Outline

° Problem: How can I perform the same operations on a set of data values

° Considering “for loops”
  • Useful for applying the same operations repetitively to arrays

° Very common structure in programming

° Arrays
  • Remember that they have a fixed size
Indices

- We can use an **int** variable or any expression that evaluates to an **int** value as an index:

  ```
  a[3]
  a[k]
  a[k - 2]
  a[(int)(6 * Math.random())]
  ```
Indices

° In Java, an array is declared with fixed length that cannot be changed.

° Java interpreter checks the values of indices at run time

° Throws IndexOutOfBoundsException if an index is negative or if it is greater than the length of the array – 1.
Why Do We Need Arrays?

- The power of arrays comes from the fact that the value of a subscript can be computed and updated at run time.

Before (no arrays):
```
int sum = 0;
sum += score0;
sum += score1;
...;
sum += score999;
```

After (with arrays):
```
int n = 1000;
int sum = 0, k;
for (k = 0; k < n; k++)
  sum += scores[k];
```
Why Arrays?

- Arrays give *direct access* to any element — no need to scan the array.

Before (no arrays):

```java
if (k == 0)
    value = score0);
else if (k == 1)
    value = score1;
else
    ...  // etc.
```

After (with arrays):

```java
value = scores[k];
```
Declaring Arrays

- The scores array could be declared as follows:
  
  ```java
  int[] scores = new int[10];
  ```

- Note the syntax, the ‘reference’ and the new object! It also says that there will be 10 scores referenced.

- The type of the variable scores is int[] (“an array of integers” or “an array of ints.”)

- Note that the array type does not specify its size, but each object of that type has a specific size.

- The reference variable scores is set to a new array object that can hold 10 integers.
Declaring Arrays

° Some other examples of array declarations:

    float[] prices = new float[500];
    boolean[] flags;
    flags = new boolean[20];
    char[] codes = new char[1750];

Can you provide examples of each type? Can you draw such an array as was provided earlier in these slides?

You saw the entries for the integer array, scores. What would a similar array of flags look like. **Draw it.**

Of characters? **Draw it.** (You will see this again!)
Bounds Checking

° Once an array is created, it has a fixed size

° An index used in an array reference must specify a valid element
  • That is, the index value must be in range 0 to N-1

° The Java interpreter throws an ArrayIndexOutOfBoundsException if an array index is out of bounds

° This is called automatic bounds checking
<table>
<thead>
<tr>
<th>Problem</th>
<th>Description</th>
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| **Bounds Checking** | - For example, if the array `codes` can hold 100 values, it can be indexed using only the numbers 0 to 99.  
- If the value of `count` is 100, then the following reference will cause an exception to be thrown: `System.out.println (codes[count]);`  
- It’s common to introduce **off-by-one errors** when using arrays. |

```java
for (int index=0; index <= 100; index++)
    codes[index] = index*50 + epsilon;
```
Bounds Checking

- Each array *object* has a **public constant** called `length` that stores the size of the array

  - It is referenced using the array name:
    
    ```
    scores.length
    ```

- Note that `length` holds the **number of elements**, not the largest index
Alternate Array Syntax

° The brackets of the array type can be associated with the element type or with the name of the array

° Therefore the following two declarations are equivalent:

\[
\text{float}[] \text{ prices;} \\
\text{float prices[];} \\
\]

° The first format generally is more readable and should be used
Declaration and Initialization

° When an array is created, space is allocated to hold its elements.

° If a list of values is not given, the elements get the default values.

```java
scores = new int[10];
// length 10, all values set to 0

words = new String[10000];
// length 10000, all values set to null
```
Initializer Lists

° An *initializer list* can be used to instantiate and fill an array in one step

° The values are delimited by braces and separated by commas

° Examples:

```cpp
int[] units = {147, 323, 89, 933, 540, 269, 97, 114, 298, 476};

char[] letterGrades = {'A', 'B', 'C', 'D', 'F'};
```
Initialization

° An array can be declared an initialized in one statement:

```java
int scores[] = new int[10]; // length 10
private double gasPrices[] = {1.49, 1.69, 1.74};
String words[] = new String[10000];
String cities[] = {"Atlanta", "Boston", "Cincinnati"};
```
Initializer Lists

° Note that when an initializer list is used:
  • ➔ the \texttt{new} operator is not used
  • ➔ no size value is specified

° The \texttt{size of the array} is determined by the number of items in the initializer list

° An initializer list can be used only in the array declaration
Arrays as Parameters

° An entire array can be passed as a parameter to a method

° The reference to the array is passed,
  • Makes the formal and actual parameters aliases of each other

° Changing an array element within the method changes the original

° An individual array element can be passed to a method as well,
  • The type of the formal parameter is the same as the element type.
  • In this case, the call is ‘by value.’
Arrays as Objects

- In Java, an array is an object. If the type of its elements is `anyType`, the type of the array object is `anyType[]`.
- There are two ways to declare an array:

```
anyType [ ] arrName;
```

or

```
anyType arrName [ ];
```

The difference becomes significant only when several variables are declared in one statement:

```
int [ ] a, b;   // both a, b are arrays
int a [ ], b;   // a is an array, b is not
```
Arrays as Objects

- As with other objects, the declaration creates only a reference, initially set to \texttt{null}.
  - An array must be created before it can be used.
- There are two ways to create an array:

\[
\text{arrName} = \text{new anyType [ length] ;}
\]

or

\[
\text{arrName} = \text{new anyType [ ] \{ val1, val2, ..., valN \};}
\]
Array’s Length

- The length of an array is determined when that array is created.
- The length is either given explicitly or comes from the length of the {...} initialization list.
- The length of an array `arrName` is referred to in the code as `arrName.length`.
- `length` appears like a public field (not a method) in an array object.
Initializing Elements

- Unless specific values are given in a `{...}` list, all the elements are initialized to the default value: 0 for numbers, false for booleans, null for objects.
- If its elements are objects, the array holds references to objects, which are initially set to null.
- Each object-type element must be initialized before it is used.
Passing Arrays to Methods

- As other objects, an array is passed to a method as a reference.
- The elements of the original array are not copied and are accessible in the method’s code.
Passing to Methods

° Example:

```java
/**
 * Swaps a [ i ] and a [ j ]
 */
public void swap (int a[ ], int i, int j)
{
    int temp = a[ i ];
    a[ i ] = a[ j ];
    a[ j ] = temp;
}
```
Returning Arrays from Methods

° As for other objects, an array can be returned from a method.
° The returned array is usually constructed within the method or obtained from calls to other methods.
° The return type of a method that returns an array with \texttt{someType} elements is designated as \texttt{someType [ ]}.
Returning from Methods

Example:

```java
public double[] solveQuadratic(double a, double b, double c)
{
    double d = b * b - 4 * a * c;
    if (d < 0) return null;
    d = Math.sqrt(d);
    double roots[] = new double[2];
    roots[0] = (-b - d) / (2*a);
    roots[1] = (-b + d) / (2*a);
    return roots;
}
```

Or simply:

```java
return new double[] {
    (-b - d) / (2*a),
    (-b + d) / (2*a)
};
```
Summary

° For loops allow for array modification
  • Typically possible to modify one element at a time

° For loop contains an initializer, condition, and condition modifier

° Arrays represent data is a series of memory locations
  • All data has same array name
  • Specific locations located with subscripts

° For loops and arrays go together well
  • Fixed number of loop iterations and array size