Unit 6: Arrays
For Each Loop + Array Algorithms

Adapted from:

1) Building Java Programs: A Back to Basics Approach
by Stuart Reges and Marty Stepp

2) Runestone CSAwesome Curriculum

https://longbaonguyen.github.io

The Enhanced For Loop

If you are working with arrays(or other collections data structures), you can use an alternative syntax for a **for** loop (enhanced form of for loop) to iterate through items of arrays/collections.

It is also referred as **for-each loop** because the loop iterates through each element of array/collection.

```
for(data_type item : collection) {
...
}
```

The Enhanced For Loop

```
int[] numbers = {1, 3, 5, -2};
for(int item : numbers) {
      System.out.print(item + " ");
}
```

Output:

```
1 3 5 -2
```

Note that there are no references to indices. Compare this with a regular for loop.

```
int[] numbers = {1, 3, 5, -2};
for(int i = 0;i < numbers.length; i++) {
      System.out.print(numbers[i] + " ");
}
```

The Enhanced For Loop

```
String[] names = {"Mike", "Jesse", "Mia"};
for(String item : names) {
      System.out.print(item + " ");
}
```

Output:

```
Mike Jesse Mia
```

```
Point[] pts = {new Point(1,2), new Point(4, 5),
                                    new Point(2,-4)};
for(Point item : pts) {
      System.out.print(item + " ");
}
(1, 2) (4, 5) (-2, 4) // assumes toString() implemented
```

Common Mistake

When we use an enhanced for a loop as in the following example, it creates a temporary variable integer `item`. By value semantics, modifying `item` does NOT modify values in the array.

```
int[] numbers = {1, 3, 5, -2};
for(int item : numbers) {
      item = 0;
}
System.out.println(Arrays.toString(numbers));



Output:
{1, 3, 5, -2}
```

For vs Enhanced For

```
Student[] students = {…} // suppose this is initialized
                           // with Student objects

double sum = 0;
// regular for loop:
for(int i = 0; i < students.length; i++){
      sum += students[i].getSalary();
}
// enhanced for loop:
for(Student s: students){
      sum += s.getSalary();
}
```

For each iteration, students[i] and s both reference the same Student object

Common Array Algorithms

Common Algorithms:

1)Find largest/smallest value of an array.

2)Compute sum, average, mode.

3)Determine if at least one element(or all elements) satisfy a certain property(e.g., all elements are even)

4)Determine the absence/presence of duplicate elements.

5)Determine the number of elements meeting a specific criteria.(e.g. number of positive elements)

6)Shift or rotate elements left or right.

7)Reverse the order of the elements.

We will cover some of these in lectures and the rest in labs/problem sets.

Array parameter (declare)

Arrays can be a parameter of a method.

`public static` **type methodName**`(`**type**`[]` **name**`) {`
`…}`

Given an array, return the **largest** value of the array.

```
public static int largest(int[] array){
     int largest = array[0];
     for(int i = 1;i < array.length; i++){
          if(array[i] > largest)
               largest = array[i];
     }
     return largest;
}
```

Array parameter (call)

Call a method by sending an array to its parameter.

methodName(**arrayName**);

```
public class MyProgram {
    public static void main(String[] args) {

        int[] iq = {126, 84, 149, 167, 95};
        int largest = largest(iq);

        System.out.println("Largest IQ = " + largest);
    }
    ...
```

- Notice that you don't write the `[]` when passing the array.

Index of Largest Value

Given an array, return the **index** of the **largest** value of the array.

```
public static int largestIndex(int[] array){
    int index = 0;
    for(int i = 1; i < array.length; i++){
        if(array[i] > array[index])
            index = i;
    }
    return index;
}
```

Note: This algorithm(and its variants) almost always show up on the AP free response section. Please know and memorize it!

All Even

Given an array, return whether all of the elements are even.

```
public static boolean allEven(int[] array){
    for(int i = 0; i < array.length; i++){
        if(array[i] % 2 != 0)
            return false;
    }
    return true;
}
```

Note: You cannot return true until all elements are checked. However, you can **early return as soon you see an odd number.**

Average

Given an array, return the **average** of the array.

```
public static double average(int[] array){
    int sum = 0;
    for(int i = 0; i < array.length; i++){
        sum += array[i];
    }
    return (double)sum / array.length;
}
```

Array of Objects

Suppose we have the following Employee class:

```
public class Employee{
      // instance variables, constructors not shown
      public double getSalary(){…}
      public double getName() {…}
}
```

Consider another class called Company which contains an array of Employee objects. This class contains two methods: an instance method called average which returns the average salary of the employees and a static version of the average method.

Array of Objects: Instance Method

```
public class Company{
       private Employee[] employees;
       // constructors not shown
       public double averageSalary(){
              double sum = 0.0;
              for(Employee e: employees){
                     sum += e.getSalary();
              }
              return sum/employees.length;
       }
}
```

The instance method averageSalary
has access to this.employees:
the current object’s list of employees

Array of Objects: Instance Method

```
public class Company{
       private Employee[] employees;
       // constructors not shown
       public double averageSalary(){
              double sum = 0.0;
              for(Employee e: employees){
                     sum += e.getSalary();
              }
              return sum/employees.length;
       }
       public static double averageSalary(Employee[] emps){
              double sum = 0.0;
              for(Employee e: emps){
                     sum += e.getSalary();
              }
              return sum/emps.length;
       }
}
```

The static method averageSalary needs an array of Employee objects as a parameter since it does NOT have access to the array employees.

Array of Objects: Instance Method

```
public class Company{
       private Employee[] employees;
       // constructors not shown
       public double averageSalary(){
              double sum = 0.0;
              for(Employee e: employees){
                     sum += e.getSalary();
              }
              return sum/employees.length;
       }
       public static double averageSalary(Employee[] emps){
              double sum = 0.0;
              for(Employee e: emps){
                     sum += e.getSalary();
              }
              return sum/emps.length;
       }
}
```

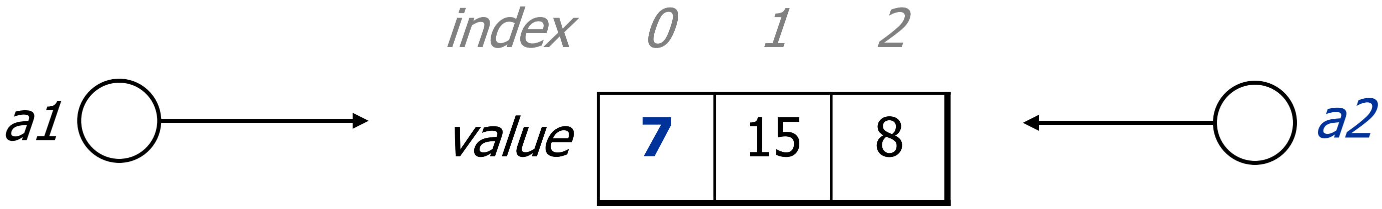
The instance method averageSalary
has access to this.employees:
the current object’s list of employees

The static method averageSalary
needs an array of Employee objects
as a parameter since it does NOT
have access to the array employees.

Reference semantics (objects)

- **reference semantics**: Behavior where variables actually store the address of an object in memory.
  - When one variable is assigned to another, the object is *not* copied; both variables refer to the *same object*.
  - Modifying the value of one variable *will* affect others.

```
int[] a1 = {4, 15, 8};
int[] a2 = a1;              // refer to same array as a1
a2[0] = 7;
System.out.println(Arrays.toString(a1)); // [7, 15, 8]
```



Reference Semantics

Example:

```
   public static void triple(int[] numbers) {

      for (int i = 0; i < numbers.length; i++) {
            numbers[i] = numbers[i] * 3;
      }
  }
   public static void main(String[] args) {

          int[] arr = {0,1,2,3};
          triple(arr);
          System.out.println(Arrays.toString(arr));
          // {0,3,6,9}
}
```

Array return (declare)

A method can return an array.

```
public static type[] methodName(parameters) {
```

Example:

```
// Returns a new array with all values tripled.
// Example: [1, 4, 0, 7] -> [3, 12, 0, 21]
public static int[] triple(int[] numbers) {
    int[] result = new int[numbers.length];
    for (int i = 0; i < numbers.length; i++) {
        result[i] = numbers[i] * 3;
    }
    return result;
}
```

Array return (call)

Storing an array returned by a method.

type[] **name** = **methodName**(**parameters**);

- Example:

```
public class MyProgram {
    public static void main(String[] args) {
        int[] a = {2, 5, 1, 6};
        int[] answer = triple(iq);
        System.out.println(Arrays.toString(answer));
    }
    ...
```

- Output:

```
[6, 15, 3, 18]
```

Array reversal question

- Write code that reverses the elements of an array.
  - For example, if the array initially stores:
    `[11, 42, -5, 27, 0, 89]`
  - Then after your reversal code, it should store:
    `[89, 0, 27, -5, 42, 11]`
    - The code should work for an array of any size.

Does it work?

Does this work?

```
int[] numbers = [11, 42, -5, 27, 0, 89];
// reverse the array
for (int i = 0; i < numbers.length; i++) {
    numbers[i] = numbers[numbers.length - 1- i];

    }
System.out.println(Arrays.toString(numbers));

// [89, 0, 27, 27, 0, 89]
 // half of array was overwritten!
```

Algorithm idea

- Swap pairs of elements from the edges; work inwards:

index	*0*	*1*	*2*	*3*	*4*	*5*
value	89	0	27	-5	42	11
	↑	↑	↑	↑	↑	↑

Note: The animation above only works in powerpoint format. It will not work if you are reading this from a pdf version. The animation simply swaps 89 and 11, then swaps 0 and 42, then 27 and -5.

Flawed algorithm

- What's wrong with this code?

```
int[] numbers = [11, 42, -5, 27, 0, 89];

// reverse the array
for (int i = 0; i < numbers.length; i++) {
    int temp = numbers[i];
    numbers[i] = numbers[numbers.length - 1 - i];
    numbers[numbers.length - 1 - i] = temp;
}
```

Flawed algorithm

What's wrong with this code?

```
int[] numbers = [11, 42, -5, 27, 0, 89];
// reverse the array
for (int i = 0; i < numbers.length; i++) {
    int temp = numbers[i];
    numbers[i] = numbers[numbers.length - 1 - i];
    numbers[numbers.length - 1 - i] = temp;
}
```

The loop goes too far and un-reverses the array! Fixed version:

```
for (int i = 0; i < numbers.length / 2; i++) {
    int temp = numbers[i];
    numbers[i] = numbers[numbers.length - 1 - i];
    numbers[numbers.length - 1 - i] = temp;
}
```

Array reverse question

Turn your array reversal code into a `reverse` method.

- Accept the array of integers to reverse as a parameter.

```
int[] numbers = {11, 42, -5, 27, 0, 89};
reverse(numbers);
System.out.println(Arrays.toString(numbers));
 // {89, 0, 27, -5, 42, 11}
```

Solution: Note that this works because of reference semantics!

```
public static void reverse(int[] x) {
    for (int i = 0; i < x.length / 2; i++) {
        int temp = x[i];
        x[i] = x[x.length - 1 - i];
        x[x.length - 1 - i] = temp;
    }
}
```

A multi-counter problem

- Problem: Write a method `mostFrequentDigit` that returns the digit value that occurs most frequently in a number.

  - Example: The number 669260267 contains:
    one 0, two 2s, four 6es, one 7, and one 9.
    `mostFrequentDigit(669260267)` returns 6.

  - If there is a tie, return the digit with the lower value.
    `mostFrequentDigit(57135203)` returns 3.

A multi-counter problem

- We could declare 10 counter variables ...

```
int counter0, counter1, counter2, counter3, counter4,
    counter5, counter6, counter7, counter8, counter9;
```

- But a better solution is to use an array of size 10.
  - The element at index *i* will store the counter for digit value *i*.
  - Example for 669260267:

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

  - How do we build such an array? And how does it help?

Creating an array of tallies

```
// assume n = 669260267
int[] counts = new int[10];
while (n > 0) {
    // pluck off a digit and add to proper counter
    int digit = n % 10;
    counts[digit]++;
    n = n / 10;
}
```

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

Tally solution

```java
// Returns the digit value that occurs most frequently in n.
// Breaks ties by choosing the smaller value.
public static int mostFrequentDigit(int n) {
    int[] counts = new int[10];
    while (n > 0) {
        int digit = n % 10;  // pluck off a digit and tally it
        counts[digit]++;
        n = n / 10;
    }

    // find the most frequently occurring digit
    int bestIndex = 0;
    for (int i = 1; i < counts.length; i++) {
        if (counts[i] > counts[bestIndex]) {
            bestIndex = i;
        }
    }

    return bestIndex;
}
```

Lab 1

1) Write a method `atLeastOneOdd` that accepts an array of integers and return whether there is at least one odd number in the array.

2) Write a method `shiftRight` that accepts an array of integers and shifts each element one position to its right. The last element is wrapped back to the first.

```
int[] a1 = {11, 34, 5, 17, 56};

shiftRight(a1);
System.out.println(Arrays.toString(a1));
// {56, 11, 34, 5, 17}
```

3) Similarly, write `shiftLeft`. Test your methods!

Lab 1

4) Write the method `mode` that accepts an array of test grades(0 – 100) and return the mode, the grade that occurs most frequently. If there are multiple modes, return the smallest.

Use the multi-counter tally solution discussed in the last few slides of this lecture. What's the length of the array of tallies?