

# **FCDS**

## **Programming I**

### **Lecture 9: Arrays I**

# Can we solve this problem?

- Consider the following program (input underlined):

How many days' temperatures?

Day 1's high temp: 45

Day 2's high temp: 44

Day 3's high temp: 39

Day 4's high temp: 48

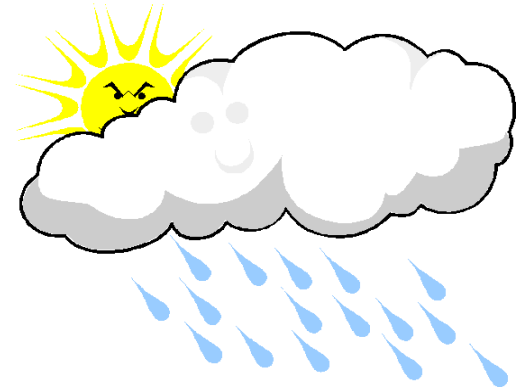
Day 5's high temp: 37

Day 6's high temp: 46

Day 7's high temp: 53

Average temp = 44.6

4 days were above average.



# Why the problem is hard

- We need each input value twice:
  - to compute the average (a cumulative sum)
  - to count how many were above average
- We could read each value into a variable... but we:
  - don't know how many days are needed until the program runs
  - don't know how many variables to declare
- We need a way to declare many variables in one step.

# Arrays

- **array**: object that stores many values of the same type.
  - **element**: One value in an array.
  - **index**: A 0-based integer to access an element from an array.

<i>index</i>	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>
<i>value</i>	12	49	-2	26	5	17	-6	84	72	3

↑	↑	↑
element 0	element 4	element 9

# Array declaration

```
type [ ] name = new type [length] ;
```

- Example:

```
int[] numbers = new int[10];
```

[illegible]

# Array declaration, cont.

- The length can be entered by the user

```
Scanner console = new Scanner(System.in)
n = console.nextInt()
int[] numbers = new int[n];
```

[illegible]

# Array declaration, cont.

- The length can be any integer expression.

```
int x = 2 * 3 + 1;
```

```
int[] data = new int[x % 5 + 2];
```

- Each element initially gets a "zero-equivalent" value.

Type	Default value
int	0
double	0.0
boolean	false
String or other object	null (means, "no object")

# Accessing elements

**name [index]**      *// access*

**name [index] = value;**      *// modify*

–Example:

```
numbers[0] = 27;
```

```
numbers[3] = -6;
```

```
System.out.println(numbers[0]);
```

```
if (numbers[3] < 0) {
```

```
    System.out.println("Element 3 is negative.");
```

```
}
```

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

*value*

<b>27</b>	0	0	<b>-6</b>	0	0	0	0	0	0
-----------	---	---	-----------	---	---	---	---	---	---



# Arrays of other types

```
double[] results = new double[5];  
results[2] = 3.4;  
results[4] = -0.5;
```

<i>index</i>	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>
<i>value</i>	0.0	0.0	<b>3.4</b>	0.0	<b>-0.5</b>

```
boolean[] tests = new boolean[6];  
tests[3] = true;
```

<i>index</i>	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
<i>value</i>	false	false	false	<b>true</b>	false	false

# Out-of-bounds

- Legal indexes: between **0** and the **array's length - 1**.
  - Reading or writing any index outside this range will throw an `ArrayIndexOutOfBoundsException`.
- Example:

```
int[] data = new int[10];
System.out.println(data[0]);    // okay
System.out.println(data[9]);    // okay
System.out.println(data[-1]);   // exception
System.out.println(data[10]);  // exception
```

[illegible]

# Accessing array elements

```
int[] numbers = new int[8];  
numbers[1] = 3;  
numbers[4] = 99;  
numbers[6] = 2;  
  
int x = numbers[1];  
numbers[x] = 42;  
numbers[numbers[6]] = 11; // use numbers[6] as  
index
```

*x*

3
---

	<i>index</i>	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>
<i>numbers</i>	<i>value</i>	0	3	11	42	99	0	2	0

# Arrays and `for` loops

- It is common to use `for` loops to access array elements.

```
for (int i = 0; i < 8; i++) {  
    System.out.print(numbers[i] + " ");  
}  
System.out.println(); // output: 0 3 11 42 99 0 2 0
```

- Sometimes we assign each element a value in a loop.

```
for (int i = 0; i < 8; i++) {  
    numbers[i] = 2 * i;  
}
```

*index*    0    1    2    3    4    5    6    7

*value*

0	2	4	6	8	10	12	14
---	---	---	---	---	----	----	----

# Arrays and `for` loops, cont.

- It is common to use `for` loops to read array elements from the user.

```
for (int i = 0; i <= 9; i++) {  
    System.out.print("Enter element " + i);  
    number[i] = console.nextInt()  
}  
System.out.println();
```

# The length field

- An array's `length` field stores its number of elements.

`name.length`

```
for (int i = 0; i < numbers.length; i++) {  
    System.out.print(numbers[i] + " ");  
}  
// output: 0 2 4 6 8 10 12 14
```

– It does not use parentheses like a String's `.length()`.

- What expressions refer to:

– The last element of any array?

`numbers[numbers.length - 1]`

– The middle element?

`numbers[(numbers.length - 1) / 2]`

# Weather question

- Use an array to solve the weather problem:

How many days' temperatures? 7

Day 1's high temp: 45

Day 2's high temp: 44

Day 3's high temp: 39

Day 4's high temp: 48

Day 5's high temp: 37

Day 6's high temp: 46

Day 7's high temp: 53

Average temp = 44.6

4 days were above average.

# Weather answer

```
// Reads temperatures from the user, computes average and # days above average.
import java.util.*;

public class Weather {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);
        System.out.print("How many days' temperatures? ");
        int days = console.nextInt();

        int[] temps = new int[days];           // array to store days' temperatures
        int sum = 0;

        for (int i = 0; i < days; i++) {      // read/store each day's temperature
            System.out.print("Day " + (i + 1) + "'s high temp: ");
            temps[i] = console.nextInt();
            sum += temps[i];
        }
        double average = (double) sum / days;

        int count = 0;                       // see if each day is above average
        for (int i = 0; i < days; i++) {
            if (temps[i] > average) {
                count++;
            }
        }

        // report results
        System.out.println("Average temp =" + average);
        System.out.println(count + " days above average");
    }
}
```



# Quick array initialization

**type[] name = {value, value, ... value};**

– Example:

```
int[] numbers = {12, 49, -2, 26, 5, 17, -6};
```

<i>index</i>	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>
<i>value</i>	12	49	-2	26	5	17	-6

- Useful when you know what the array's elements will be
- The compiler figures out the size by counting the values

# Array traversal

- **traversal:** An examination of each element of an array.
- What element are prime numbers in the following array?

```
int[] a = {1, 7, 5, 6, 4, 14, 11};  
for (int i = 0; i < a.length; i++) {  
    if (isPrime(a[i])) {  
        System.out.println(a[i]);  
    }  
}
```

**Output:**

**7**

**5**

**11**

# Array traversal (Example)

**// Find the smallest element in an array.**

```
public class Smallest {
    public static void main(String[] args) {
        int[] num = {12, 49, -5, 26, -2, 17, 6}; // array
                                                initialization

        int min = num[0];
        int minIndex = 0;

        for (int i = 1; i < num.length; i++) {
            if (num[i] < min) {
                min = num[i];
                minIndex = i;
            }
        }

        // report results
        System.out.println("The smallest element is: " + min);
        System.out.println("The index of the smallest element is: "
+ minIndex);
    }
}
```

# "Array mystery" problem

- What element values are stored in the following array?

```
int[] a = {1, 7, 5, 6, 4, 14, 11};  
for (int i = 0; i < a.length - 1; i++)  
{  
    if (a[i] > a[i + 1]) {  
        a[i + 1] = a[i + 1] * 2;  
    }  
}
```

*index*    0    1    2    3    4    5    6

*value*

1	7	10	12	8	14	22
---	---	----	----	---	----	----

# Parallel Arrays

- These are independent arrays of the same size, that have a meaningful connection to each other.
- For example, one array with a students gpa, and one with his letter grade.

	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>
<b>GPA</b>	60	72	40	86	75	96	66	14
	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>
<b>Grade</b>	'D'	'C'	'F'	'B'	'C'	'A'	'C'	'F'

# Parallel Arrays (Example)

**// Print the name of the student with the highest gpa.**

```
public class ParallelArrays {
    public static void main(String[] args) {
        int[] GPA = {60, 92, 40, 86};
        String[] name = {"Aly", "Samer", "May", "Ahmed"};
        int max = GPA[0];
        int maxIndex = 0;
        for (int i = 1; i < GPA.length; i++) {
            if (GPA[i] > max) {
                max = GPA[i];
                maxIndex = i;
            }
        }
        System.out.println("The student with the highest
grade is: " + name[maxIndex] + "and his GPA is" + max);
    }
}
```

# Limitations of arrays

- You cannot resize an existing array:

```
int[] a = new int[4];  
a.length = 10;           // error
```

- You cannot compare arrays with `==` or `equals`:

```
int[] a1 = {42, -7, 1, 15};  
int[] a2 = {42, -7, 1, 15};  
if (a1 == a2) { ... }           // false!  
if (a1.equals(a2)) { ... }     // false!
```

- An array does not know how to print itself:

```
int[] a1 = {42, -7, 1, 15};  
System.out.println(a1);         // [I@98f8c4]
```

# The Arrays class

- Class `Arrays` in package `java.util` has useful static methods for manipulating arrays:

Method name	Description
<code>copyOf(array, length)</code>	returns a new copy of an array
<code>equals(array1, array2)</code>	returns <code>true</code> if the two arrays contain same elements in the same order
<code>fill(array, value)</code>	sets every element to the given value
<code>sort(array)</code>	arranges the elements into sorted order
<code>toString(array)</code>	returns a string representing the array, such as <code>"[10, 30, -25, 17]"</code>

- Syntax: `Arrays.methodName(parameters)`



# Arrays.toString

- `Arrays.toString` accepts an array as a parameter and returns a `String` representation of its elements.

```
int[] e = {0, 2, 4, 6, 8};  
e[1] = e[3] + e[4];  
System.out.println("e is " + Arrays.toString(e));
```

## Output:

```
e is [0, 14, 4, 6, 8]
```

– Must import `java.util.*`;

# Weather question 2

- Modify the weather program to print the following output:

```
How many days' temperatures? 7
```

```
Day 1's high temp: 45
```

```
Day 2's high temp: 44
```

```
Day 3's high temp: 39
```

```
Day 4's high temp: 48
```

```
Day 5's high temp: 37
```

```
Day 6's high temp: 46
```

```
Day 7's high temp: 53
```

```
Average temp = 44.6
```

```
4 days were above average.
```

```
Temperatures: [45, 44, 39, 48, 37, 46, 53]
```

```
Two coldest days: 37, 39
```

```
Two hottest days: 53, 48
```

# Weather answer 2

```
// Reads temperatures from the user, computes average and # days above average.
import java.util.*;

public class Weather2 {
    public static void main(String[] args) {
        ...
        int[] temps = new int[days];           // array to store days' temperatures
        ...   (same as Weather program)

        // report results
        System.out.println("Average temp =" + average);
        System.out.println(count + " days above average");

        System.out.println("Temperatures: " + Arrays.toString(temps));
        Arrays.sort(temps);
        System.out.println("Two coldest days: " + temps[0] + ", " + temps[1]);
        System.out.println("Two hottest days: " + temps[temps.length - 1] +
                           ", " + temps[temps.length - 2]);
    }
}
```