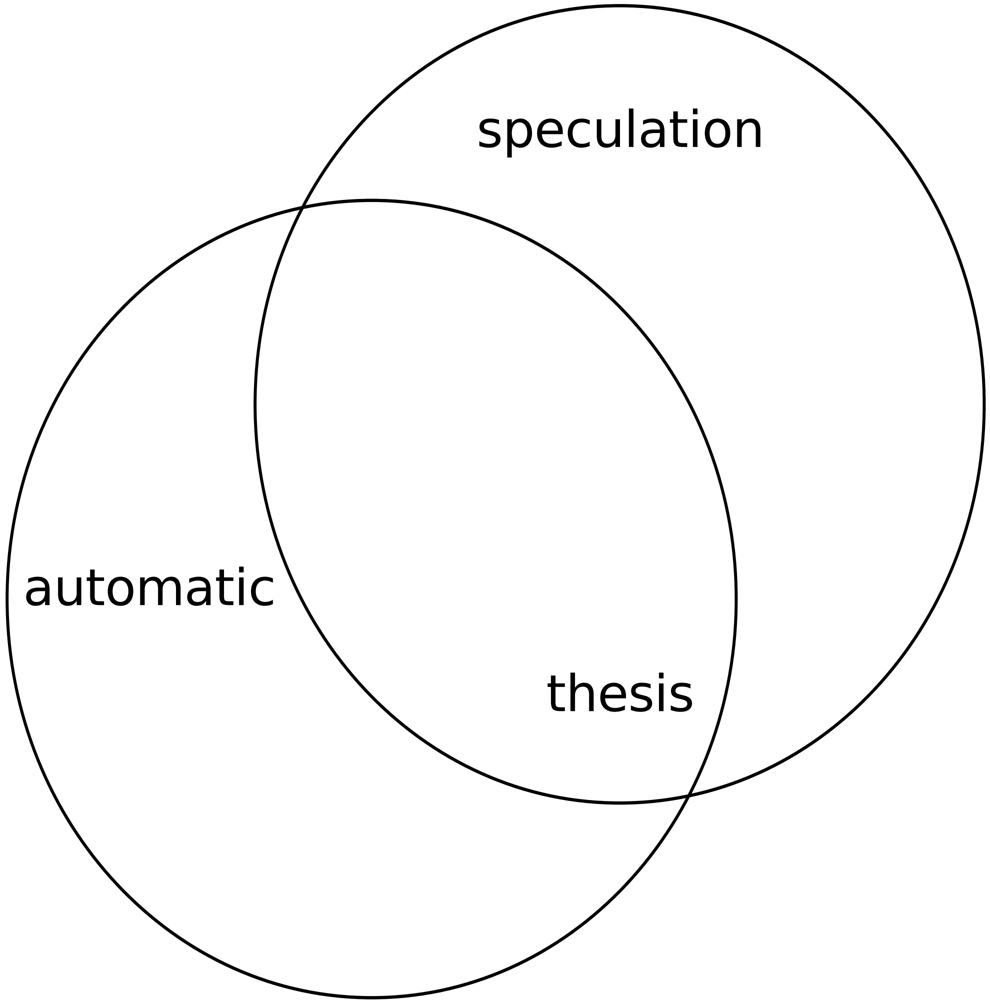

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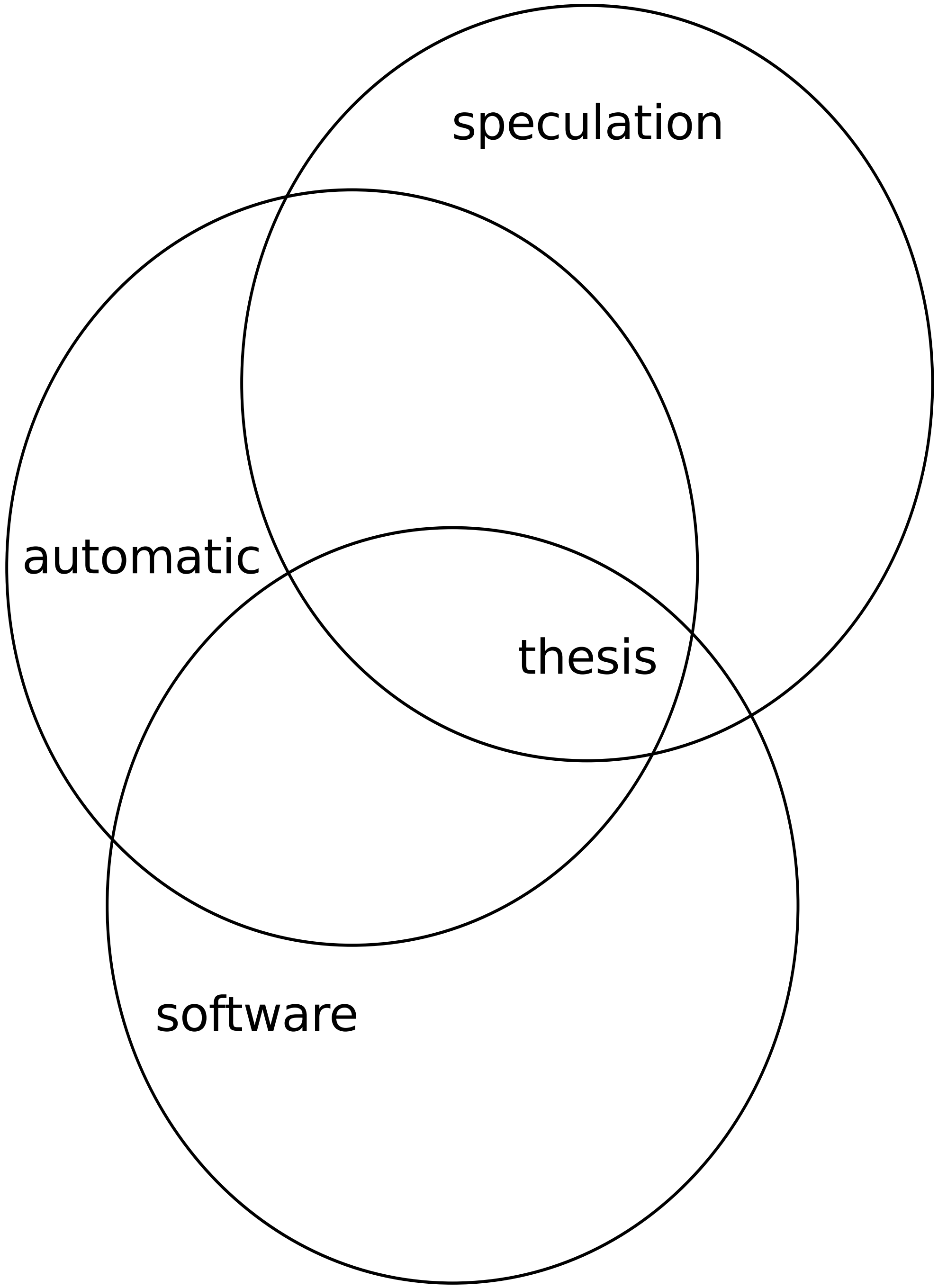

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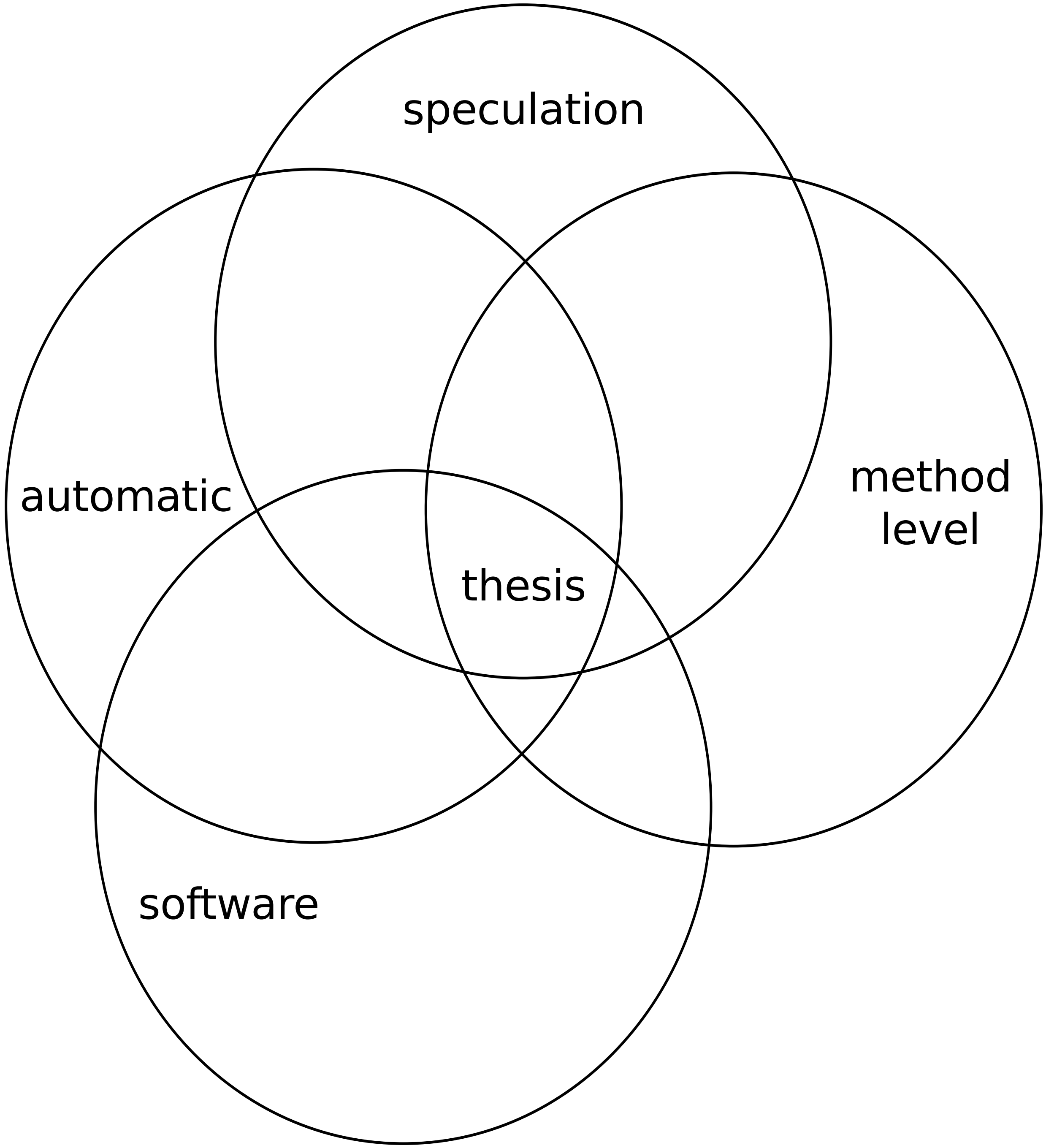
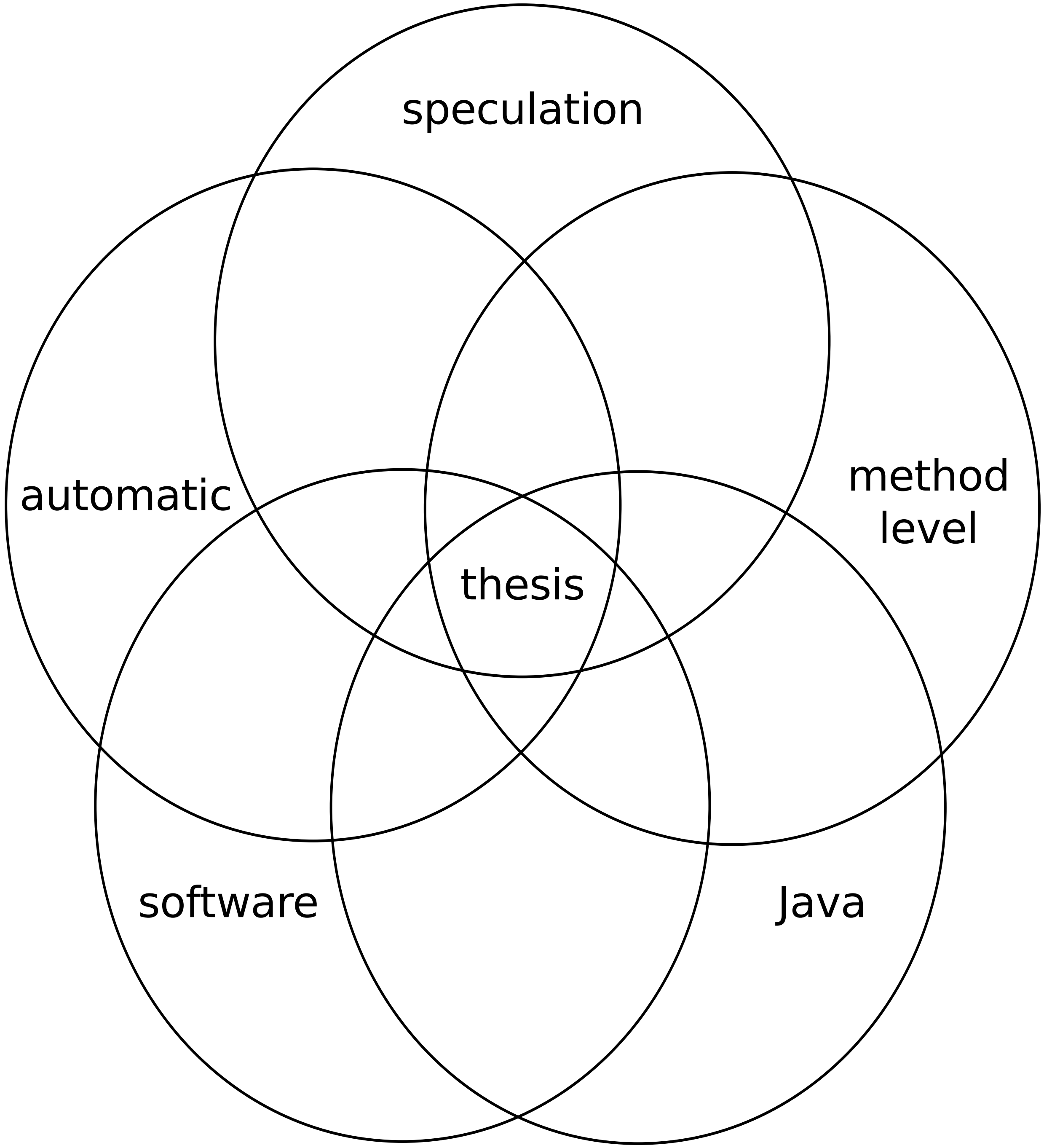
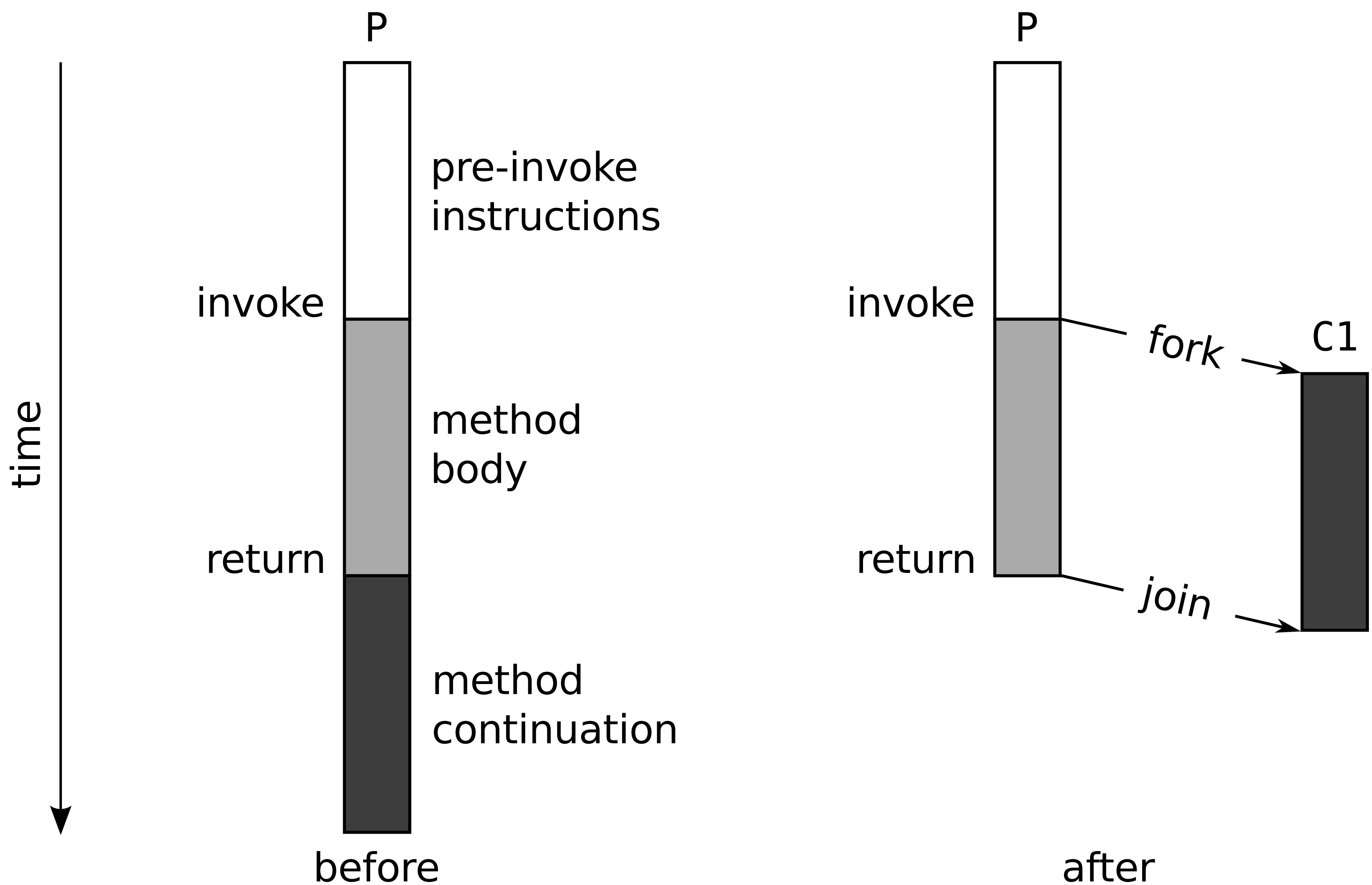


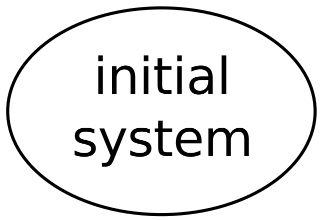
Parallelization



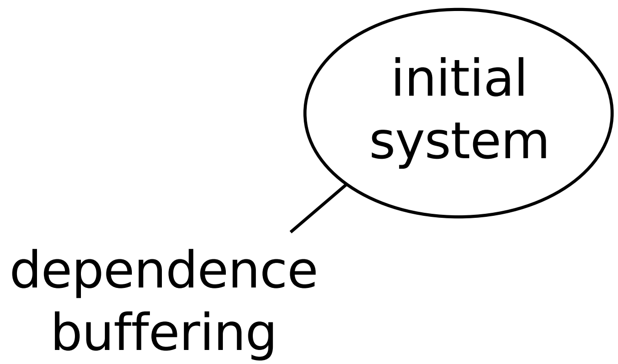
Method Level Speculation



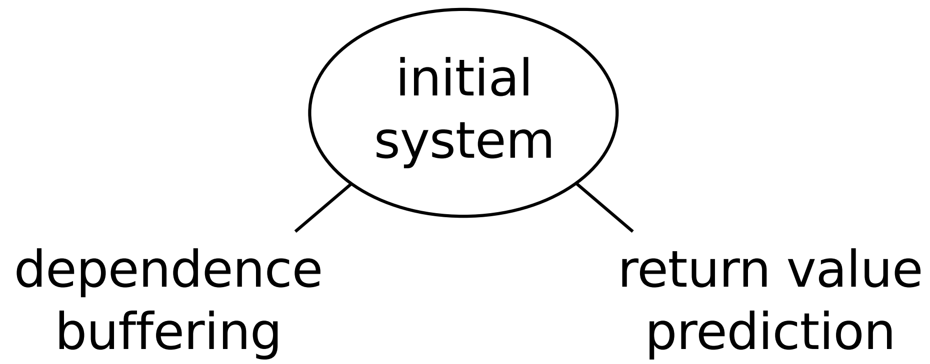
Initial System



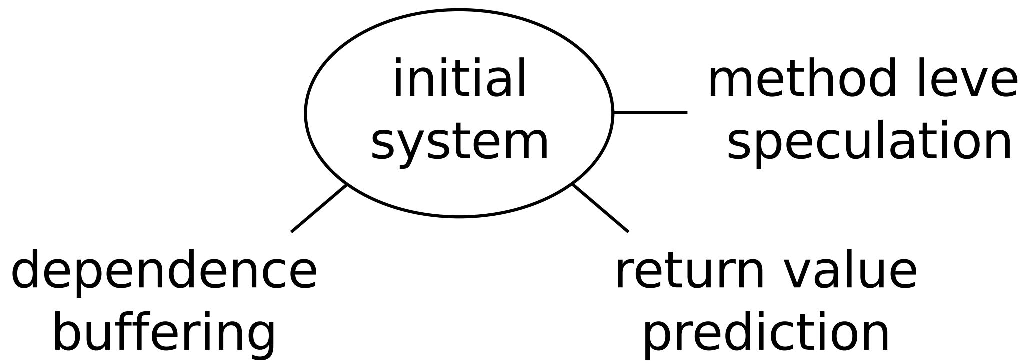
Initial System



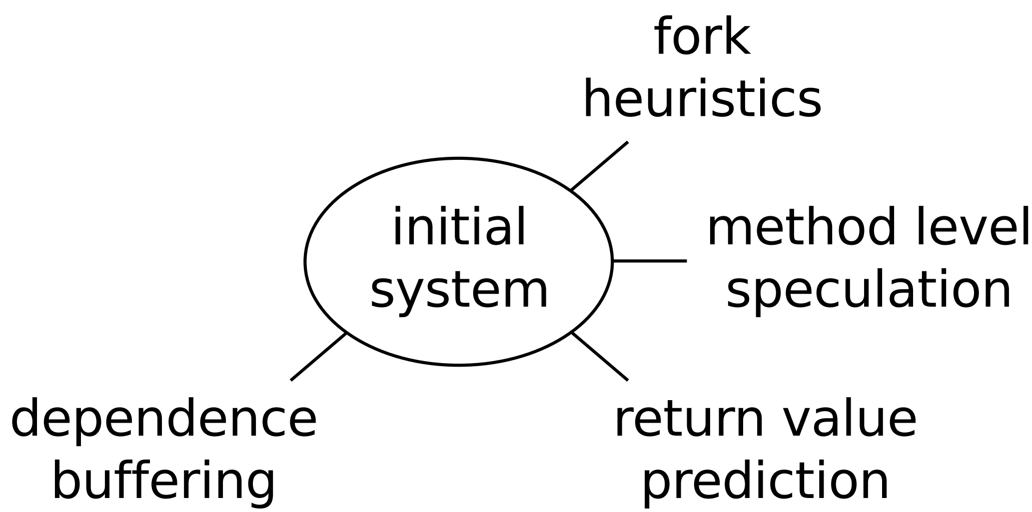
Initial System



Initial System



Initial System



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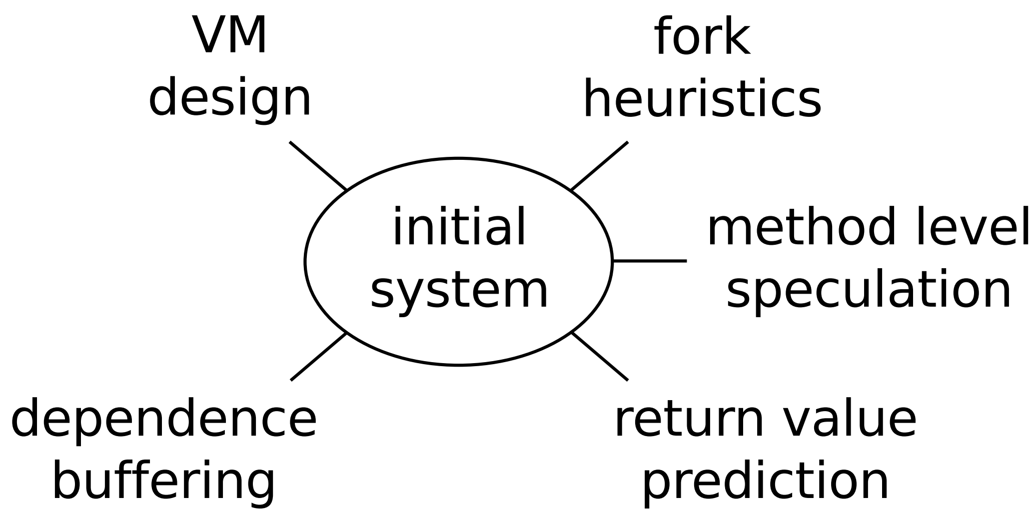

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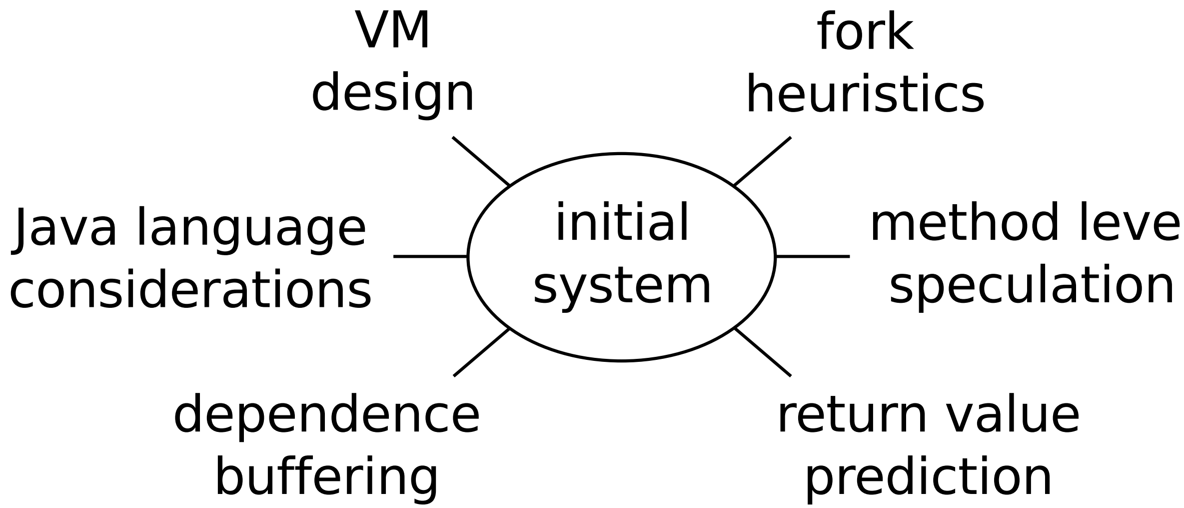


Example

```
// execute foo() non-speculatively
r = foo (x, y, z);
```

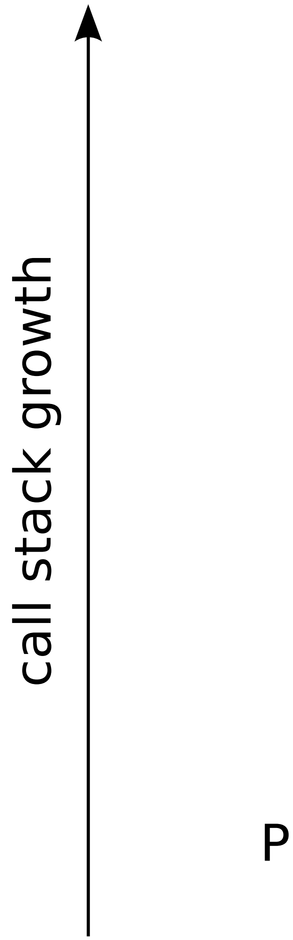
Example

```
// execute foo() non-speculatively
r = foo (x, y, z);

// execute foo()'s continuation speculatively?
```

Single Child Speculation

```
A(){
   a;
   B(){
      b;
   }
   a';
}
```



Single Child Speculation

```
A(){
  a;
  B(){
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  }
  a';
}
```

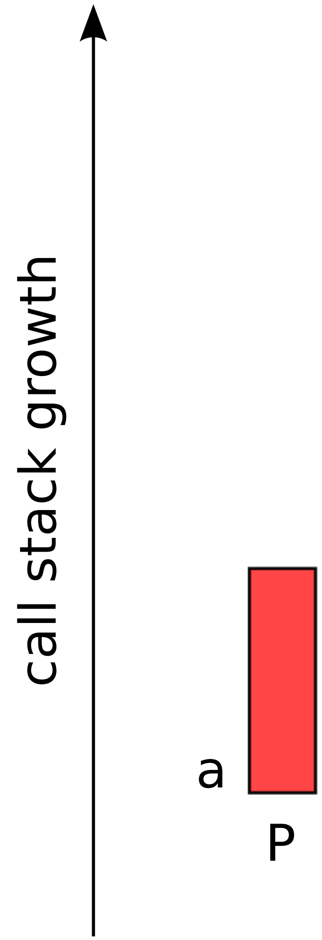

Single Child Speculation

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   B(){
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}
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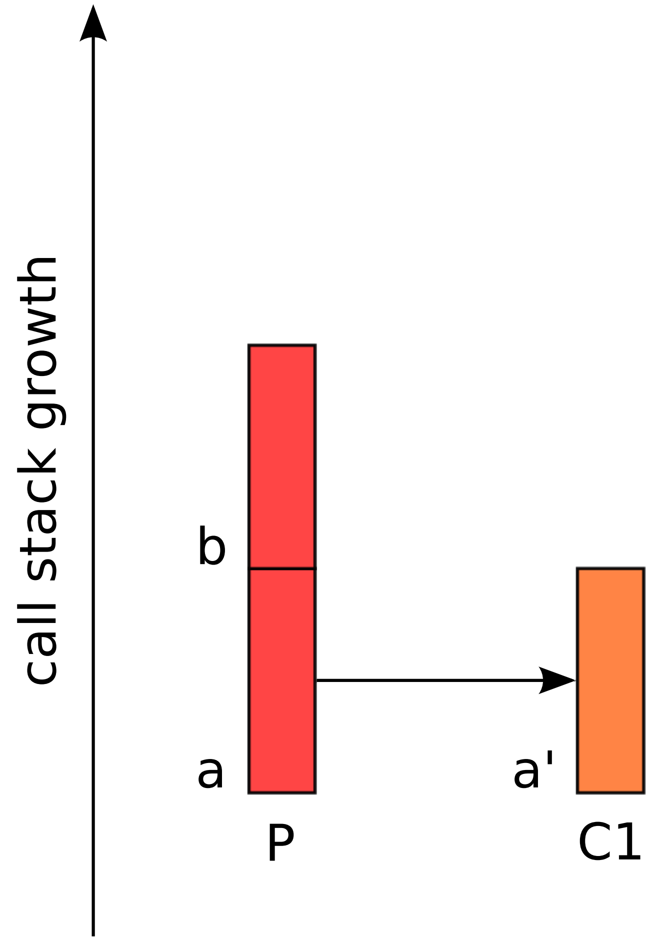
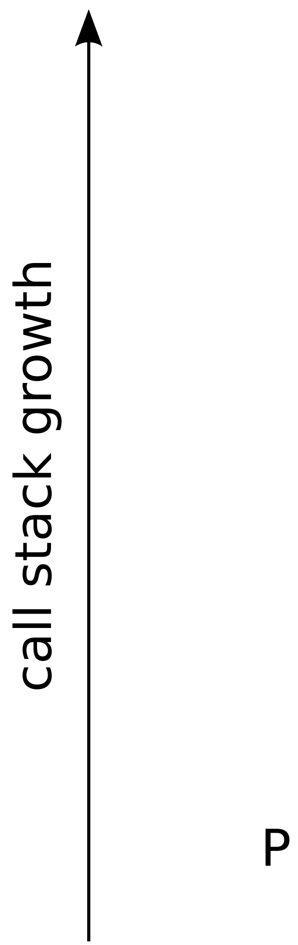


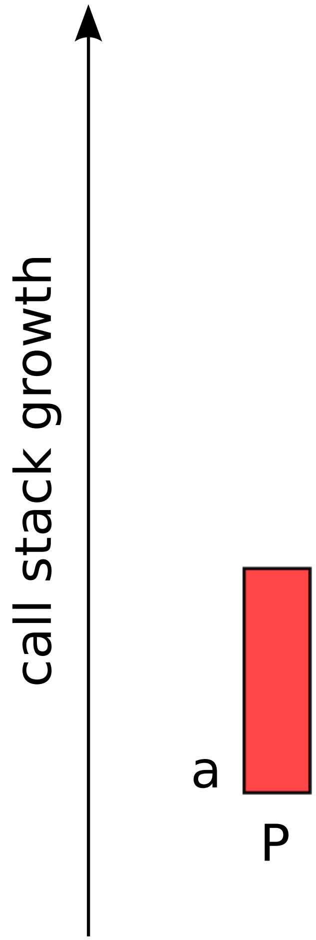
Out-of-Order Nesting

```
A(){
   a;
   B(){
      b;
      C(){
         c;
      }
      b';
   }
   a';
}
```



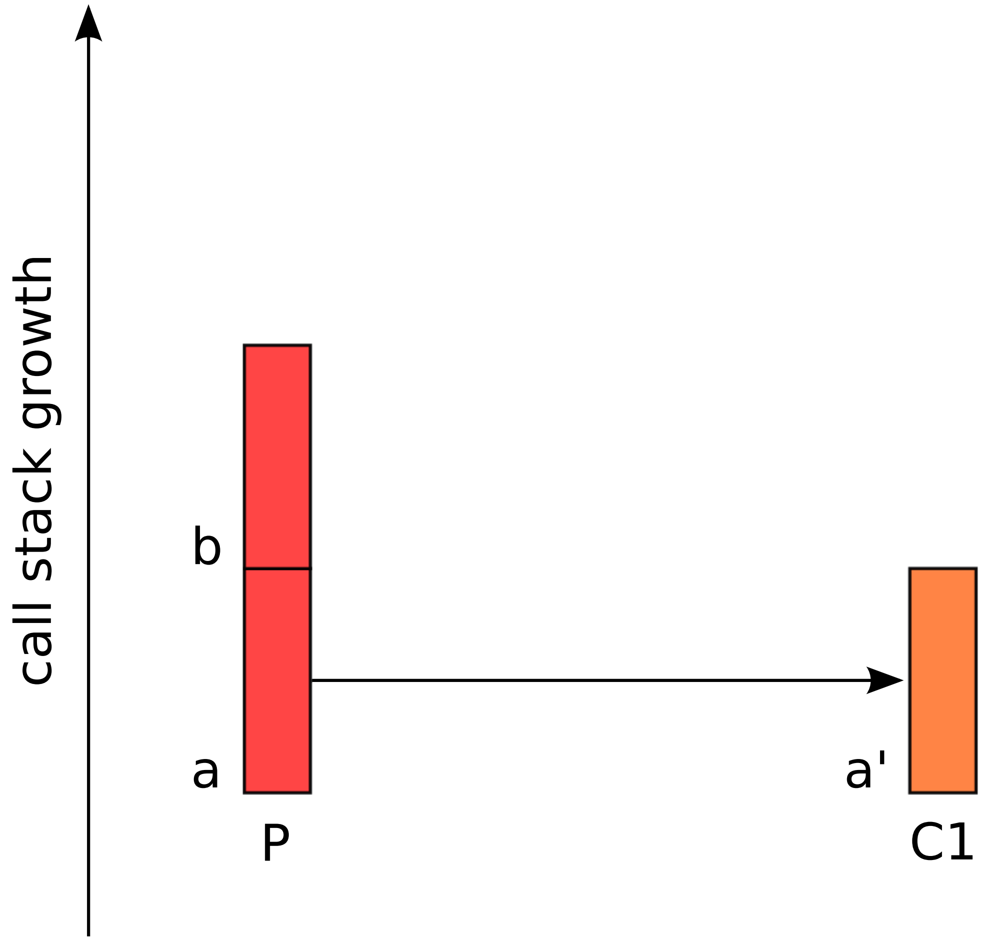
Out-of-Order Nesting

```
A(){
  a;
  B(){
    b;
    C(){
      c;
    }
    b';
  }
  a';
}
```



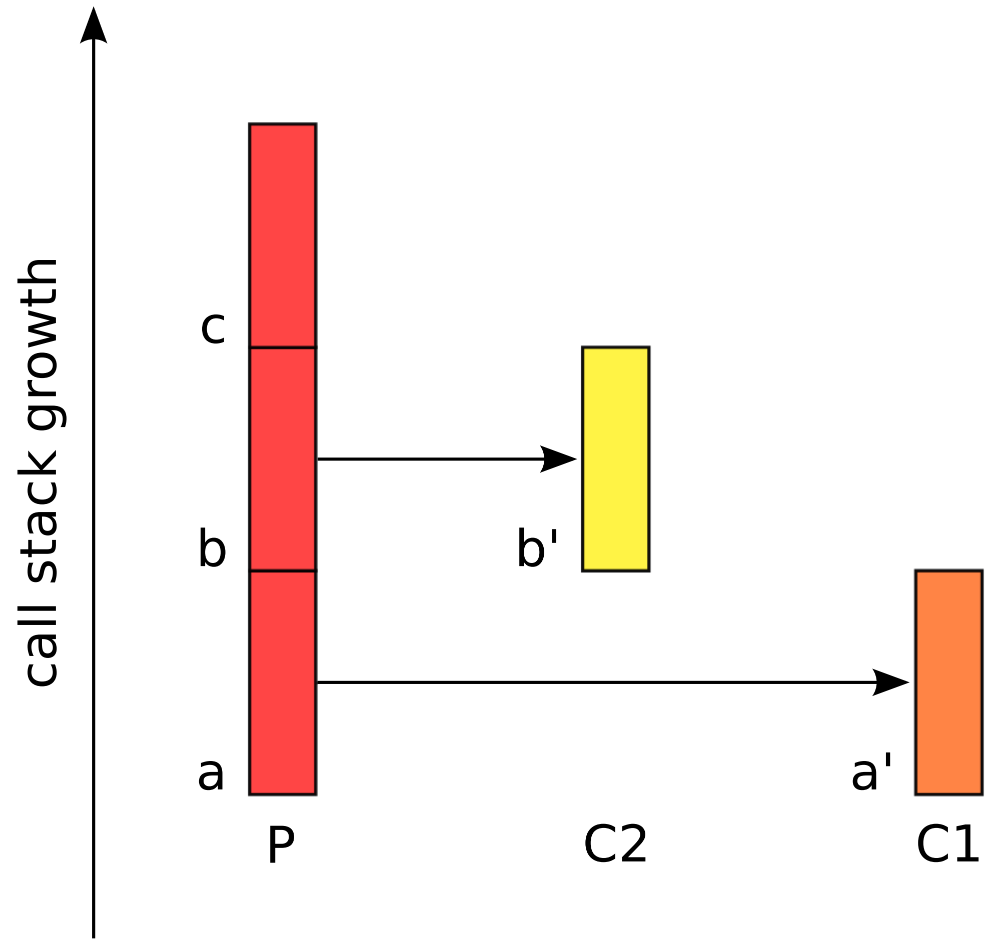
Out-of-Order Nesting

```
A(){
   a;
   B(){
      b;
      C(){
         c;
      }
      b';
   }
   a';
}
```



Out-of-Order Nesting

```
A(){
   a;
   B(){
      b;
      C(){
         c;
      }
      b';
   }
   a';
}
```



Example

```
// execute foo() non-speculatively
r = foo (x, y, z);

// execute foo()'s continuation speculatively
if (r > 10)        // predict return value
  {
    ...
  }
```

Return Value Prediction

predictor	history	prediction
last value	$1, 1, 1$	1

Return Value Prediction

predictor	history	prediction
last value	$1, 1, 1$	1
stride	$1, 2, 3$	4

Return Value Prediction

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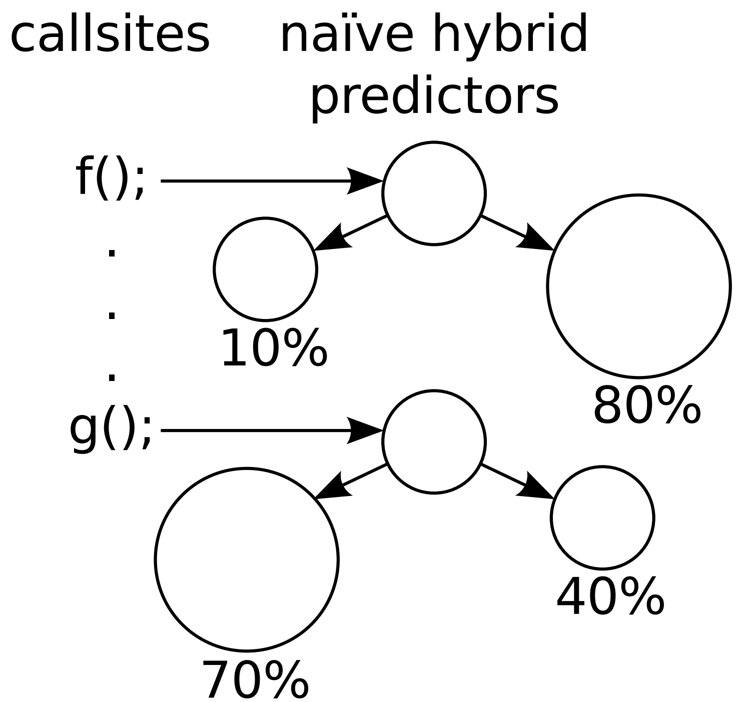
last value	$1, 1, 1$	1
stride	$1, 2, 3$	4
context	$1, 5, 6, 8, \ldots, 1, 5, 6$	8

Return Value Prediction

predictor	history	prediction
last value	$1, 1, 1$	1
stride	$1, 2, 3$	4
context	$1, 5, 6, 8, \ldots, 1, 5, 6$	8
memoization	$f(2, 4) : 7, \ldots, f(2, 4)$	7

Software Hybrid RVP



Example

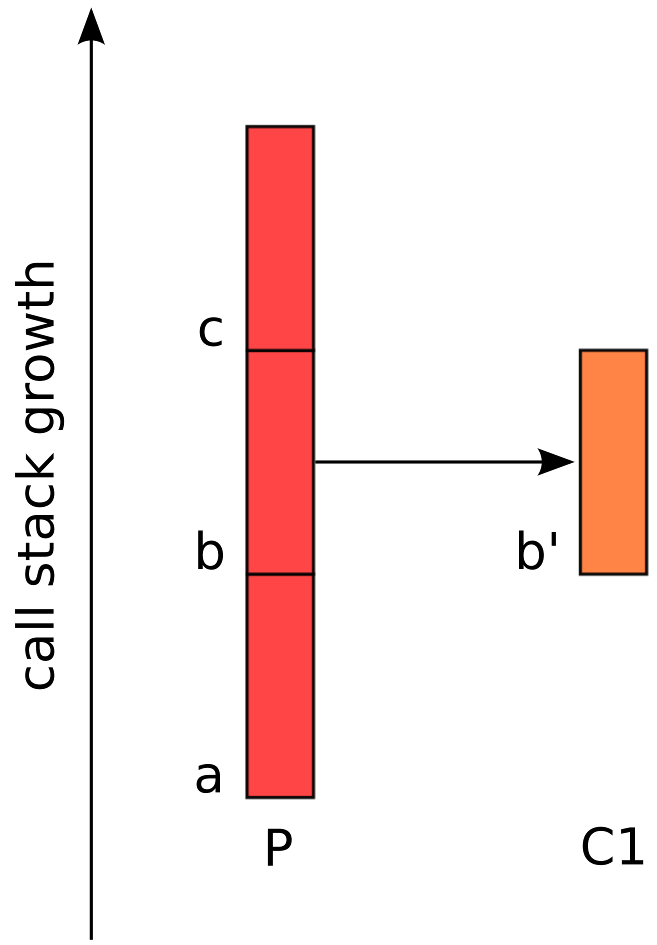
```
// execute foo() non-speculatively
r = foo (x, y, z);

// execute foo()'s continuation speculatively
if (r > 10)        // predict return value
  {
    s = o1.f;      // buffer heap & static reads
    o2.f = r;      // buffer heap & static writes
  }
```

Example

```
// execute foo() non-speculatively
r = foo (x, y, z);

// execute foo()'s continuation speculatively
if (r > 10)        // predict return value
  {
    s = o1.f;      // buffer heap & static reads
    o2.f = r;      // buffer heap & static writes
  }

// invoke bar () speculatively
o3.bar ();
```

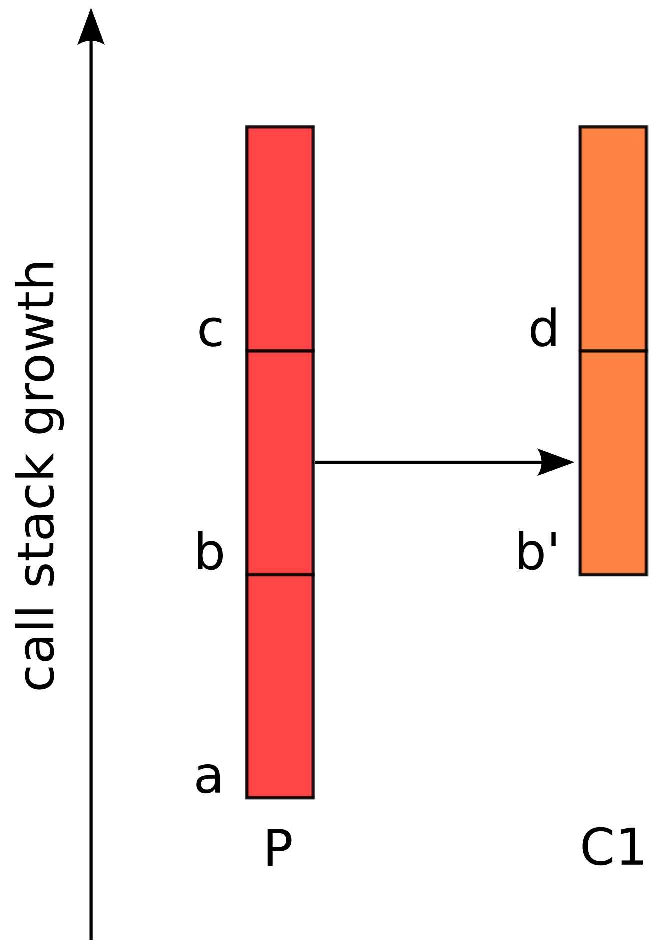
Speculative Method Invocation

```
A(){
  a;
  B(){
    b;
    C(){
      c;
    }
    b';
    D(){
      d;
    }
  }
  a';
}
```



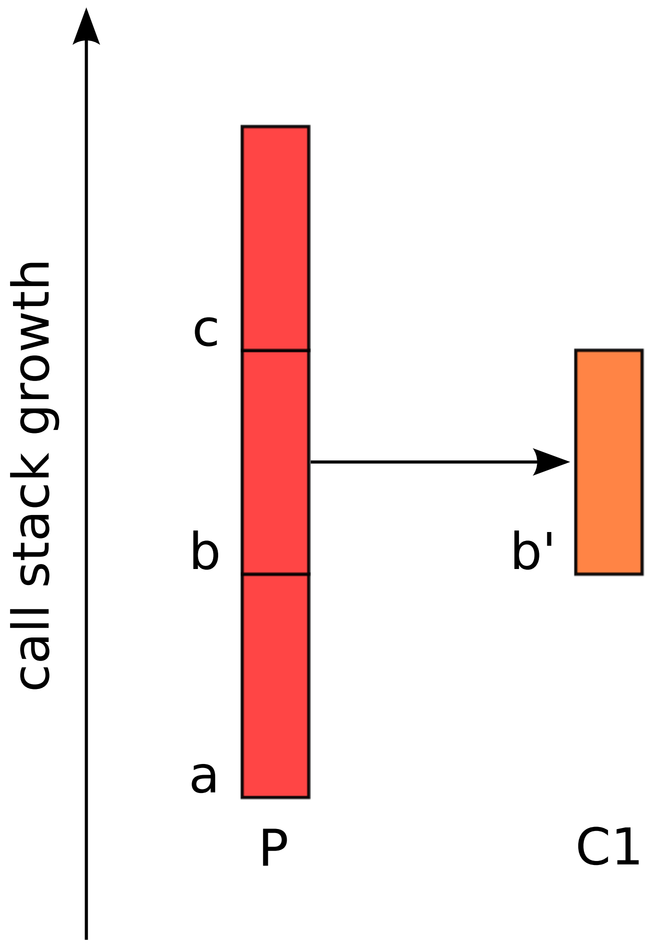
Speculative Method Invocation

```
A(){
   a;
   B(){
      b;
      C(){
         c;
      }
      b';
      D(){
         d;
      }
   }
   a';
}
```



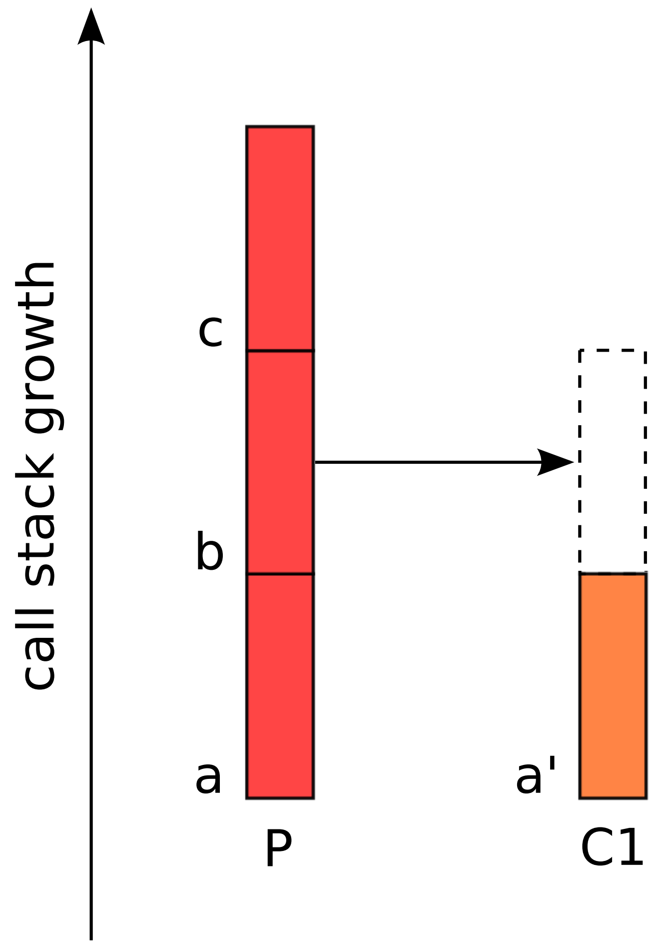
Speculative Method Invocation

```
A(){
   a;
   B(){
      b;
      C(){
         c;
      }
      b';
      D(){
         d;
      }
   }
   a';
}
```



Speculative Method Invocation

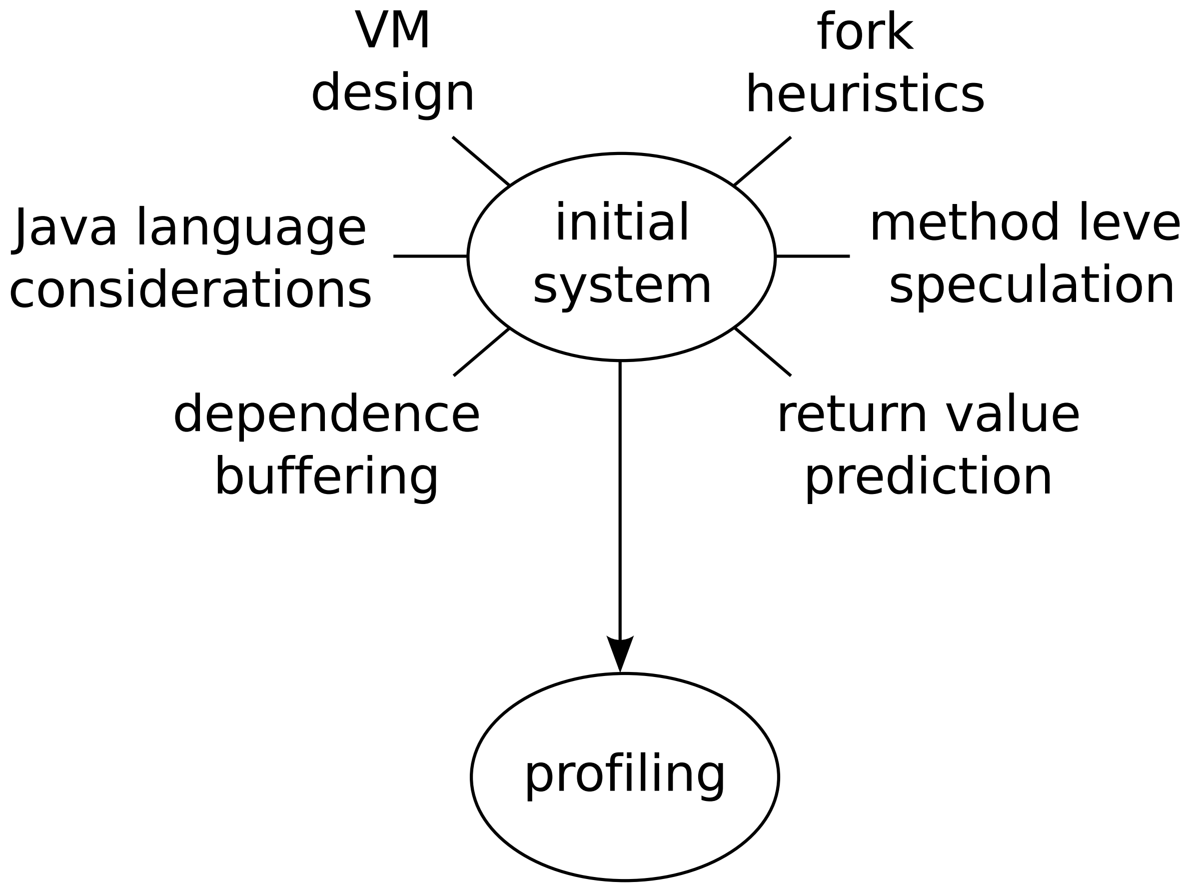
```
A(){
   a;
   B(){
      b;
      C(){
         c;
      }
      b';
      D(){
         d;
      }
   }
   a';
}
```



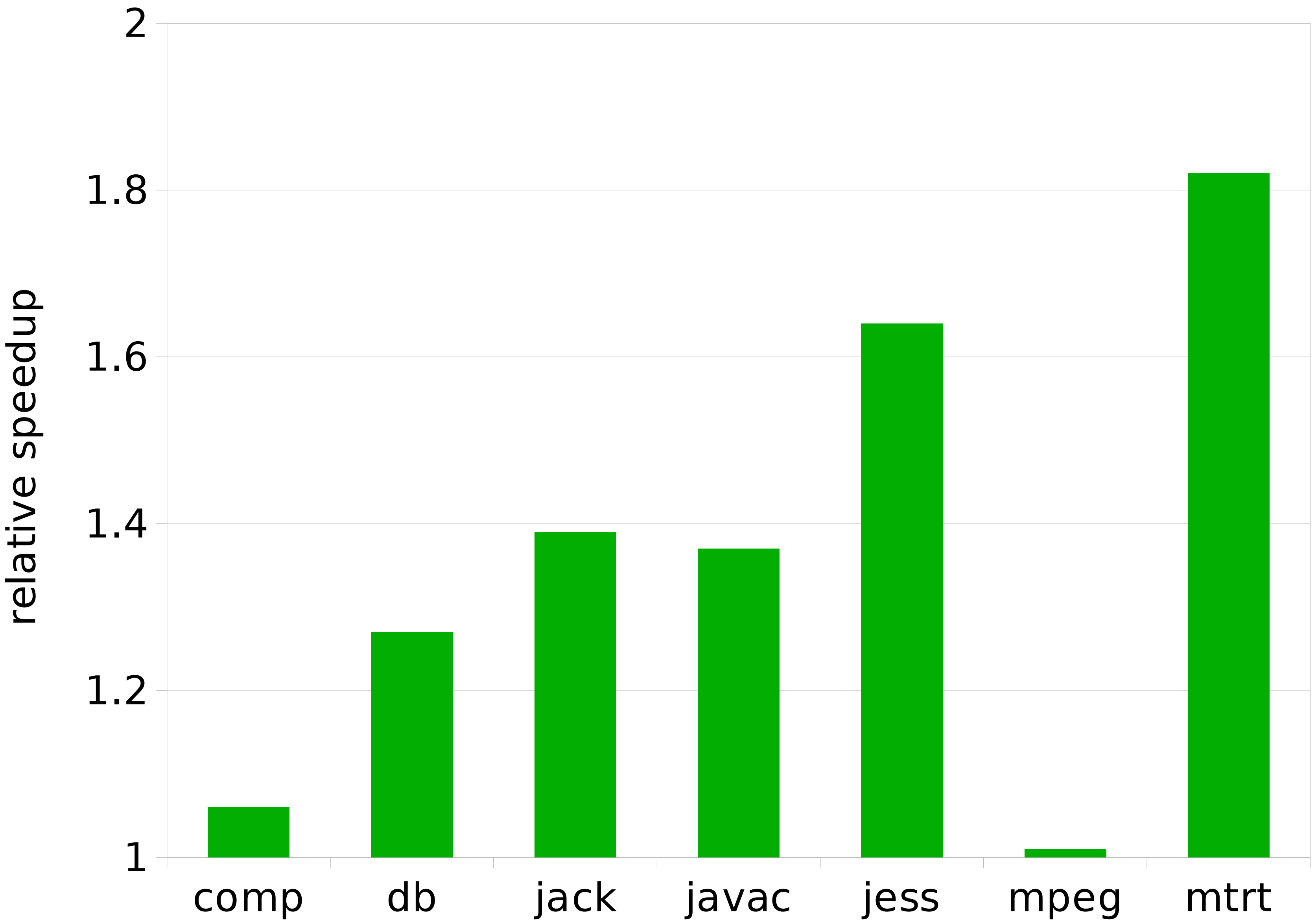
Example

```
// execute foo() non-speculatively
r = foo (x, y, z);

// execute foo()'s continuation speculatively
if (r > 10)      // predict return value
  {
    s = o1.f;    // buffer heap & static reads
    o2.f = r;    // buffer heap & static writes
  }

// invoke bar () speculatively
o3.bar ();

// stop speculation due to unsafe operation
synchronized (o4) { ... }
```

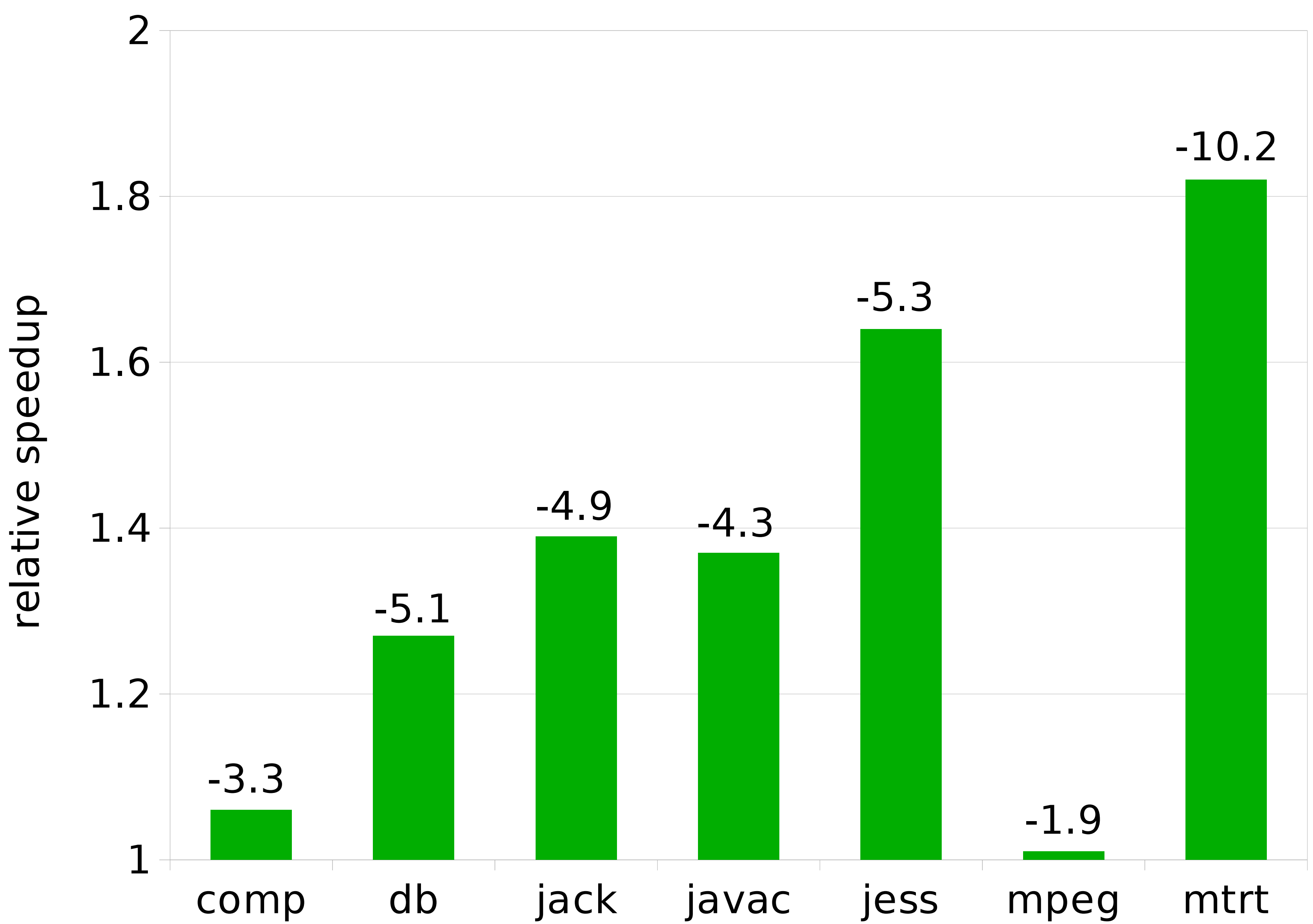
Profiling


VM design
fork heuristics
Java language considerations
initial system
method level speculation
dependence buffering
return value prediction
profiling

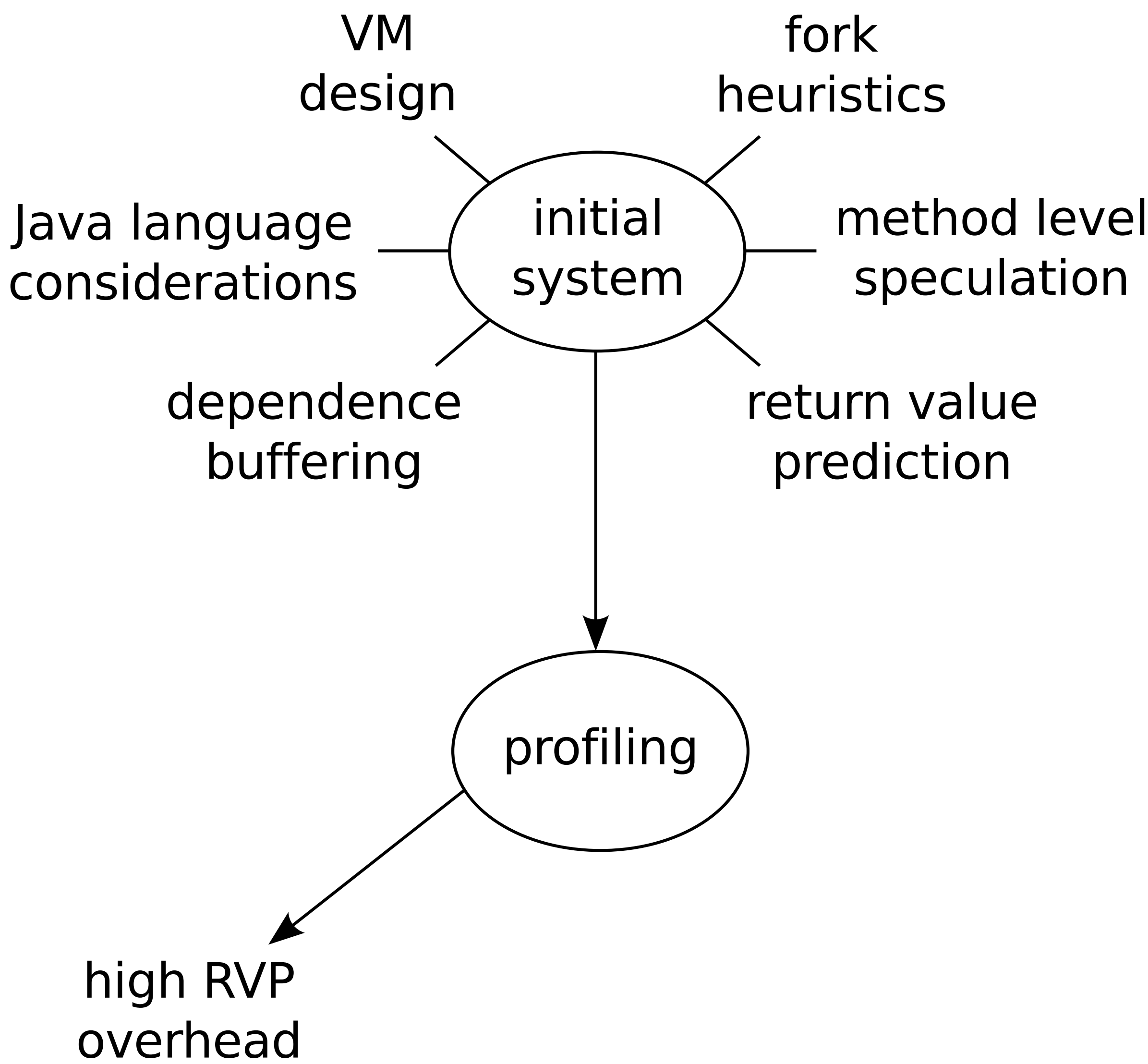
Speedup...


relative speedup
2
1.8
1.6
1.4
1.2
1
comp
db
jack
javac
jess
mpeg
mtrt

Speedup... and Slowdown



Profiling



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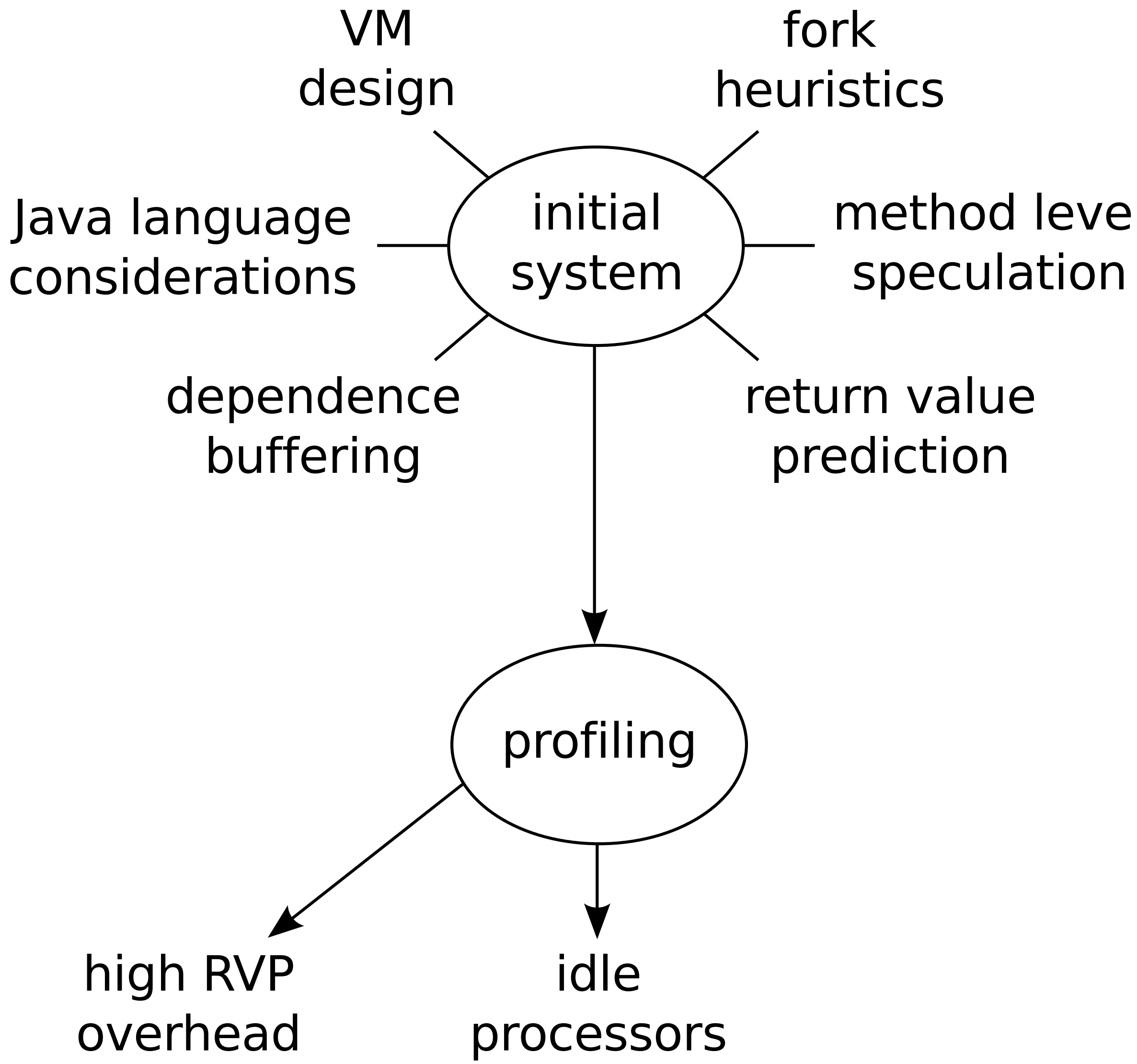
high RVP overhead

Profiling


VM
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method level
speculation
dependence
buffering
return value
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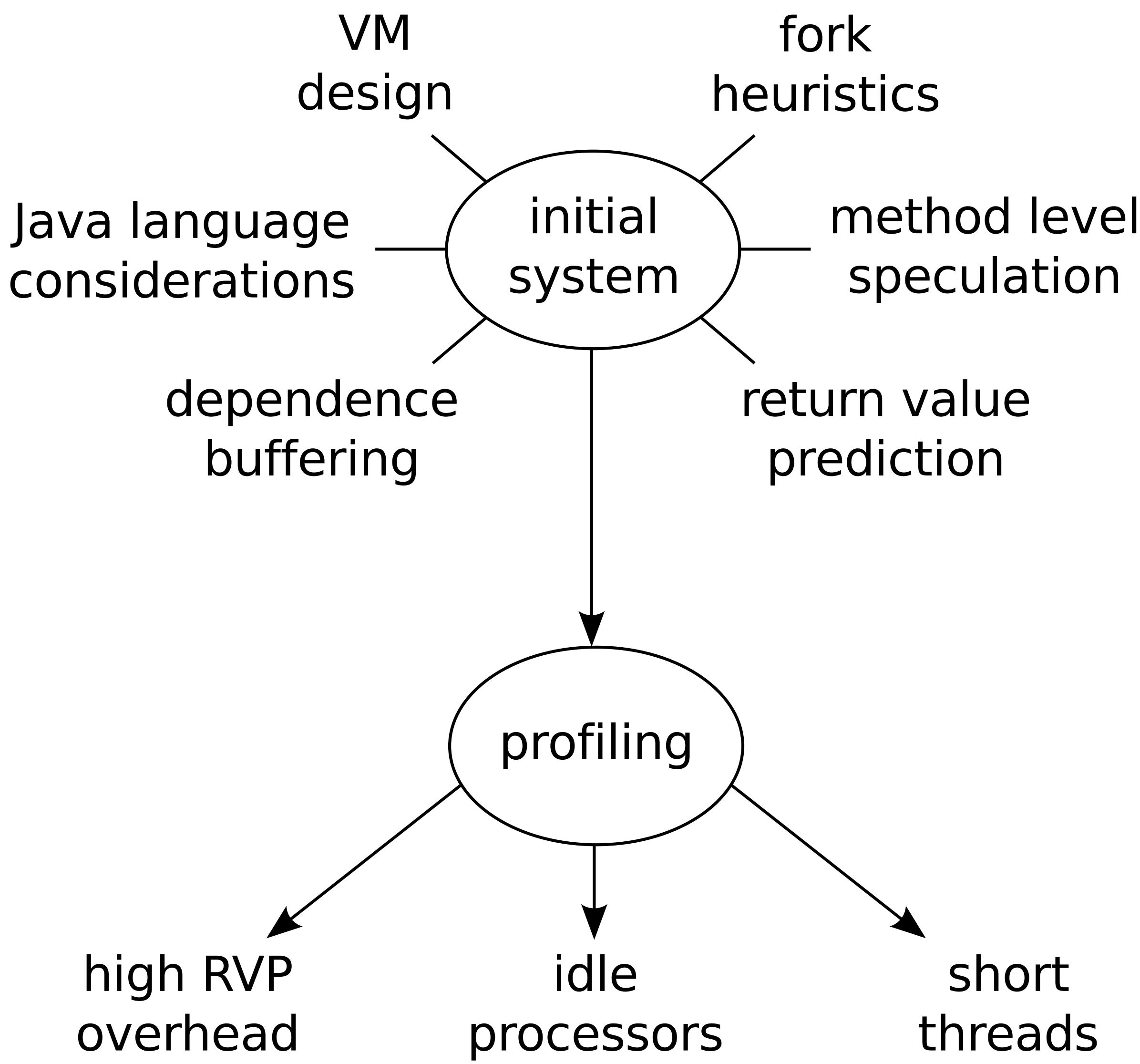
profiling
high RVP
overhead
idle
processors

Profiling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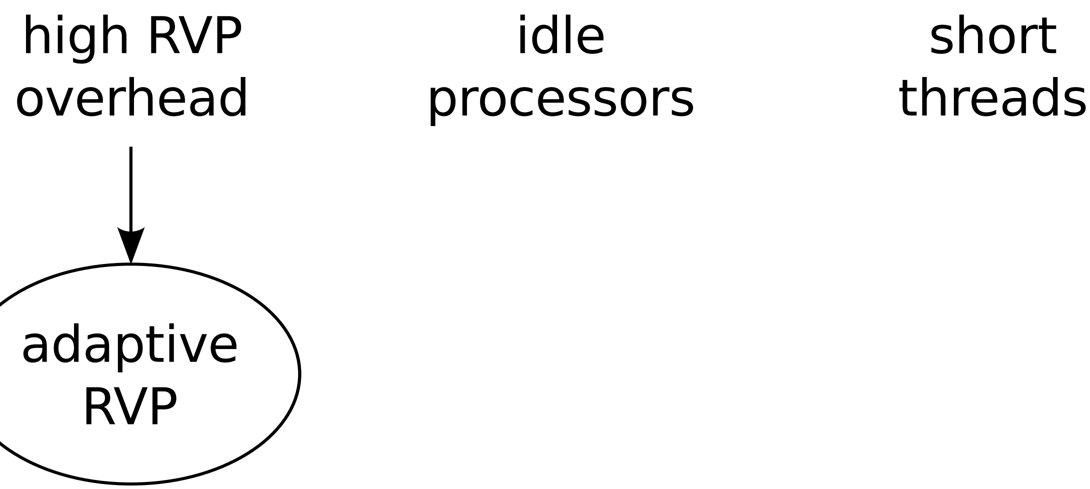
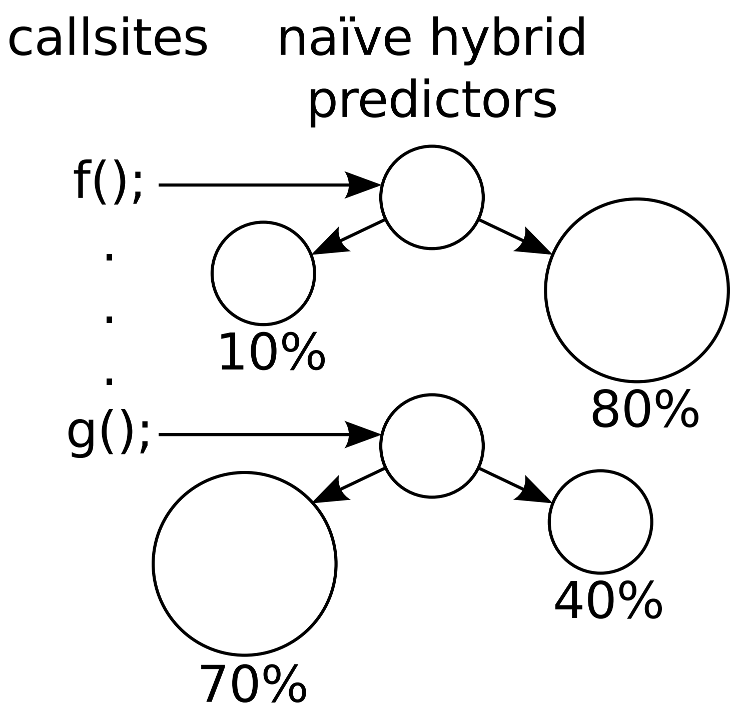
short threads

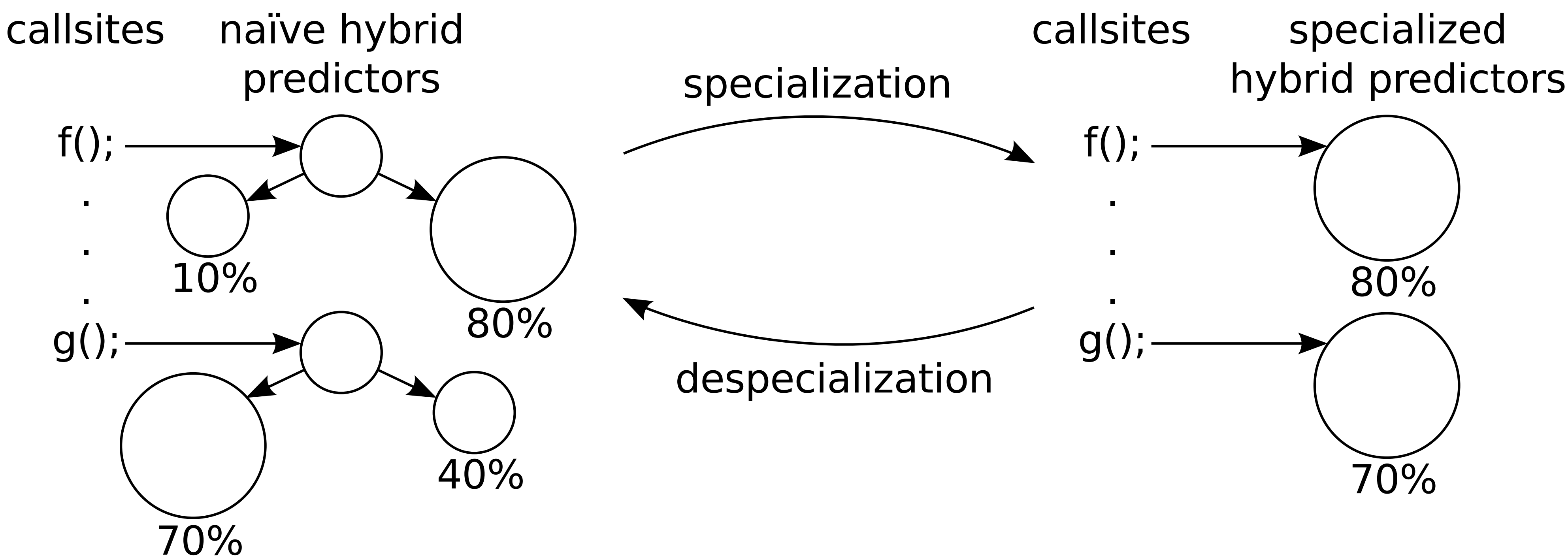
Optimization



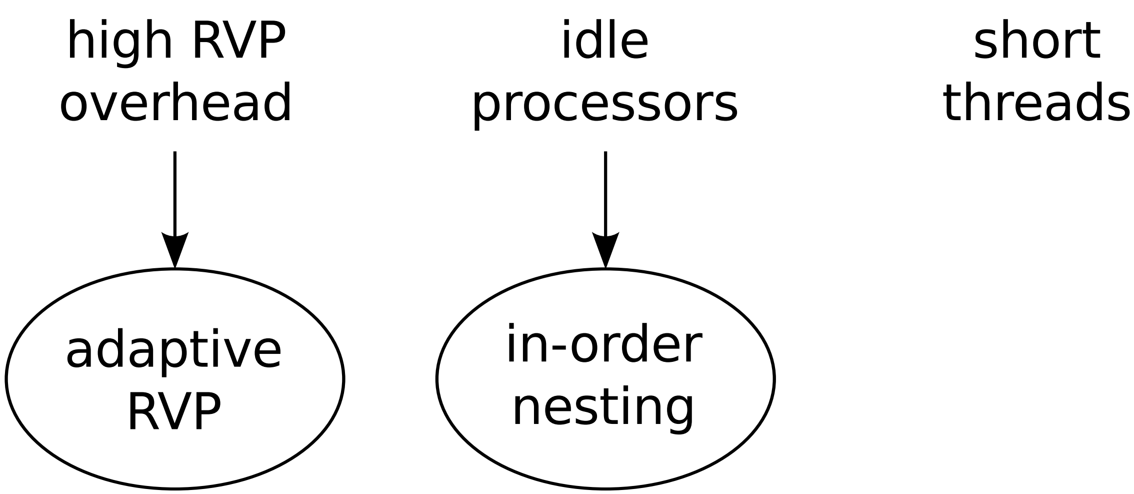
Adaptive RVP



Adaptive RVP

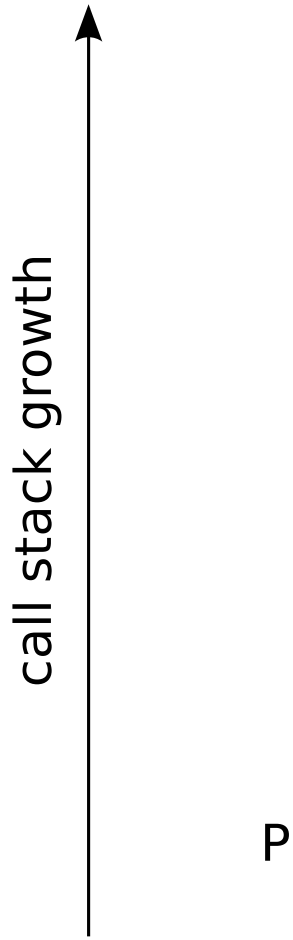


Optimization



In-Order Nesting

```
A(){
   a;
   B(){
      b;
   }
   a';
   C(){
      c;
   }
   a'';
}
```



In-Order Nesting

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  B(){
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  a';
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    c;
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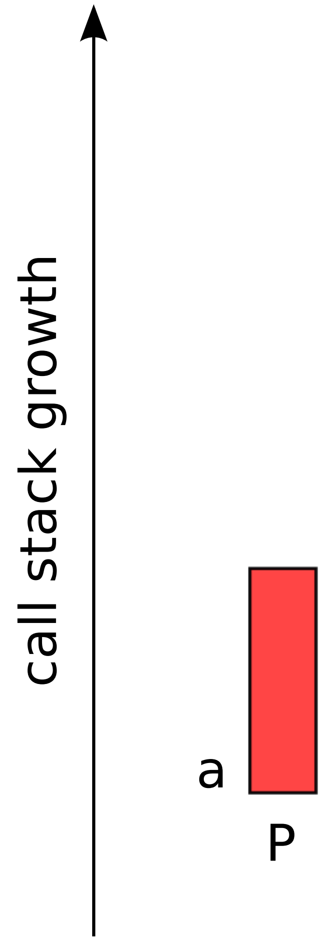

In-Order Nesting

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   a';
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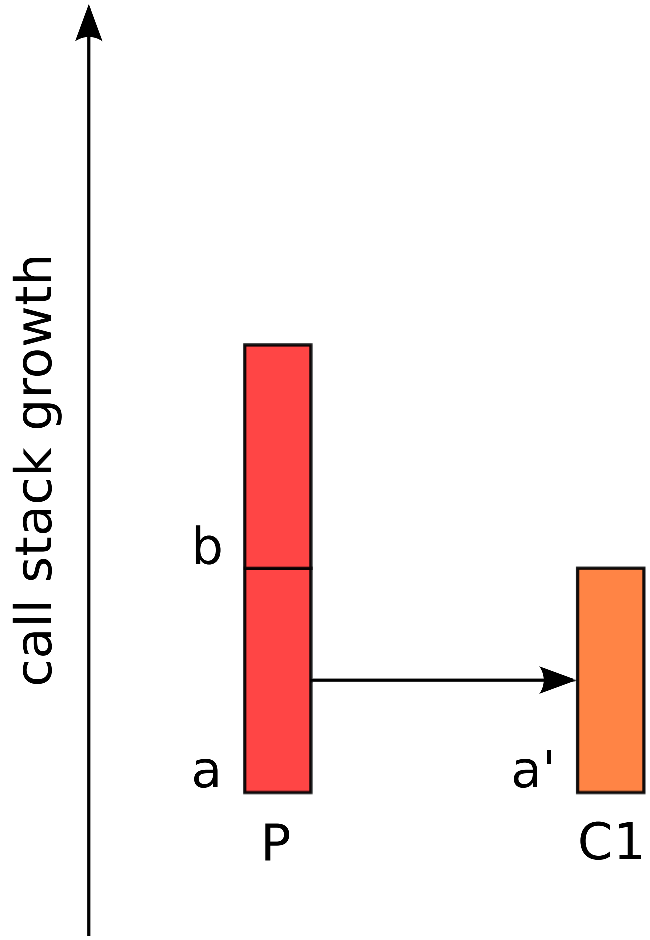

In-Order Nesting

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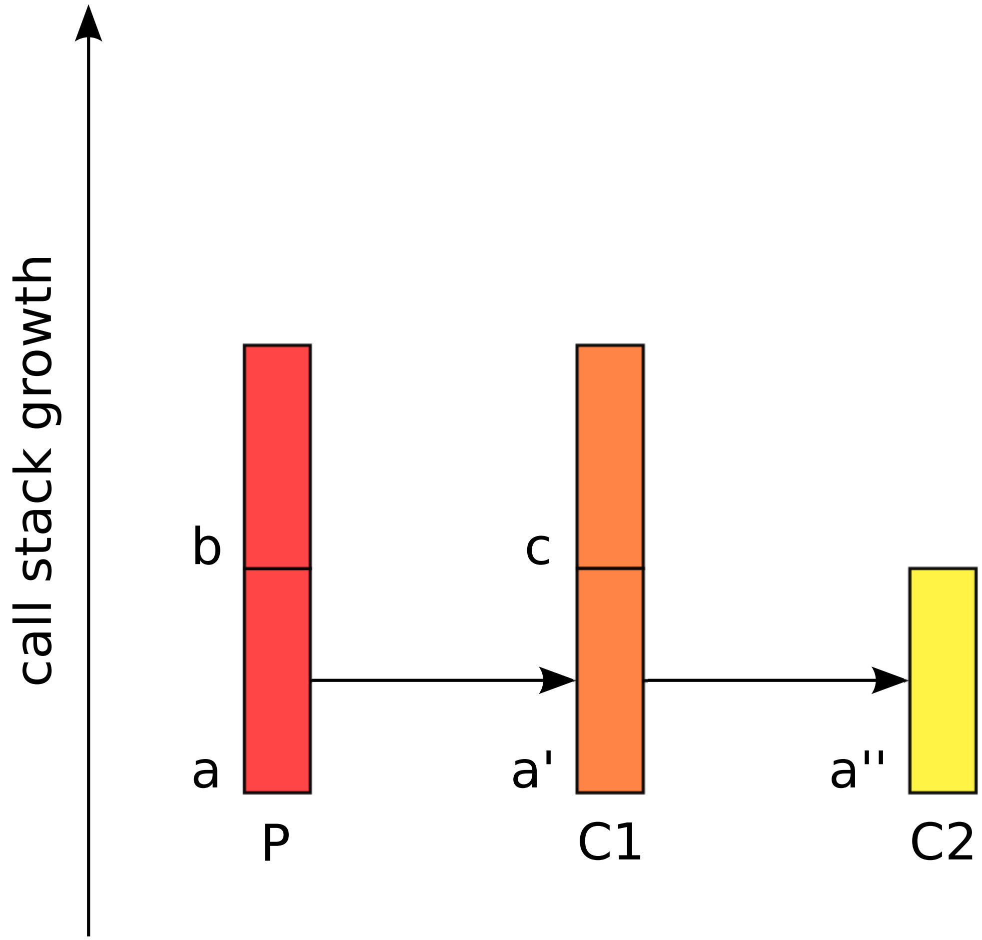
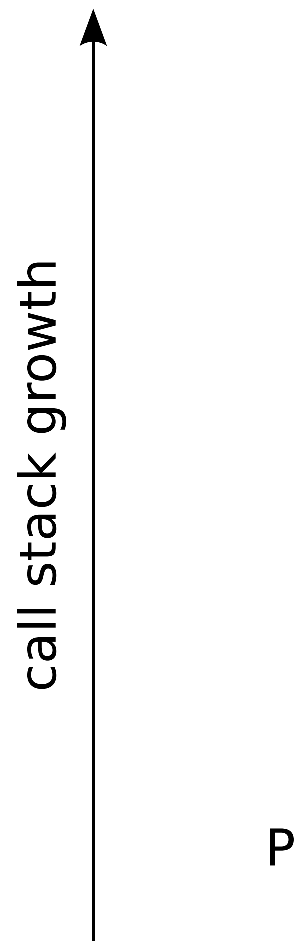


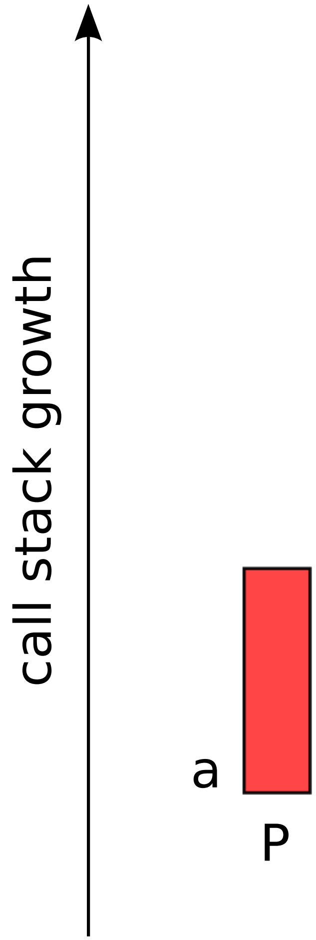
Mixed Nesting

```
A(){
  a;
  B(){
    b;
    C(){
      c;
    }
    b';
    D(){
      d;
    }
    b'';
  }
  a';
}
```



Mixed Nesting

```
A(){
  a;
  B(){
    b;
    C(){
      c;
    }
    b';
    D(){
      d;
    }
    b'';
  }
  a';
}
```



Mixed Nesting

```
A(){
   a;
   B(){
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      C(){
         c;
      }
      b';
      D(){
         d;
      }
      b'';
   }
   a';
}
```

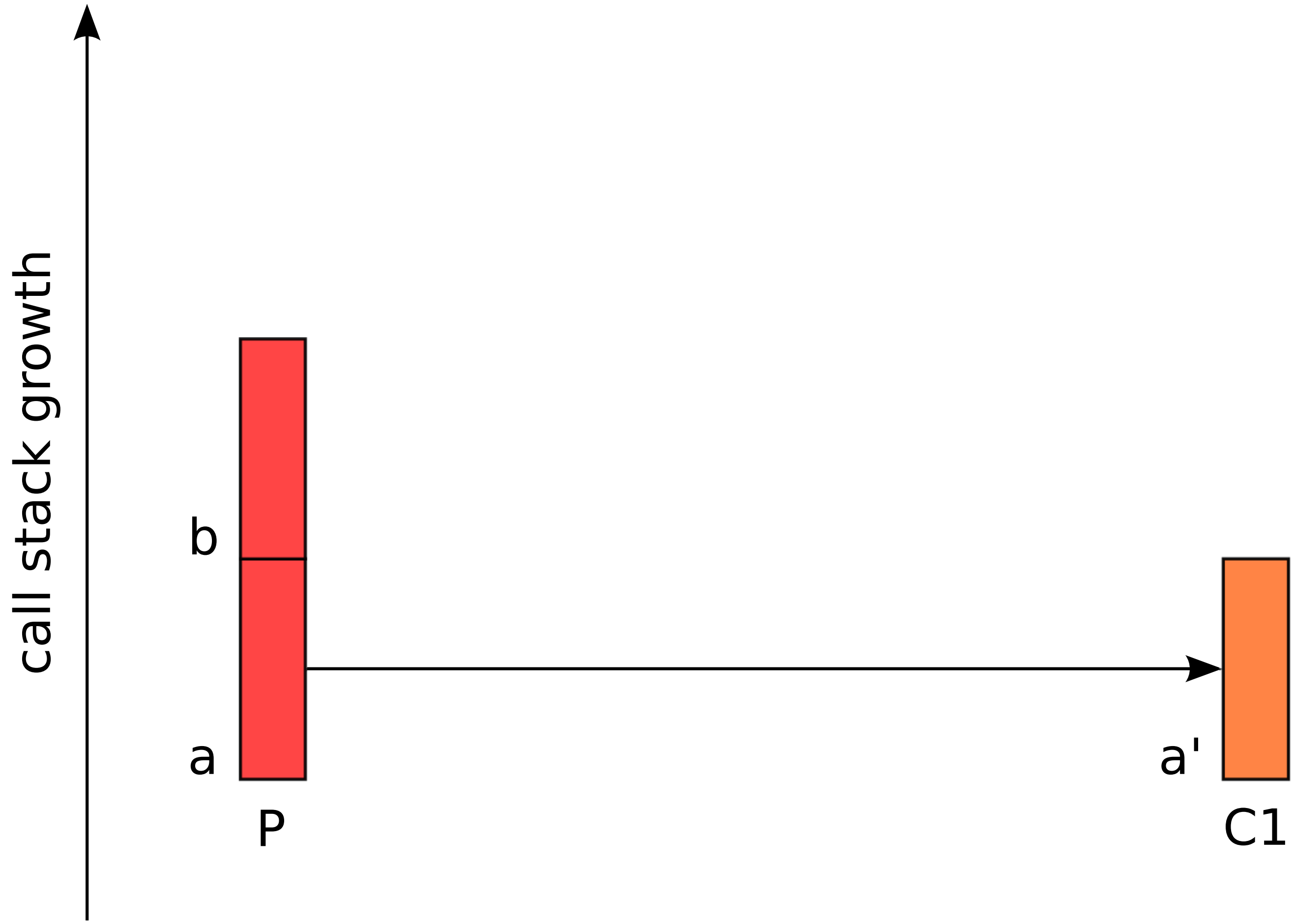

Mixed Nesting

```
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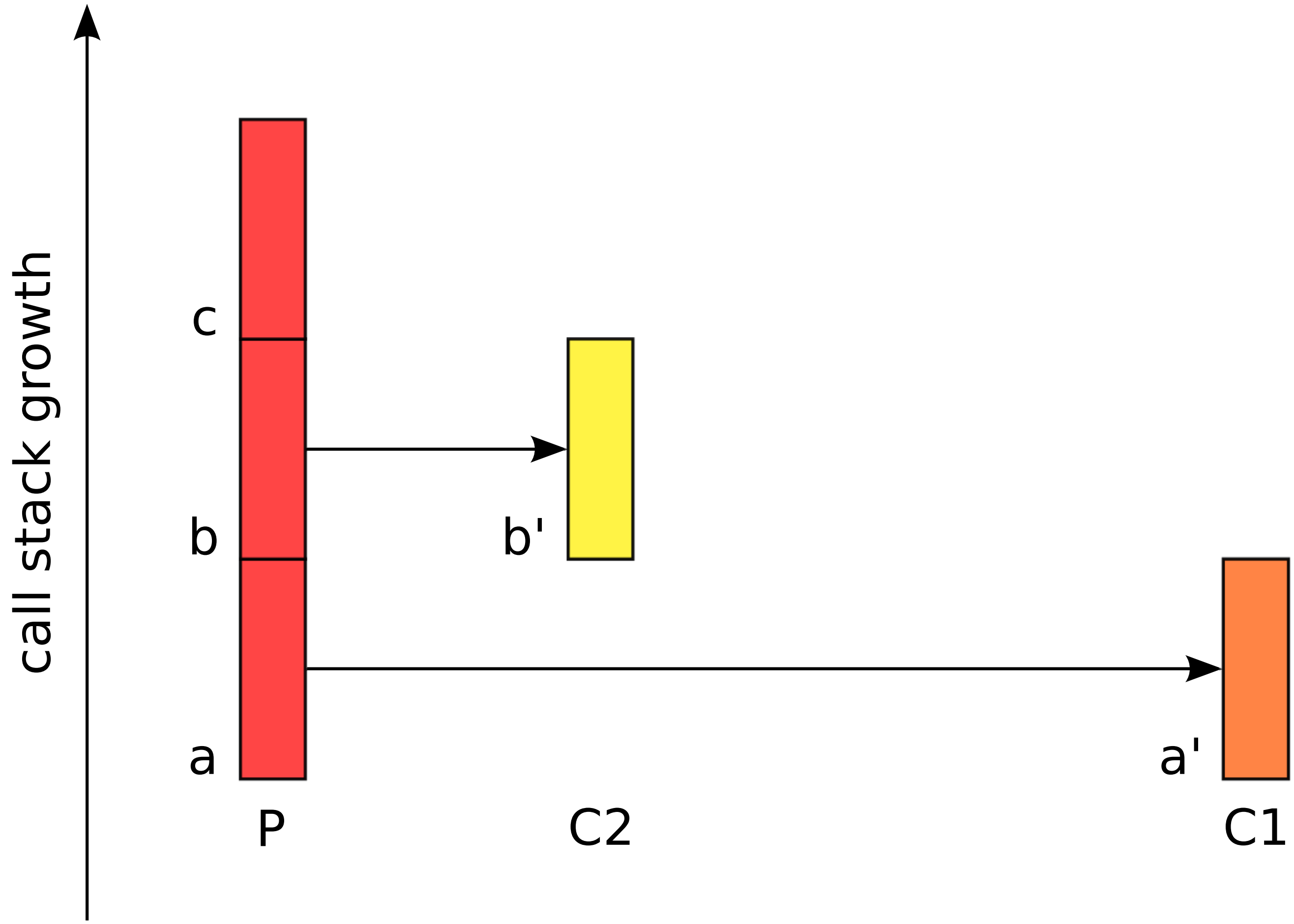

Mixed Nesting

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      d;
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  }
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```
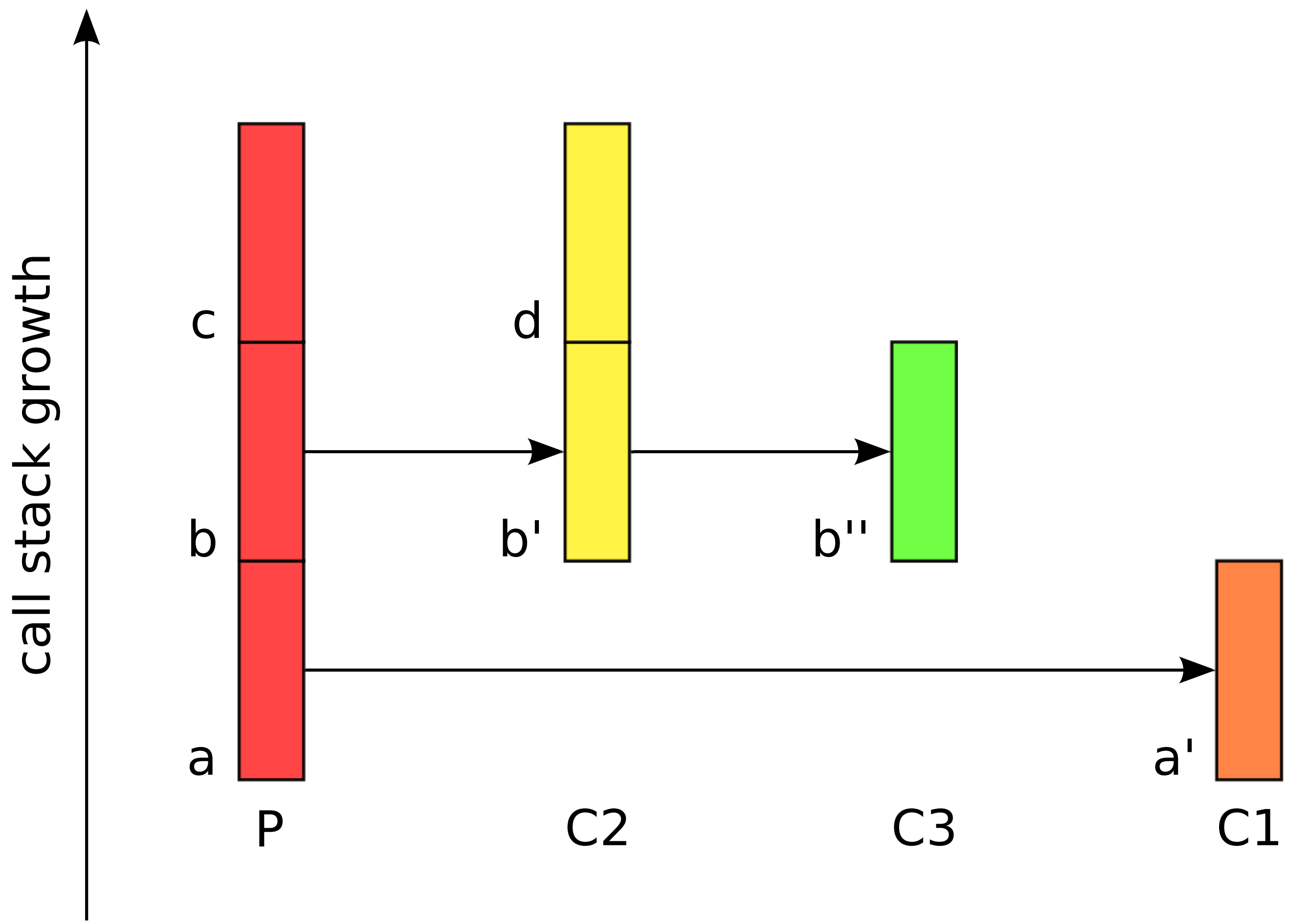
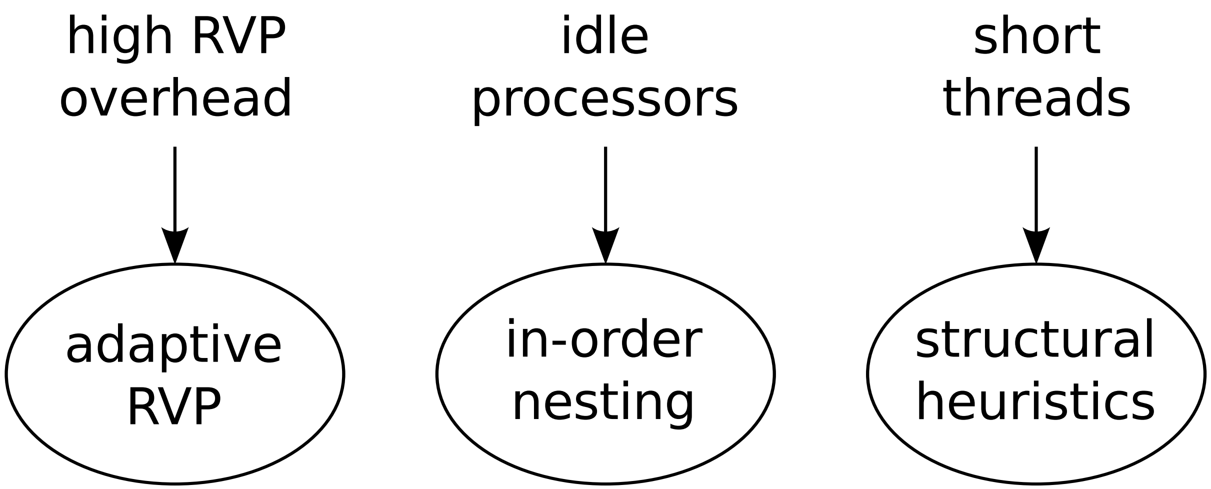



Optimization



Structural Fork Heuristics

```
tail (i, n) {
  work (i);
  if (i < n)
    tail (i + 1, n);
}
```

```
iterate (n) {
  for (i = 1; i <= n; i++)
    work (i);
}
```

```
head (i, n) {
  if (i < n)
    head (i + 1, n);
  work (i);
}
```

```
tree (node *n) {
  if (!leaf (n)) {
    tree (n->left);
    tree (n->right);
  }
  work (n);
}
```

Structural Fork Heuristics

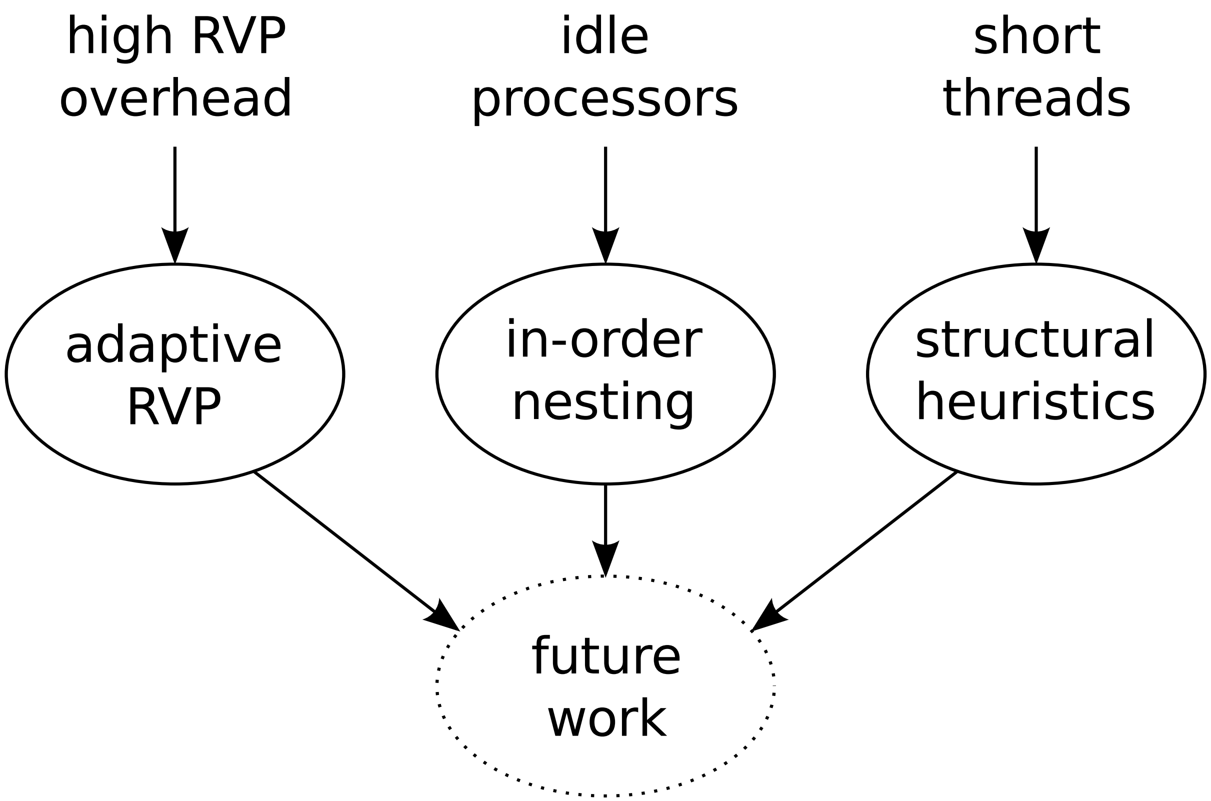
```
// in-order nesting
tail (i, n) {
  spec work (i);
  if (i < n)
    tail (i + 1, n);
}
```

```
// in-order nesting
iterate (n) {
  for (i = 1; i <= n; i++)
    spec work (i);
}
```

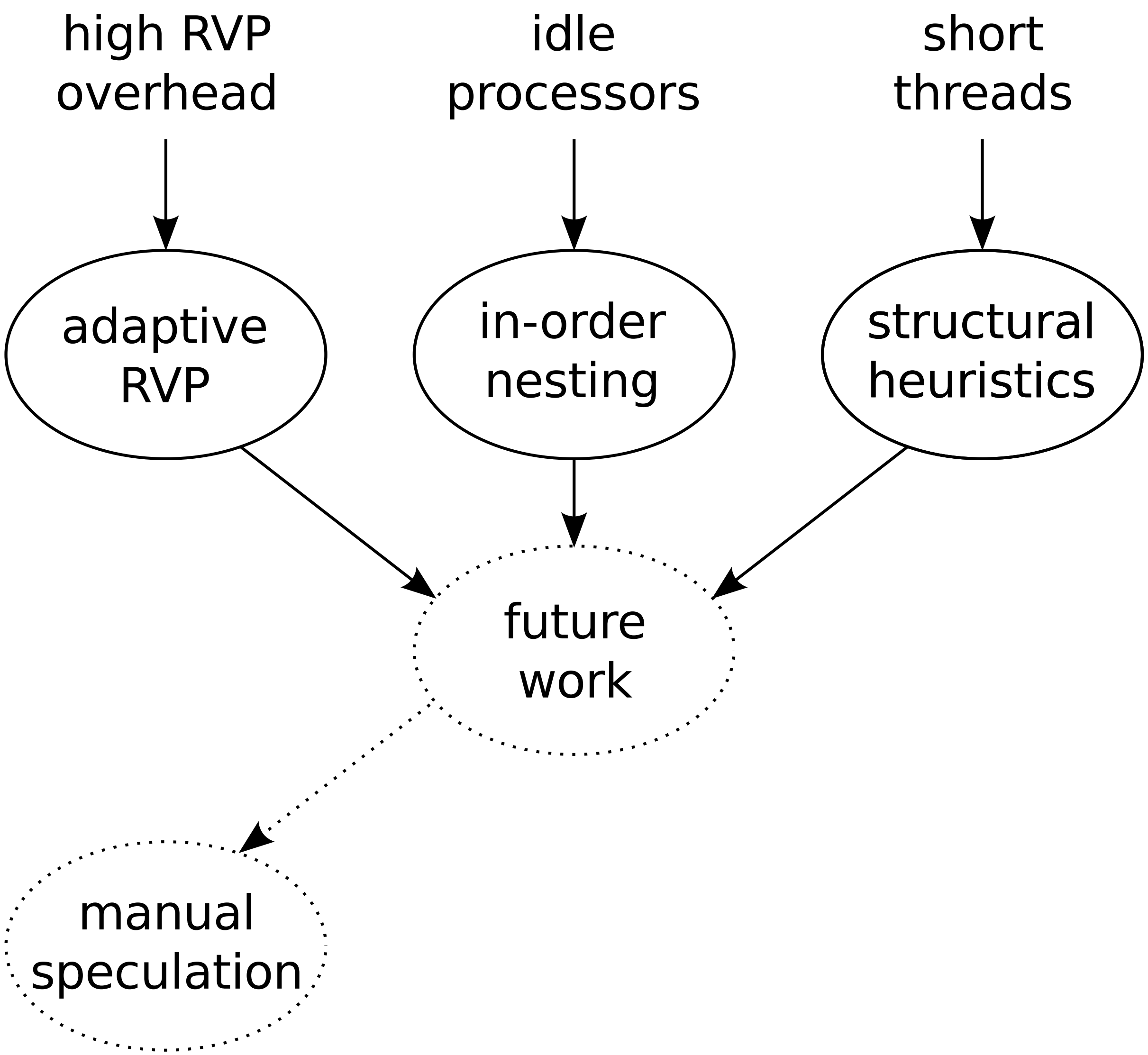
```
// out-of-order nesting
head (i, n) {
  if (i < n)
    spec head (i + 1, n);
  work (i);
}
```

```
// mixed nesting
tree (node *n) {
  if (!leaf (n)) {
    spec tree (n->left);
    spec tree (n->right);
  }
  work (n);
}
```

Future Work


high RVP overhead
idle processors
short threads
adaptive RVP
in-order nesting
structural heuristics
future work

Future Work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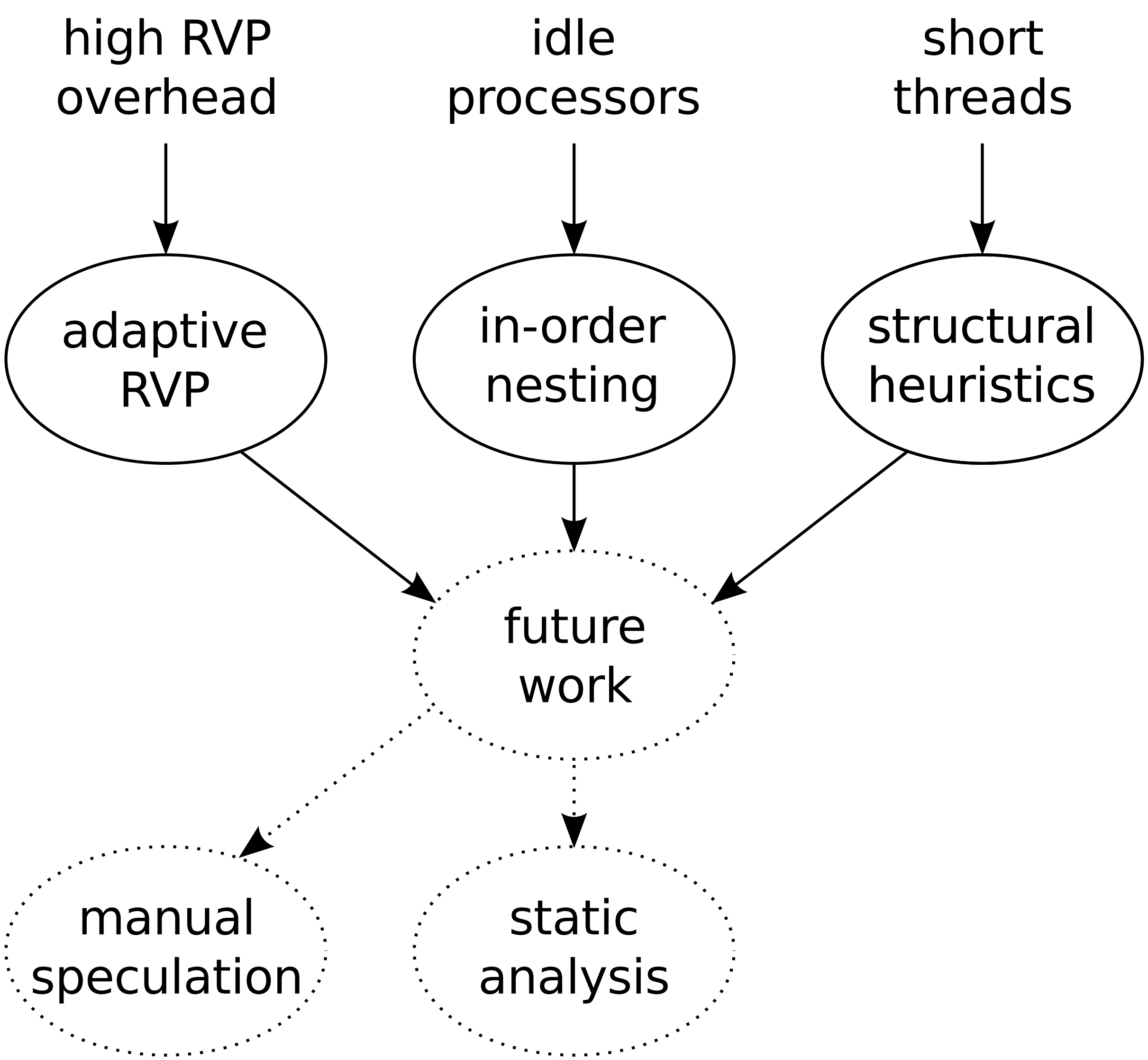
manual speculation

Future Work



high RVP overhead
idle processors
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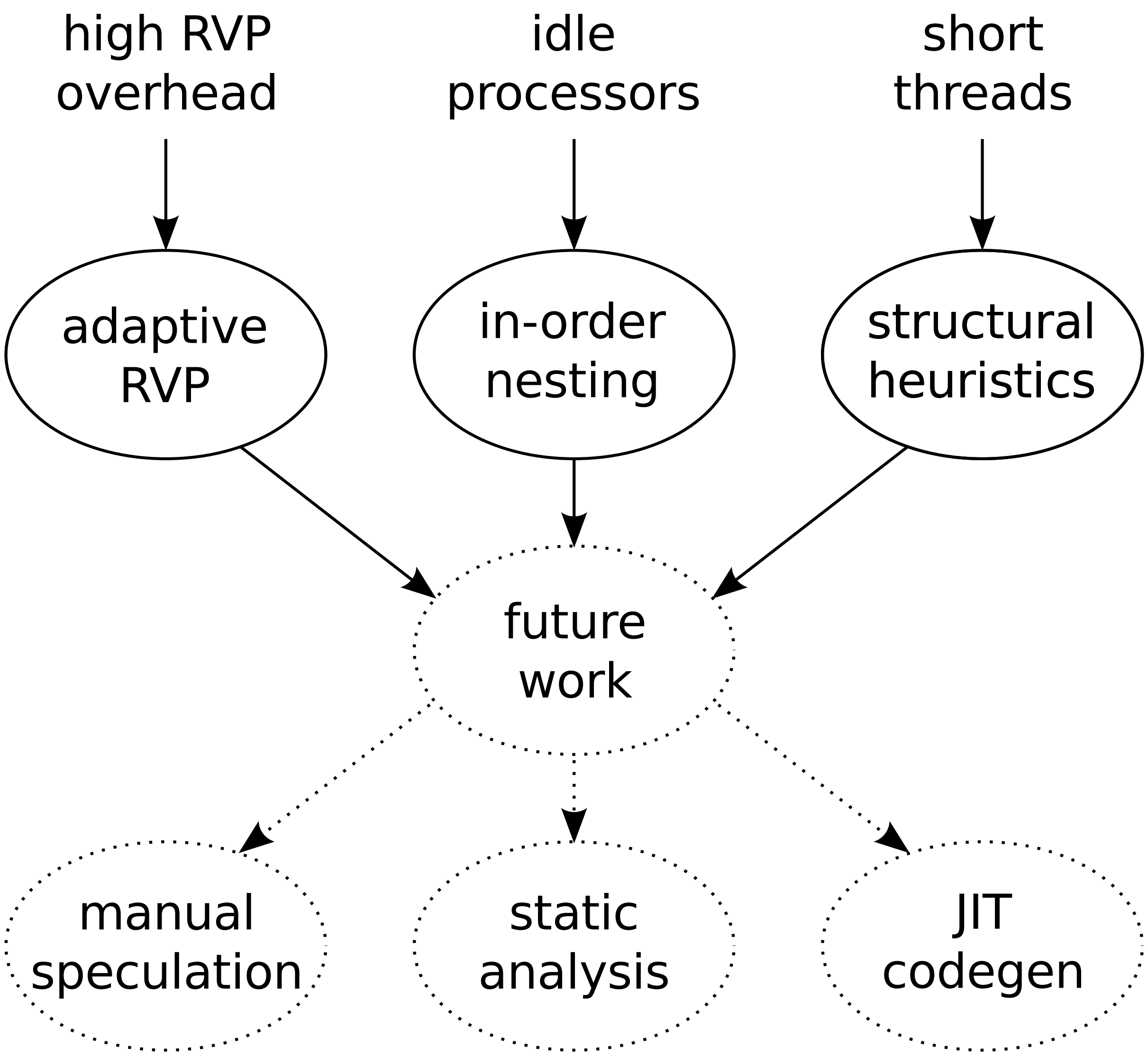
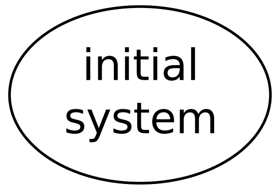
in-order nesting
structural heuristics
future work
manual speculation
static analysis

Future Work


high RVP overhead
idle processors
short threads
adaptive RVP
in-order nesting
structural heuristics
future work
manual speculation
static analysis
JIT codegen

Conclusions

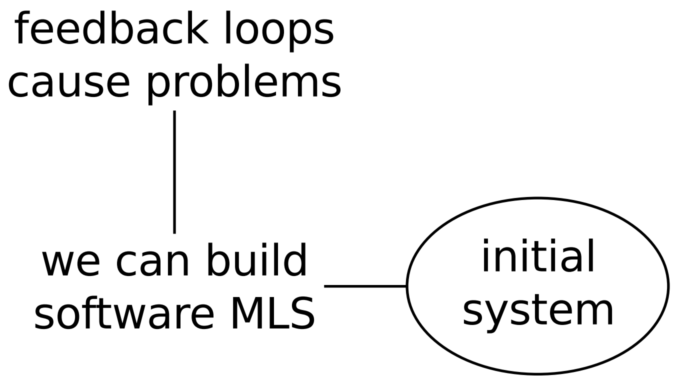


Conclusions

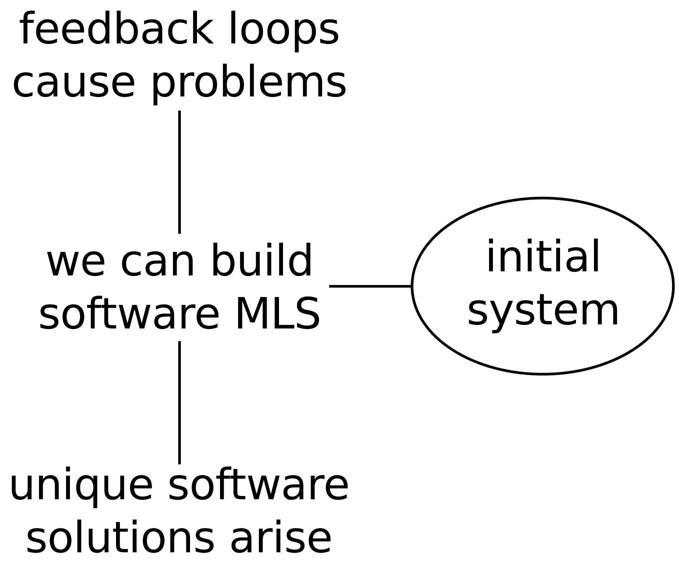
we can build software MLS

initial system

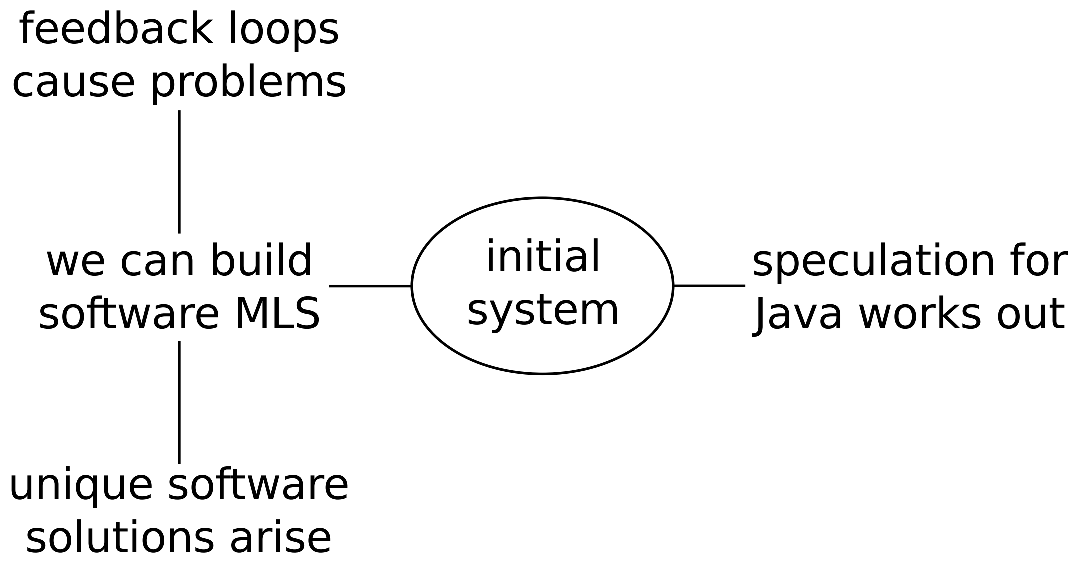
Conclusions



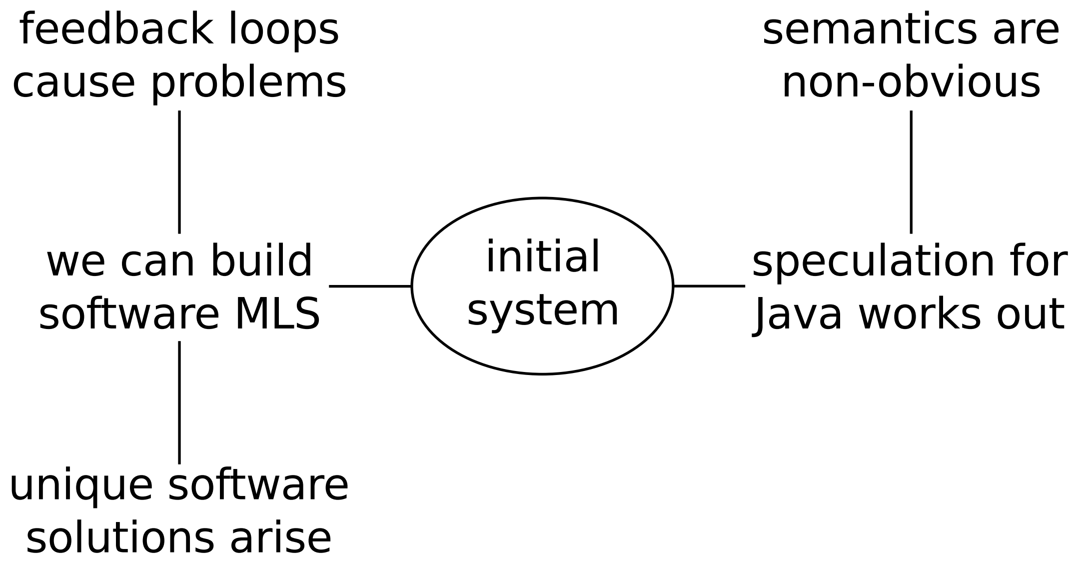
Conclusions



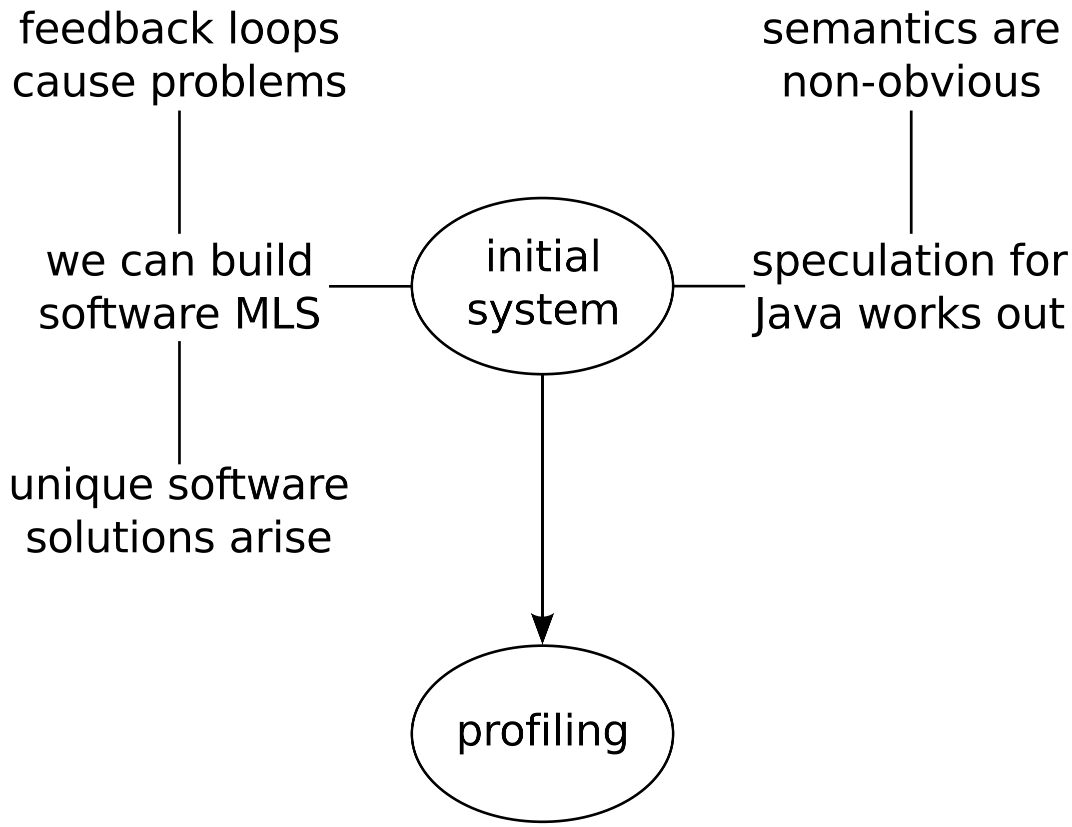
Conclusions



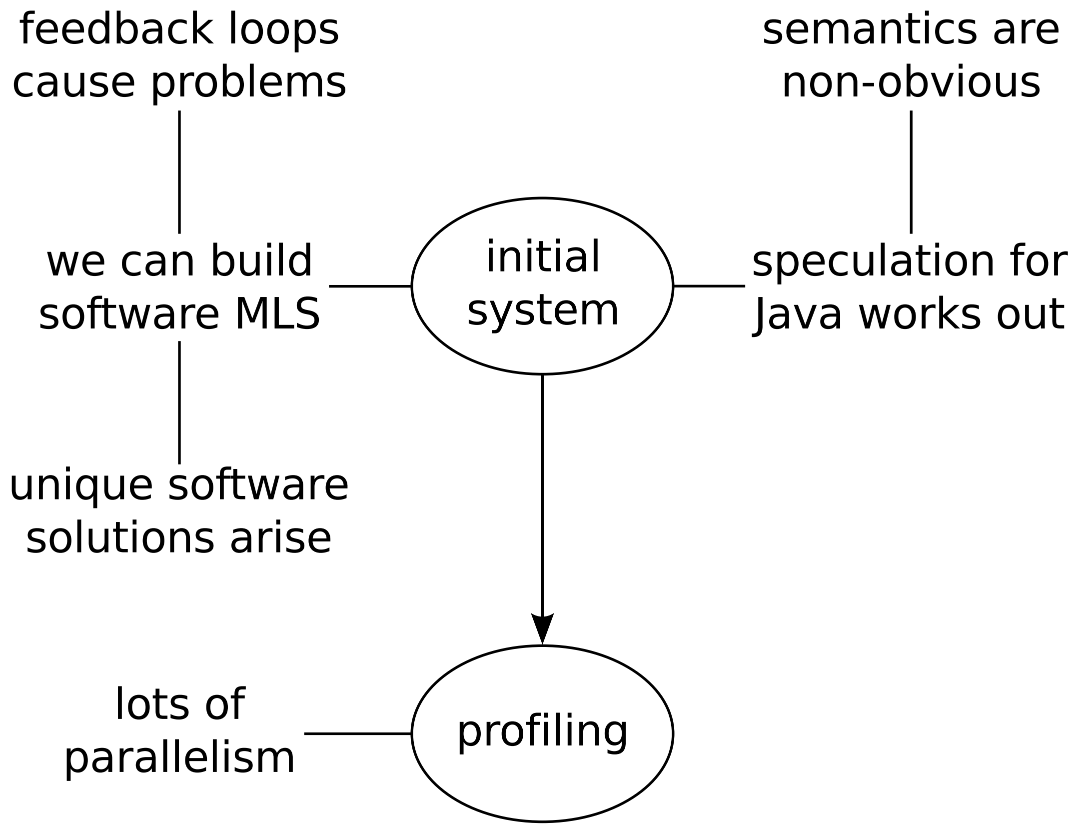
Conclusions



Conclusions



Conclusions



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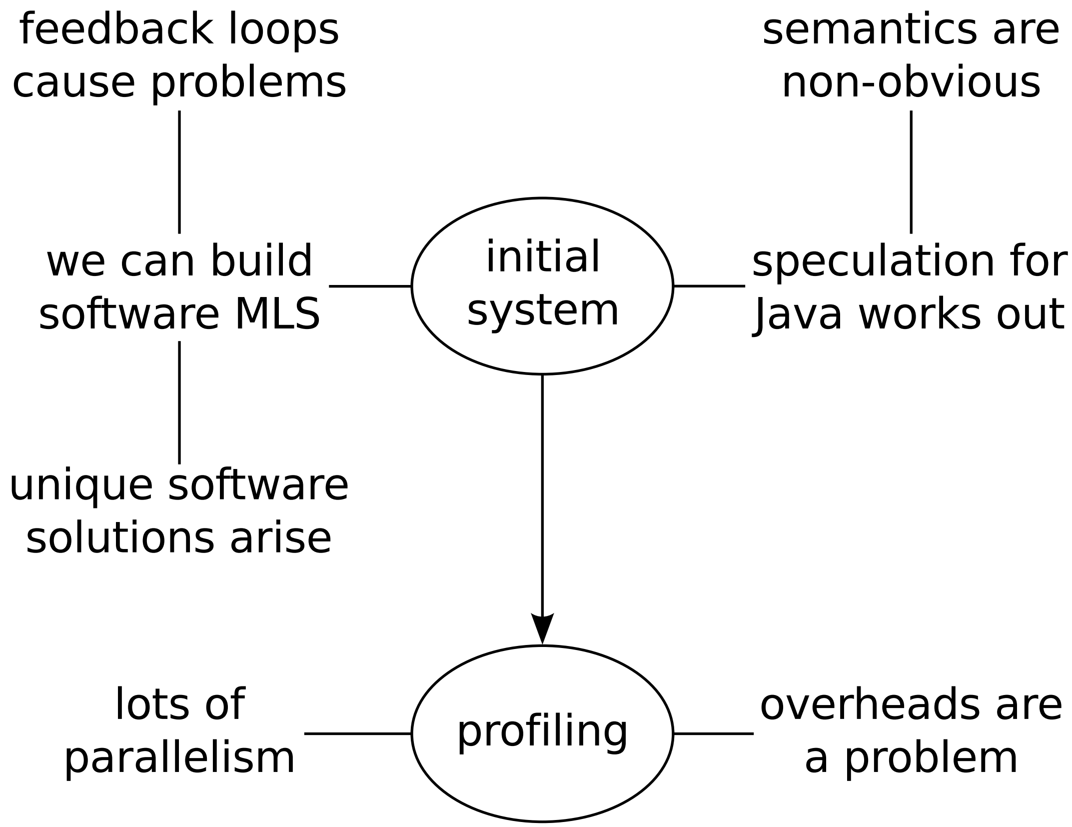
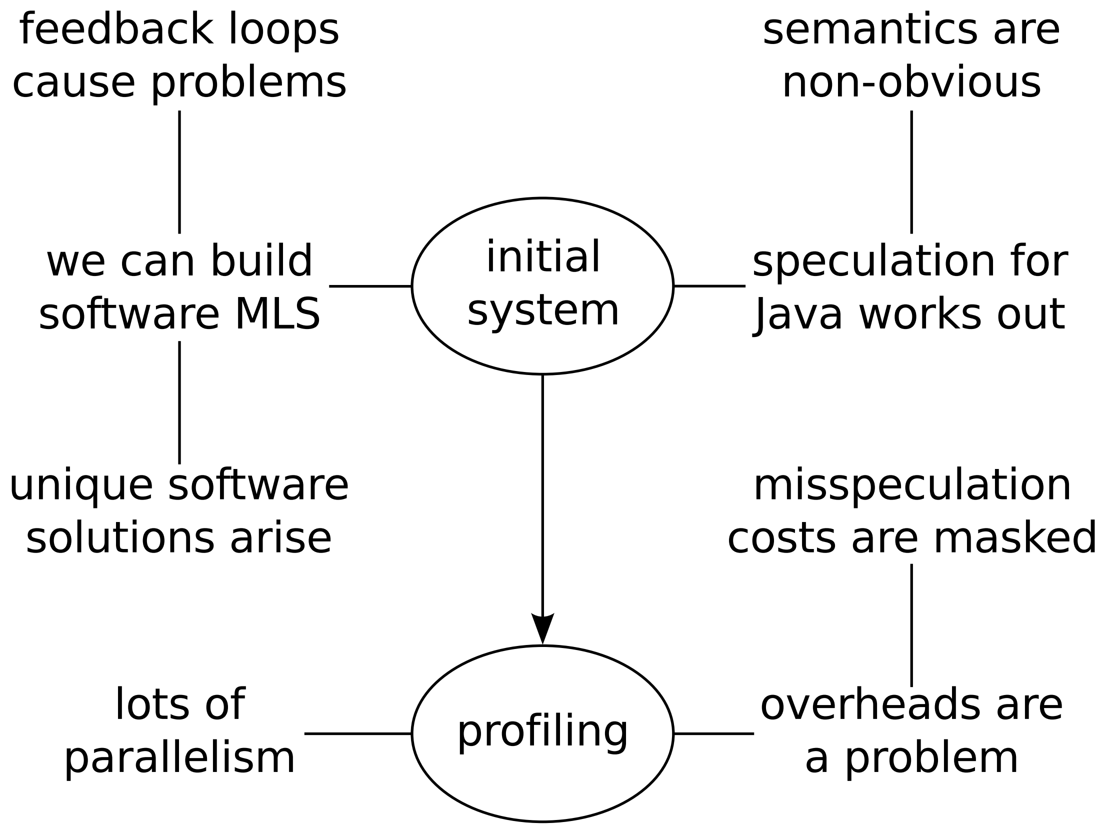
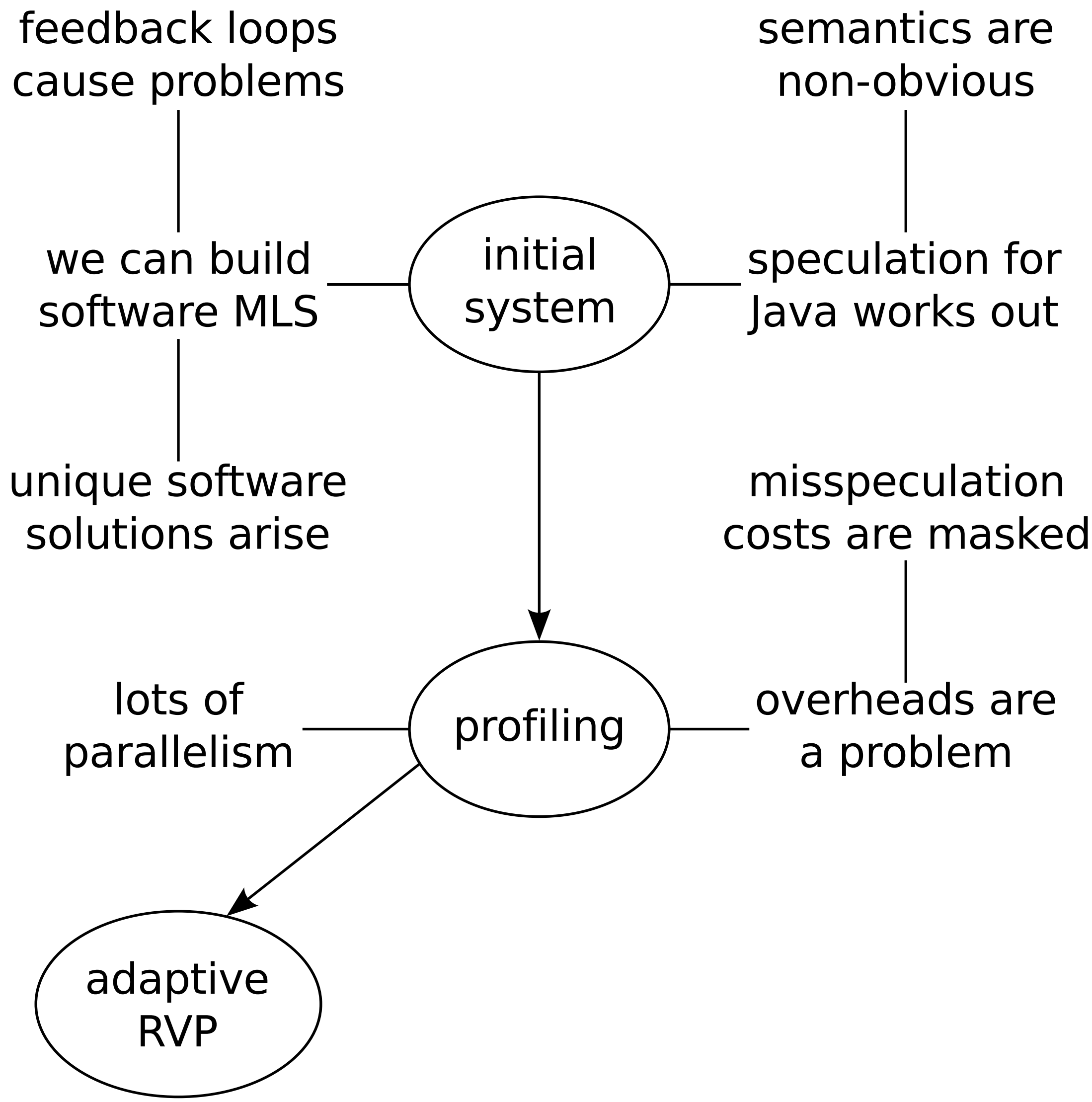


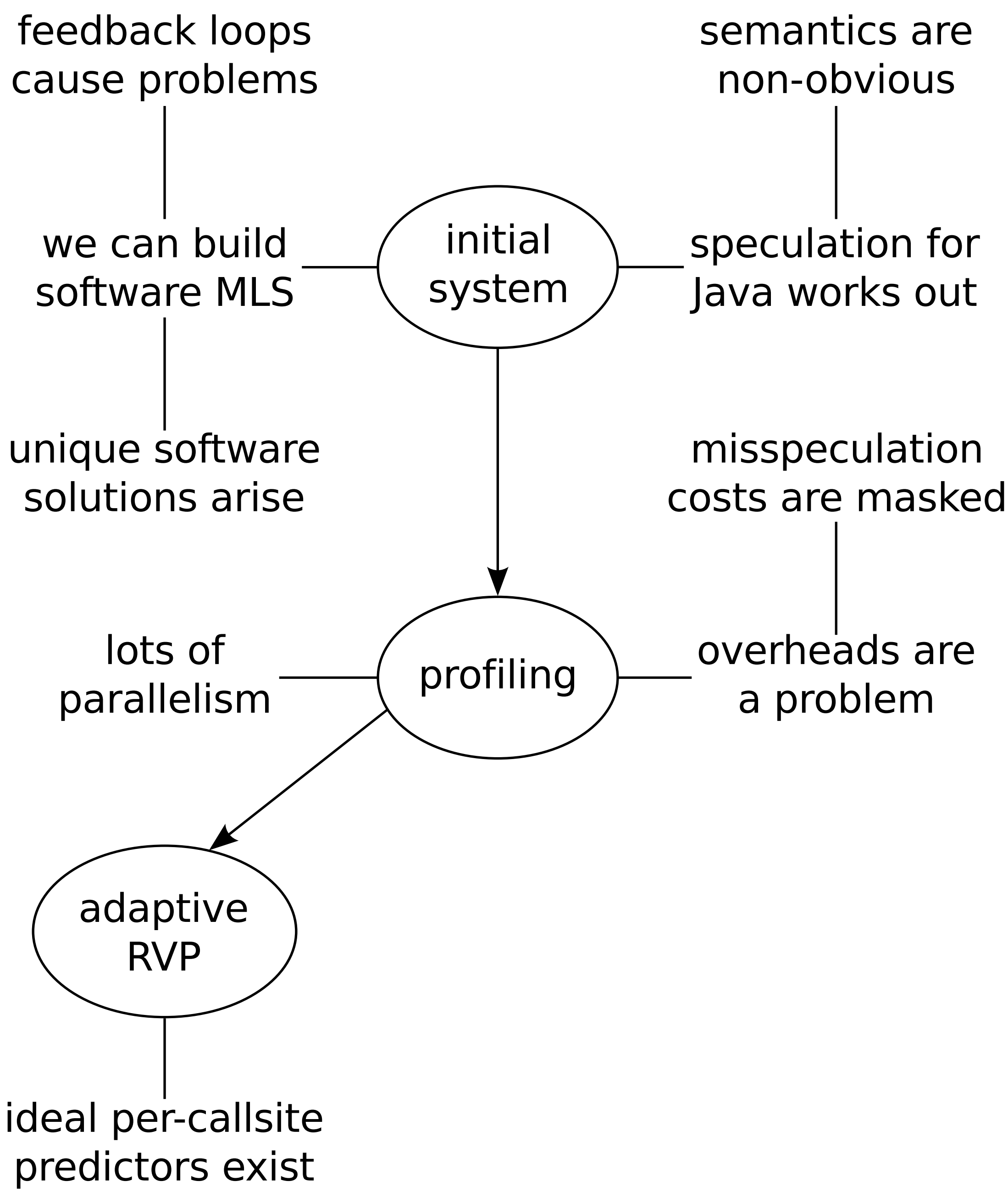
Conclusions



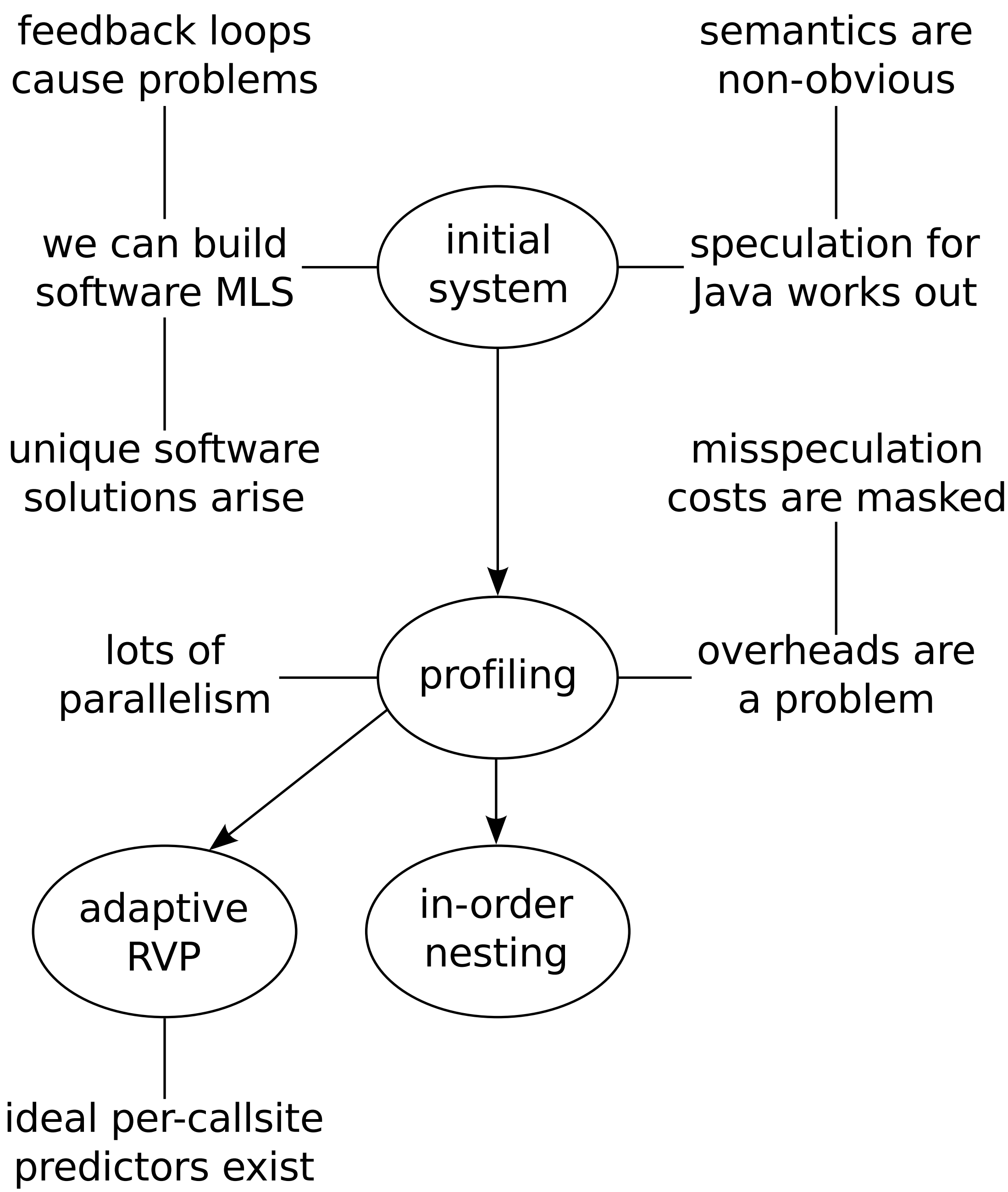
Conclusions



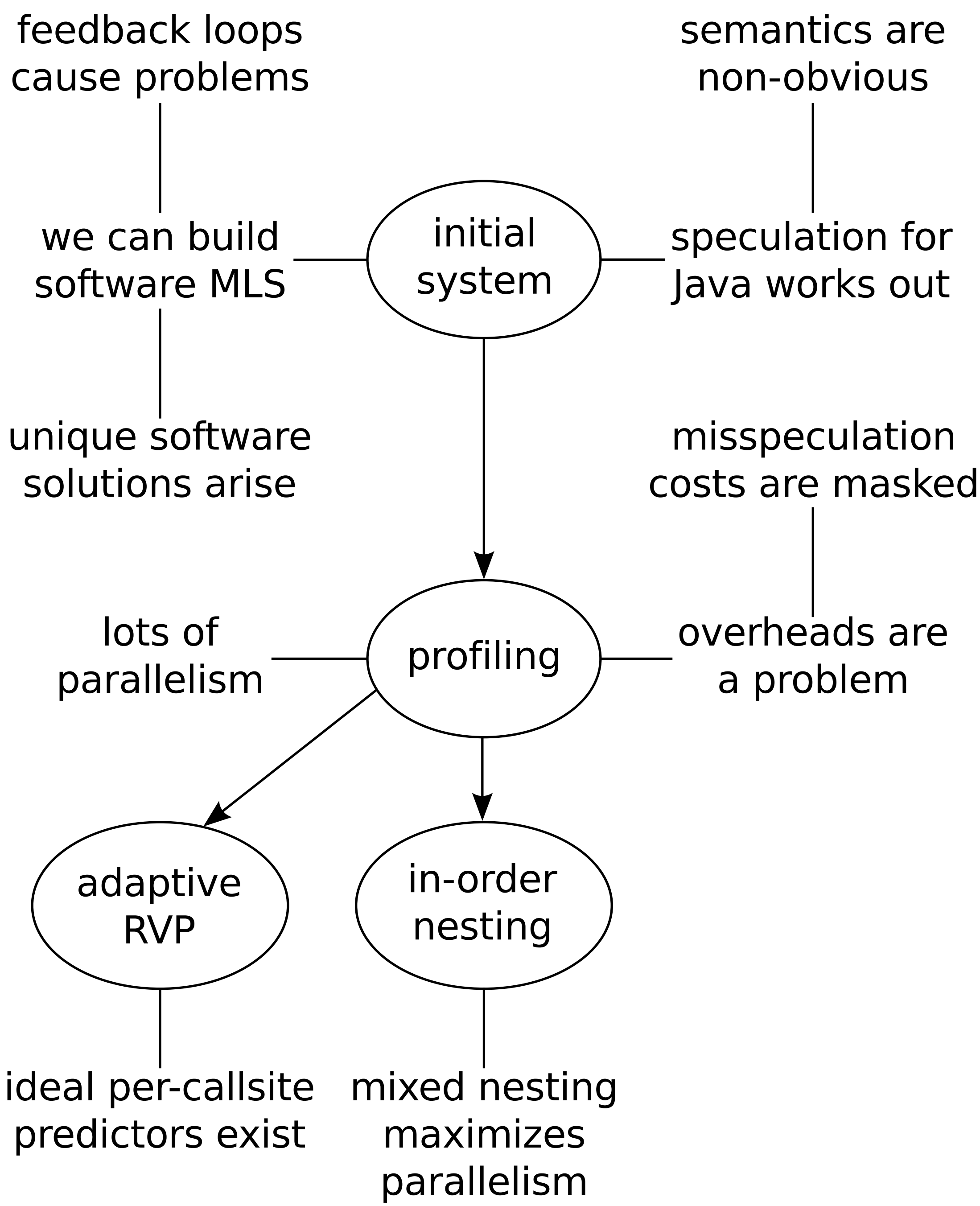
Conclusions



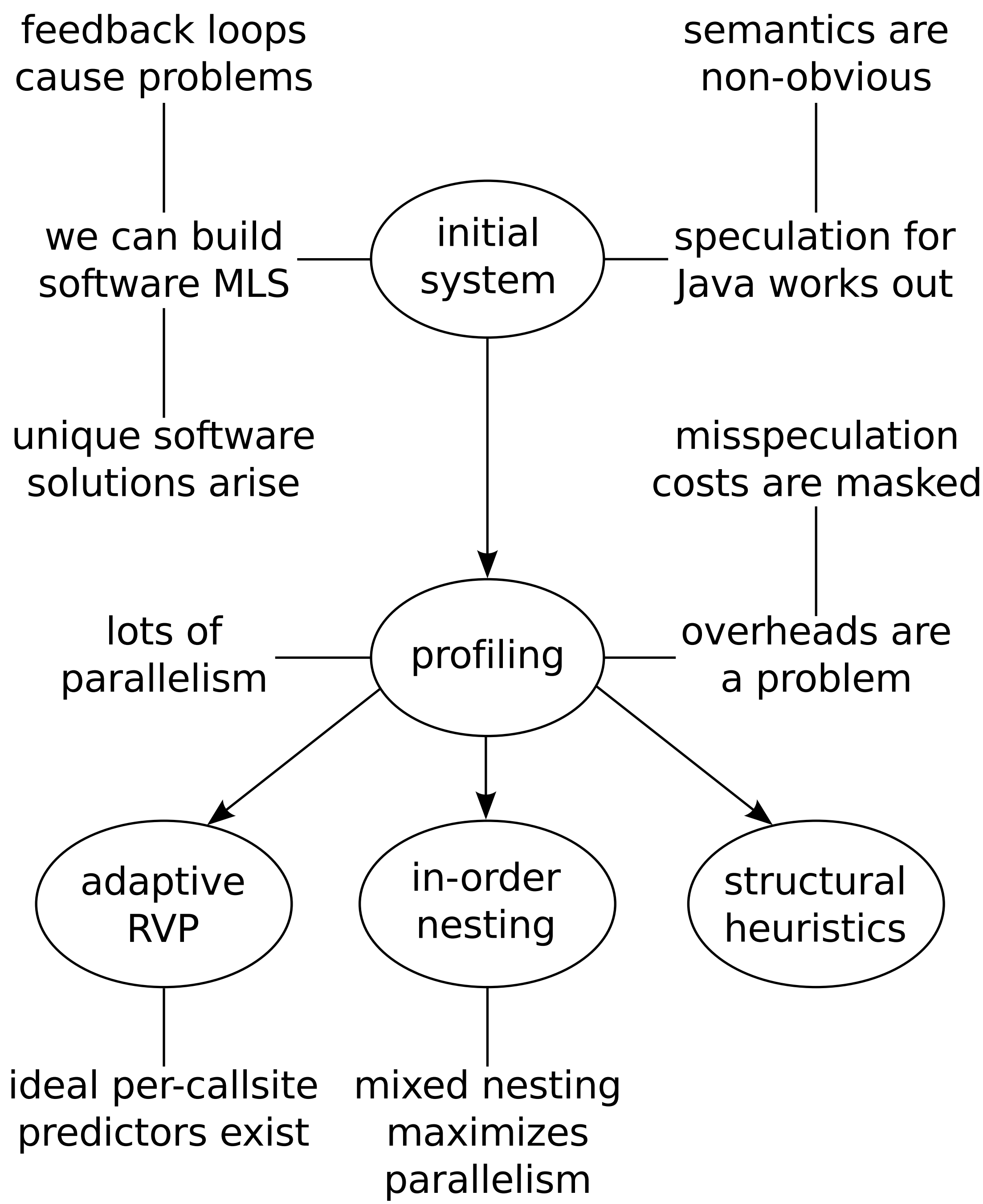
Conclusions



Conclusions



Conclusions



Conclusions