CSE 331
Software Design & Implementation

Kevin Zatloukal

Spring 2021

ADT Implementation: Abstraction Functions

Specifying an ADT

Different types of methods:

1. **`creators`**
2. **`observers`**
3. **`producers`**
4. **`mutators`** (if mutable)

Described in terms of how they change the **abstract state**

- abstract description of what the object means
- specs have no information about concrete representation
  - leaves us free to change those in the future

IntSet, a mutable data type

```
// Overview: An IntSet is a mutable,
// unbounded set of integers.  A typical
// IntSet is { x1, ..., xn }.
class IntSet {
```

(Note: Javadoc is highly simplified...)

IntSet: mutators

```
// modifies: this
// effects:  this = this U {x}
public void add(int x)

// modifies: this
// effects:  this = this - {x}
public void remove(int x)
```

Specifications written in terms of how the **abstract state** changes

Useful Building Blocks for Abstract States

Some useful “math” concepts for describing states abstractly

- numbers
- characters
- lists
- sets
- tuples (fixed length)
- objects
  - parts are named, not numbered (as in tuples)
  - e.g. {chars: “protected”, color: 3}

Implementing a Data Abstraction (ADT)

To implement an ADT:

- select the representation of instances
- implement operations using the chosen representation

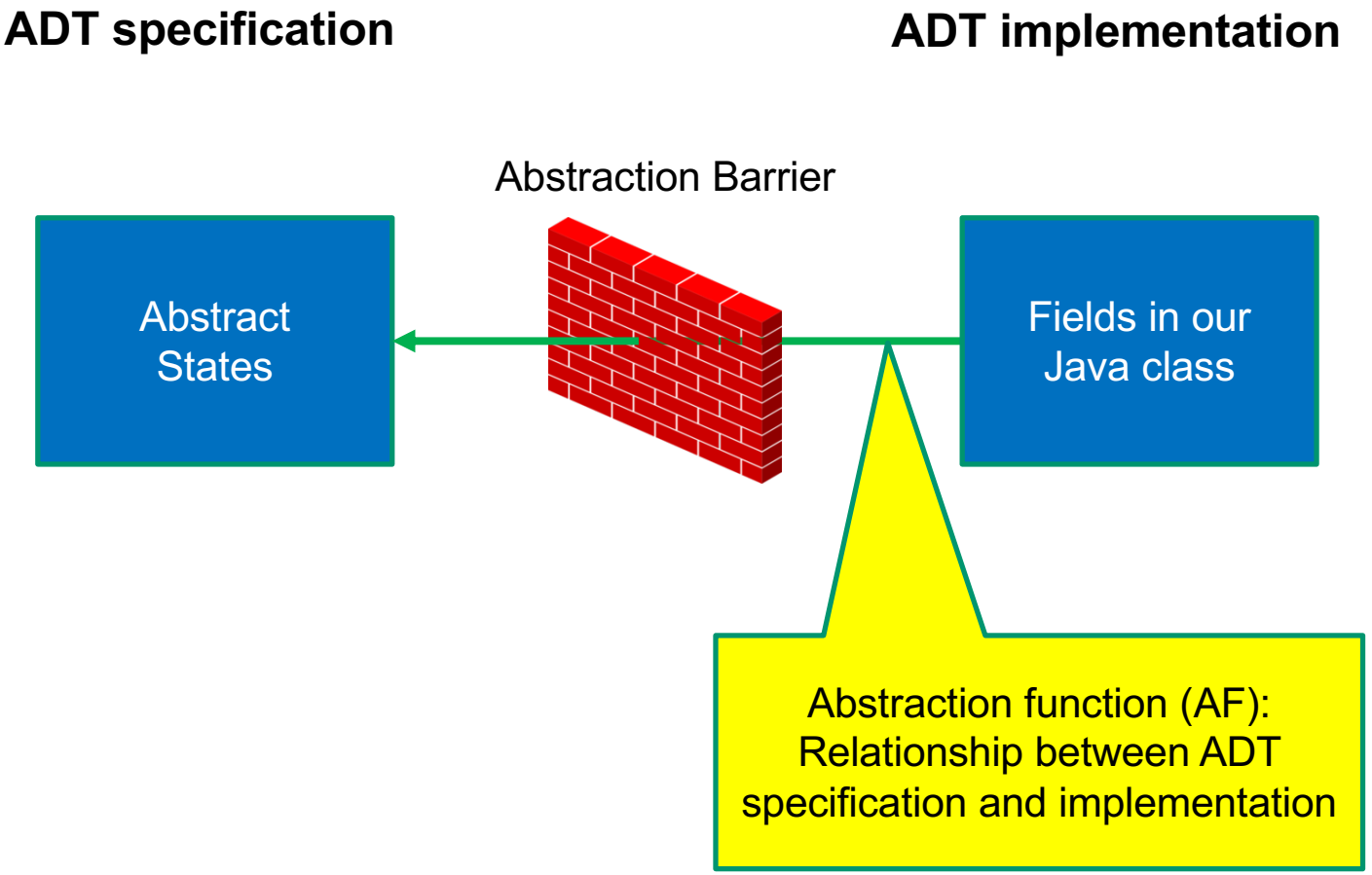
Choose a representation so that:

- it is possible to implement required operations
- the most frequently used operations are efficient / simple / …
  - abstraction allows the rep to change later
  - almost always better to start simple

Use **reasoning** to verify the operations are correct

- specs are written in terms of *abstract states* not *actual fields*
- two intellectual tools are helpful for this...

Data abstraction outline



Connecting implementations to specs

For implementers / debuggers / maintainers of the implementation:

Abstraction Function: maps Object → abstract state

- says what the data structure *means* in vocabulary of the ADT
- maps the fields to the abstract state they represent
  - can check that the abstract value after each method meets the postcondition described in the specification

Representation Invariant: (next lecture)

Example: Circle

```
/** Represents a mutable circle in the plane. For example,
  * it can be a circle with center (0,0) and radius 1. */
public class Circle {

  // Abstraction function:
  // AF(this) = a circle with center at this.center
  //   and radius this.rad
  private Point center;
  private double rad;

  //  ...

}
```

Example: Circle 2

```
/** Represents a mutable circle in the plane. For example,
  * it can be a circle with center (0,0) and radius 1. */
public class Circle {

  // Abstraction function:
  // AF(this) = a circle with center at this.center
  //   and radius this.center.distanceTo(this.edge)
  private Point center, edge;

  //  ...

}
```

Example: Polynomial

```
/** An immutable polynomial with integer coefficients.
  * Examples include 0, 2x, and x + 3x^2 + 5x. */
public class IntPoly {

  // Abstraction function:
  // AF(this) = sum of coeffs[i] * x^i
  //                for i = 0 .. coeffs.length-1
  private final int[] coeffs;

  //  ...

}
```

Example: Polynomial 2

```
/** An immutable polynomial with integer coefficients.
  * Examples include 0, 2x, and x + 3x^2 + 5x. */
public class IntPoly {

  // Abstraction function:
  // AF(this) = sum of monomials in this.terms
  private final List<IntTerm> terms;

  //  ...

}
```

The abstraction function

- Purely conceptual (not a Java function)

- Allows us to check correctness
  - use reasoning to show that the method leaves the abstract state such that it satisfies the postcondition

Example: IntDeque

```
// List that only allows insert/remove at ends.
```

push

unshift

Example: IntDeque

```
// List that only allows insert/remove at ends.
```

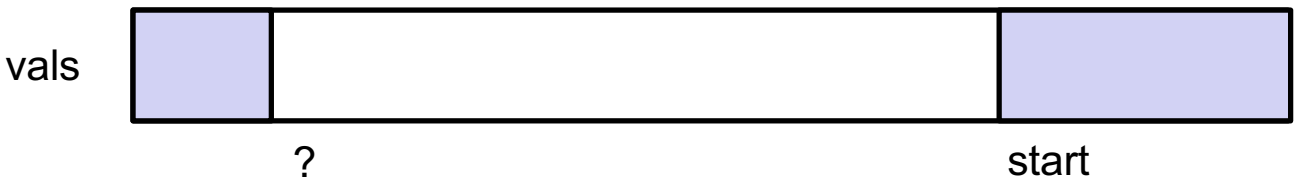
push + unshift

push + unshift

push + unshift

Example: IntDeque

```
// List that only allows insert/remove at ends.
```



Example: IntDeque

```
/** List that only allows insert/remove at ends. */
public class IntDeque {

  // AF(this) =
  //   vals[start..start+len-1]      if start+len < vals.length
  //   vals[start..] + vals[0..len-(vals.length-start)-1]  o.w.
  private int[] vals;
  private int start, len;

  // Creates an empty list.
  public IntDeque() {
    vals = new int[3];
    start = len = 0;
  }
```

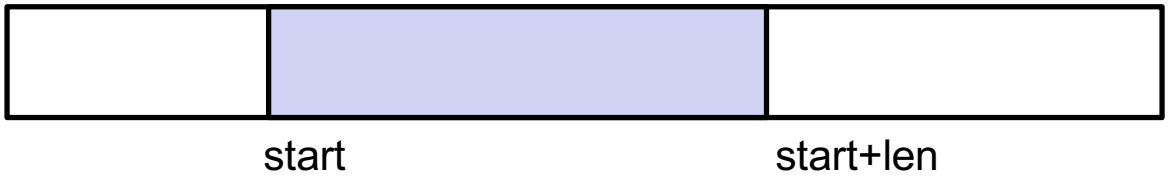
AF(this) = vals[0..-1] = []

Example: IntDeque

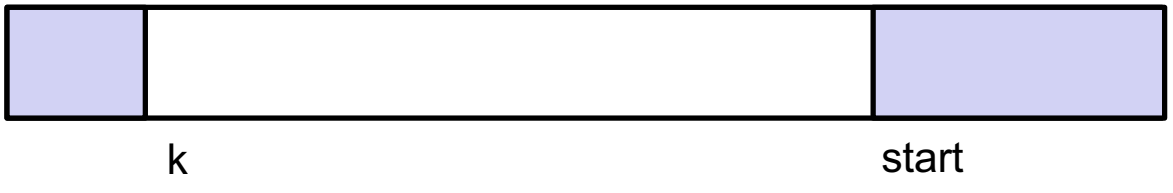
```
/** List that only allows insert/remove at ends. */
public class IntDeque {

  // AF(this) =
  //   vals[start..start+len-1]      if start+len < vals.length
  //   vals[start..] + vals[0..len-(vals.length-start)-1]  o.w.
  private int[] vals;
  private int start, len;

  // ...

  // @returns length of the list
  public int getLength() {
    return len;
  }
```

Example: IntDeque

```
// List that only allows insert/remove at ends.
```



#items = len



#items = vals.length – start + k

#items = len iff k = len – (vals.length – start)

Example: IntDeque

```
/** List that only allows insert/remove at ends. */
public class IntDeque {

  // AF(this) =
  //   vals[start..start+len-1]      if start+len < vals.length
  //   vals[start..] + vals[0..len-(vals.length-start)-1]  o.w.
  private int[] vals;
  private int start, len;

  // ...

  // @returns length of the list
  public int getLength() {
    return len;
  }
```

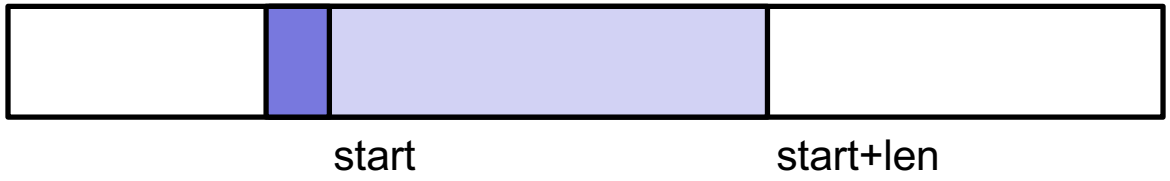
Example: IntDeque

```
/** List that only allows insert/remove at ends. */
public class IntDeque {

  // ...

  // @requires 0 <= i < length
  // @returns this[i]
  public int get(int i) { ... }
```

Example: IntDeque

```
// List that only allows insert/remove at ends.
```

unshift



Example: IntDeque

```
// AF(this) =
//   vals[start..start+len-1]          if start+len < vals.length
//   vals[start..] + vals[0..len-(vals.length-start)-1]    o.w.

// @requires 0 < list length
// @returns value at the front of the list
// @modifies this
// @effects first element of list removed
public int unshift() {
  int val = get(0);
  if (start + 1 < vals.length)
    start += 1;
  else
    start = 0;
  len -= 1;
  return val;
}
```

IntDeque.java