CSE 143
Lecture 2

Implementing `ArrayIntList`

reading: 15.1 - 15.3

slides adapted from Marty Stepp , Hélène Martin, Ethan Apter and Benson Limketkai
http://www.cs.washington.edu/143/

Exercise

- Pretend for a moment that there is **no `ArrayList` class**.
  - Write a program that reads a file `data.txt` (of unknown size) full of integers and prints them in reverse order.

```
17
932085
-32053278
100
3
```

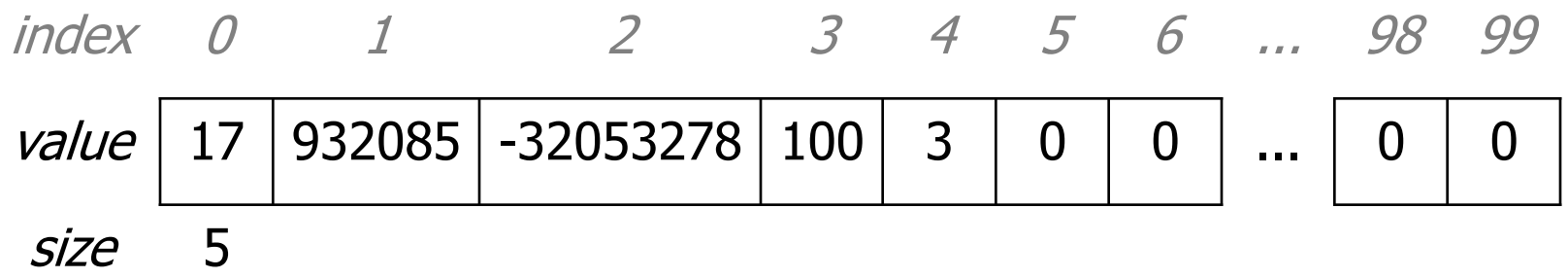
  - Output:

```
3
100
-32053278
932085
17
```

"Unfilled array" solution

- We are using an array to store a *list* of values.
  - Only the values at indexes [0, *size* - 1] are relevant.

```
int[] nums = new int[100];              // make a big array
int size = 0;
Scanner input = new Scanner(new File("data.txt"));
while (input.hasNextInt()) {
    nums[size] = input.nextInt();       // read each number
    size++;                             // into the array
}
for (int i = size - 1; i >= 0; i--) {
    System.out.println(nums[i]);        // print reversed
}
```



Exercise

- Let's write a class that implements a list using an `int[]`
  - We'll call it `ArrayIntList`
  - its behavior:
    - `add(`**value**`),`
    - `get(`**index**`),`
    - `size(),`
    - `remove(`**index**`),`
    - `indexOf(`**value**`),`
    - `toString(),`

      ...

    `add(`**index**`,` **value**`),`

    `set(`**index**`,` **value**`),`

    `isEmpty(),`

    `contains(`**value**`),`
  - The list's *size* will be the number of elements added to it so far.
    - The actual array length ("capacity") in the object may be larger. We'll start with an array of **length 10** by default.

Implementing add

- How do we add to the end of a list?

```
public void add(int value) {   // just put the element
    list[size] = value;        // in the last slot,
    size++;                    // and increase the size
}
```

index	0	1	2	3	4	5	6	7	8	9
value	3	8	9	7	5	12	0	0	0	0
size	6									

- `list.add(42);`

index	0	1	2	3	4	5	6	7	8	9
value	3	8	9	7	5	12	**42**	0	0	0
size	**7**									

Implementing `add` #2

- How do we add to the middle or end of the list?
  - must *shift* elements to make room for the value *(see book 7.3)*

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	3	8	9	7	5	12	0	0	0	0
size	6									

  - `list.add(3, 42);  // insert 42 at index 3`

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	3	8	9	**42**	7	5	12	0	0	0
size	**7**									

  - Note: The order in which you traverse the array matters!

add #2 code

```
public void add(int index, int value) {
    for (int i = size; i > index; i--) {
        list[i] = list[i - 1];
    }
    list[index] = value;
}
```

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	3	8	9	7	5	12	0	0	0	0
size	6									

- `list.add(3, 42);`

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	3	8	9	**42**	**7**	**5**	**12**	0	0	0
size	**7**				→					

Implementing `remove`

- How can we remove an element from the list?

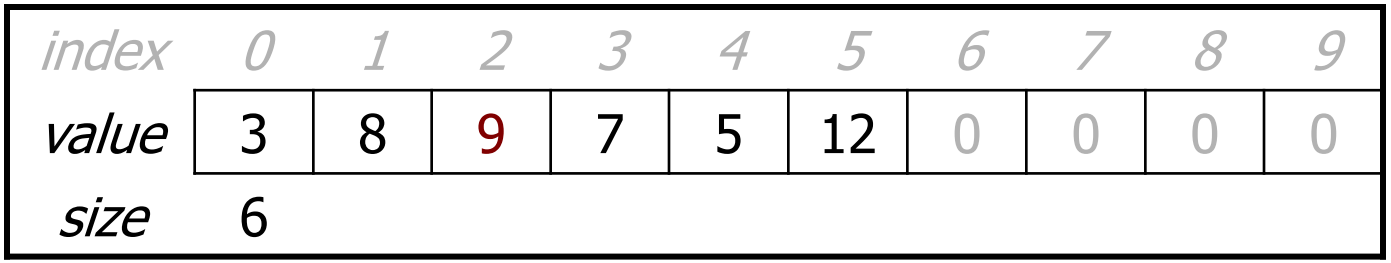
index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	3	8	9	7	5	12	0	0	0	0
size	6									

- `list.remove(2);` `// delete 9 from index 2`

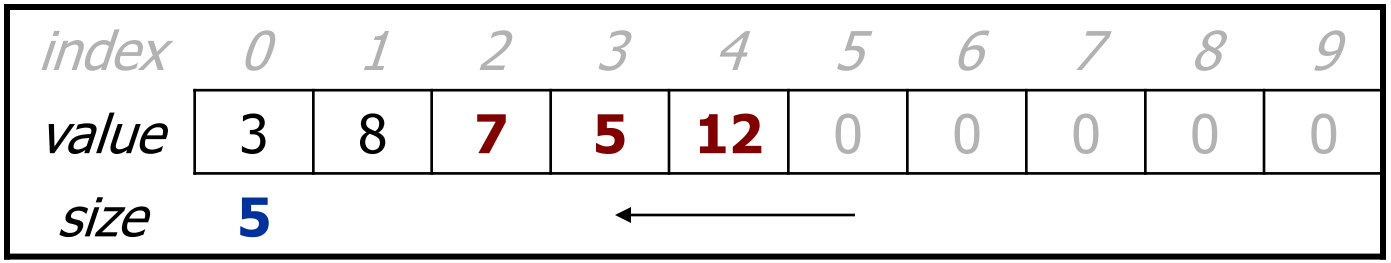
index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	3	8	7	5	12	0	0	0	0	0
size	**5**									

Implementing `remove`, cont.

- Again, we need to shift elements in the array
  - this time, it's a left-shift
  - in what order should we process the elements?
  - what indexes should we process?



- `list.remove(2);` `// delete 9 from index 2`



Implementing `remove` code

```
public void remove(int index) {
    for (int i = index; i < size; i++) {
        list[i] = list[i + 1];
    }
    size--;
    list[size] = 0;      // optional (why?)
}
```

index	0	1	2	3	4	5	6	7	8	9
value	3	8	9	7	5	12	0	0	0	0
size	6									

- `list.remove(2);` `// delete 9 from index 2`

index	0	1	2	3	4	5	6	7	8	9
value	3	8	**7**	**5**	**12**	0	0	0	0	0
size	**5**			←						

Printing an `ArrayIntList`

- Let's add a method that allows clients to print a list's elements.
  - You may be tempted to write a `print` method:

```
// client code
ArrayIntList list = new ArrayIntList();
...
list.print();
```

    - Why is this a bad idea? What would be better?

The `toString` method

- Tells Java how to convert an object into a `String`

```
ArrayIntList list = new ArrayIntList();
System.out.println("list is " + list);
                // ("list is " + list.toString());
```

- Syntax:

```
public String toString() {
    code that returns a suitable String;
}
```

- Every class has a `toString`, even if it isn't in your code.
  - The default is the class's name and a hex (base-16) number:

```
ArrayIntList@9e8c34
```

toString solution

```
// Returns a String representation of the list.
public String toString() {
    if (size == 0) {
        return "[]";
    } else {
        String result = "[" + elementData[0];
        for (int i = 1; i < size; i++) {
            result += ", " + elementData[i];
        }
        result += "]";
        return result;
    }
}
```

Other methods

- Let's implement the following methods in our list:
  - `get(`**index**`)`
    Returns the element value at a given index.
  - `set(`**index**`, `**value**`)`
    Sets the list to store the given value at the given index.
  - `size()`
    Returns the number of elements in the list.
  - `isEmpty()`
    Returns `true` if the list contains no elements; else `false`.
    (Why write this if we already have the `size` method?)

Searching methods

- Implement the following methods:
  - `indexOf` - returns the first index an element is found, or -1 if not
  - `contains` - returns true if the list contains the given int value

- Why do we need `isEmpty` and `contains` when we already have `indexOf` and `size` ?
  - Adds convenience to the client of our class:

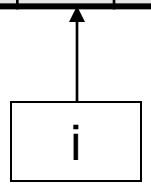
```
// less elegant
if (myList.size() == 0) {
if (myList.indexOf(42) >= 0) {
```

```
// more elegant
if (myList.isEmpty()) {
if (myList.contains(42)) {
```

Sequential search

- **sequential search**: Locates a target value in an array/list by examining each element from start to finish.
  - How many elements will it need to examine?
  - Example: Searching the array below for the value **42**:

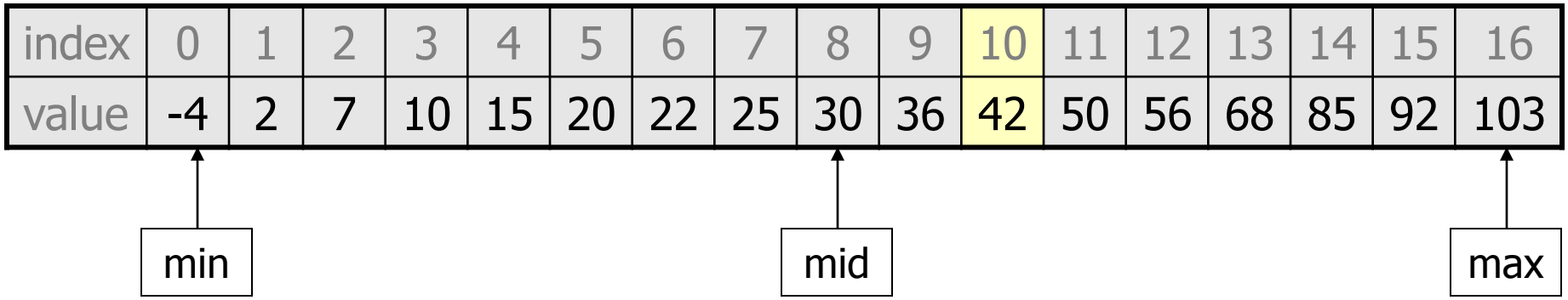
index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
value	-4	2	7	10	15	20	22	25	30	36	42	50	56	68	85	92	103



  - Notice that the array is sorted. Could we take advantage of this?

Binary search (13.1)

- **binary search**: Locates a target value in a *sorted* array/list by successively eliminating half of the array from consideration.
  - How many elements will it need to examine?
  - Example: Searching the array below for the value **42**:



The `Arrays` class

- Class `Arrays` in `java.util` has many useful array methods:

Method name	Description
`binarySearch(`**array**`, `**value**`)`	returns the index of the given value in a *sorted* array (or < 0 if not found)
`binarySearch(`**array**`, `**minIndex**`, `**maxIndex**`, `**value**`)`	returns index of given value in a *sorted* array between indexes *min* / *max* - 1 (< 0 if not found)
`copyOf(`**array**`, `**length**`)`	returns a new resized copy of an array
`equals(`**array1**`, `**array2**`)`	returns `true` if the two arrays contain same elements in the same order
`fill(`**array**`, `**value**`)`	sets every element to the given value
`sort(`**array**`)`	arranges the elements into sorted order
`toString(`**array**`)`	returns a string representing the array, such as `"[10, 30, -25, 17]"`

- Syntax: `Arrays.`**methodName**`(`**parameters**`)`

Arrays.binarySearch

```
// searches an entire sorted array for a given value
// returns its index if found;  a negative number if not found
// Precondition: array is sorted
Arrays.binarySearch(array, value)

// searches given portion of a sorted array for a given value
// examines minIndex (inclusive) through maxIndex (exclusive)
// returns its index if found;  a negative number if not found
// Precondition: array is sorted
Arrays.binarySearch(array, minIndex, maxIndex, value)
```

- The `binarySearch` method in the `Arrays` class searches an array very efficiently if the array is sorted.
  - You can search the entire array, or just a range of indexes (useful for "unfilled" arrays such as the one in `ArrayIntList`)
  - If the array is not sorted, you may need to sort it first

Using `binarySearch`

```
// index    0  1  2  3   4   5   6   7   8   9  10  11  12  13  14  15
int[] a = {-4, 2, 7, 9, 15, 19, 25, 28, 30, 36, 42, 50, 56, 68, 85, 92};

int index  = Arrays.binarySearch(a, 0, 16, 42);   // index1 is 10
int index2 = Arrays.binarySearch(a, 0, 16, 21);   // index2 is -7
```

- `binarySearch` returns the index where the value is found
- if the value is *not* found, `binarySearch` returns:

  `-(insertionPoint + 1)`

  - where `insertionPoint` is the index where the element *would* have been, if it had been in the array in sorted order.
  - To insert the value into the array, negate `insertionPoint` + 1

```
int indexToInsert21 = -(index2 + 1);  // 6
```