Konzepte objektorientierter Programmierung

Prof. Dr. Peter Müller
Werner Dietl
Software Component Technology

Exercises 14: Specification

Wintersemester 06/07

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

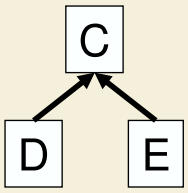
Abstract Interpretation Algorithm

- Abstract interpretation is a fixpoint iteration

```
in( 0 ) := ( [ ] , [ P0,...,Pn,T,...,T ] )
worklist := { i | instri is an instruction of the method }
while worklist ≠ ∅ do
  i := min( worklist )
  remove i from worklist
  out( i ) = apply_rule( instri )
  forall q in successors( i ) do
    in( q ) := pointwise_scs( in( q ),out( i ) )
    if in( q ) has changed then worklist := worklist ∪ { q }
  end
end
```

Abstract Interpretation Example

```
0: aload 0
1: astore 2
2: aload 1
3: goto 1
```



worklist

	in	out
0:	([ ] , [D,E,T])	([D] , [D,E,T])
1:	([D] , [D,E,T]) ([C] , [D,E,T]) ([C] , [D,E,T])	([ ] , [D,E,D]) ([ ] , [D,E,C])
2:	([ ] , [D,E,D]) ([ ] , [D,E,C])	([E] , [D,E,D]) ([E] , [D,E,C])
3:	([E] , [D,E,D]) ([E] , [D,E,C])	([E] , [D,E,D]) ([E] , [D,E,C])

Exercise 1: Singly-linked List

```
class List {
  int i;
  List next;

  // invariant next != null  =>  i == next.i

  // increment i in the whole list
  void inc() {
   …
  }
}
```

Specification of Method inc

```
// ensures ∀n reachable(this, n):
//                 old(n.i) + 1 == n.i
void inc() { … }
```

- The method reachable returns true, iff the second node can be reached from the first node
- After executing the method the old value of the element incremented by one equals the new value of the element

Proof-Obligations for inc

- Proof postcondition fulfilled:
  $\{ P \wedge \forall S: INV_S \}$ inc() $\{ Q \}$
- Proof invariant still fulfilled:
  $\{ P \wedge \forall S: INV_S \}$ inc() $\{ INV_{List} \}$
- The method inc has true as precondition
- The postcondition is shown on the last slide
- The invariant for the class was given

Proof-Obligations for inc

{ $\forall$S: INV_S }
  inc()
{ $\forall$n reachable(this, n): old(n.i) + 1 == n.i}

{ $\forall$S: INV_S }
  inc()
{ $\forall$x: allocated(x) && type(x) <: List
  => (x.next != null => x.i == x.next.i) }

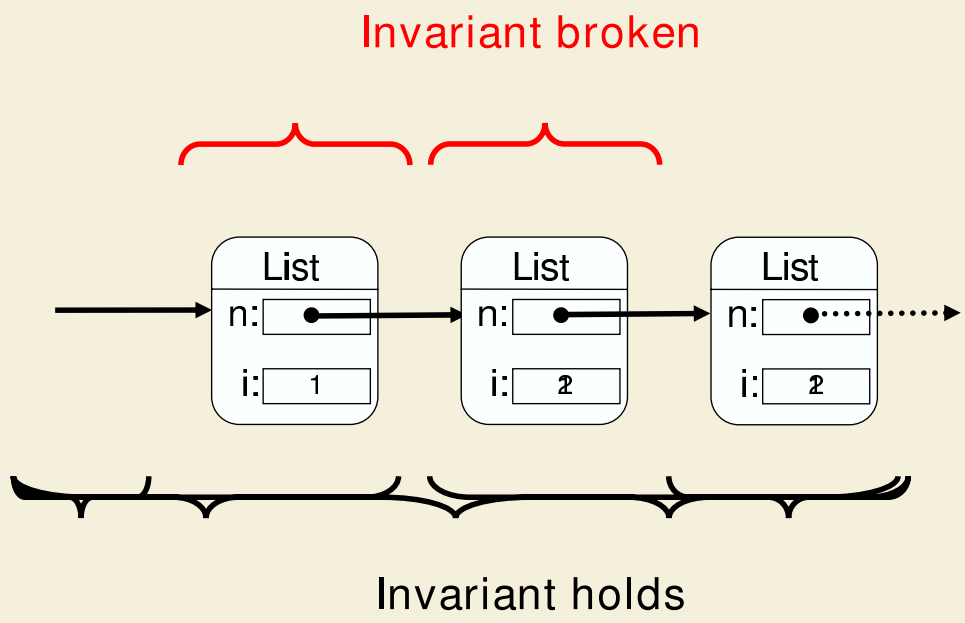
Recursive Implementation of inc

```
void inc() {
  ++i;
  if( next != null ) next.inc();
}
```

or

```
void inc() {
  if( next != null ) next.inc();
  ++i;
}
```

Are the Proof-Obligations fulfilled?



Alternative Implementation 1

- Iterate over the list:

```
void inc() {
  List n = this;

  while( n != null ) {
  ++n.i;
  n = n.next;
  }
}
```

Alternative Implementation 2

- Declare a private helper method `inc2` and allow it to break the invariant

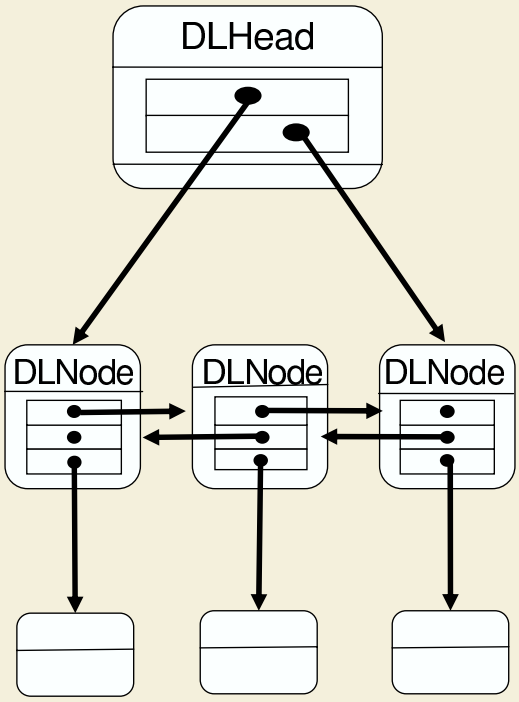
```
public void inc() {
  inc2();
}

// helper
private void inc2() {
 if( next != null ) next.inc2();
 ++i;
}
```

Exercise 2: Doubly-linked List

```
public class DLHead {
  private class DLNode {
    DLNode prev;
    DLNode next;
    Object elem;
  }
  private DLNode first;
  private DLNode last;
  …
```

What we want:



Invariant 1: I'm my successor's predecessor

```
private class DLNode {
   // invariant this.next != null =>
   //              this.next.prev == this
   …
```

- But is this enough?
- ➔ No, `prev` could link into another List

Invariant 2: I'm my predecessor's successor

```
private class DLNode {
   // invariant this.next != null =>
   //           this.next.prev == this
   // invariant this.prev != null =>
   //           this.prev.next == this
   …
```

- Is this enough now?
- ➔ No, we could have a circular list

Invariant 3: first / last come / go nowhere

```
public class DLHead {
  private DLNode first;
  private DLNode last;

  // invariant first != null =>
  //       first.prev == null
  // invariant last != null =>
  //       last.next == null
  ...
```

- ➔ No, we could have two independent lists

Invariant 4: first and last use same list 1

```
public class DLHead {
  private DLNode first;
  private DLNode last;

  // invariant first != null =>
  //       first.next* == last
  // or:
  // invariant last != null =>
  //       last.prev* == first
  …
```

Invariant 4: first and last use same list 2

```
public class DLHead {
  private DLNode first;
  private DLNode last;

  // invariant reach( first, last )

  boolean reach(DLNode from, DLNode to)
  { … }
```

Using dummy-nodes

- Both the specification and implementation get simpler by always having a dummy first and last element
- These elements are always there and do not contain any data
- Example:

```
// invariant first.prev == null
// invariant last.next == null
```

Marrying a Man and a Woman

```
public class Man {
  private Woman wife;

  // invariant wife != null =>
  //   wife.getHusband() == this

  public boolean isMarried() {
    return wife != null;
  }
  …
```

Marrying a Man and a Woman

```
public class Woman {
  private Man husband;

  // invariant husband != null =>
  //   husband.getWife() == this

  public boolean isMarried() {
    return husband != null;
  }
  …
```

First Version

```
// Get married to 'w'
// require w != null && !w.isMarried()
// ensure isMarried() && wife == w
public void marry1( Woman w ) {
  wife = w;
  w.marry1( this );
}
```

- Doesn't work: call w.marry1 violates precondition

Second Version

```
// Get married to 'w'
// require w != null && !w.isMarried()
// ensure isMarried() && wife == w
public void marry2( Woman w ) {
  w.marry2( this );
  wife = w;
}
```

- Doesn't work: Infinite recursion

Third Version

```
// Get married to 'w'
// require w != null && !w.isMarried()
// ensure isMarried() && wife == w
public void marry3( Woman w ) {
  w.setHusband( this );
  wife = w;
}
// helper
void setWife(Woman w){ wife = w; }
```

Exam

- Thursday March 8th, from 15:00 until 16:30 in ETA F 5.
- "Questions and Answers" session: Thursday March 1st, starting at 14:00 in IFW A 32.1
- Bring all your questions!

Questions?