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# Object-Oriented Programming

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## Collection of Data

# Acknowledgement

- The contents of these slides have origin from School of Computing, National University of Singapore.
- We greatly appreciate support from Mr. Aaron Tan Tuck Choy, and Dr. Low Kok Lim for kindly sharing these materials.

# Policies for students

- These contents are only used for students PERSONALLY.
- Students are NOT allowed to modify or deliver these contents to anywhere or anyone for any purpose.

# Recording of modifications

- Course website address is changed to <http://sakai.it.tdt.edu.vn>
- Slides “Practice Exercises” are eliminated.
- Course codes cs1010, cs1020, cs2010 are placed by 501042, 501043, 502043 respectively.

# Objectives

Using **arrays**

**Generics:** Allowing operations not tied to a specific data type

Classes: **Vector** and **ArrayList**

# References



## Book

- **Array:** Chapter 1, Section 1.1, pages 35 to 38
- **Generics:** Chapter 9, Section 9.4, pages 499 to 507



IT-TDT Sakai → 501043  
website → Lessons

- <http://sakai.it.tdt.edu.vn>

# Outline (1/2)

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# Outline (2/2)

## 3. Vector

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3.3 Example

## 4. ArrayList

4.1 Introduction

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# 0. Recapitulation

- We explored OOP concepts learned in week 2 in more details (**constructors, overloading methods, class and instance methods**).
- In week 3, we learned some new OOP concepts (**encapsulation, accessors, mutators, “this” reference, overriding methods**)
- **UML** was introduced to represent OO components

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# **1 Array**

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A collection of homogeneous data

# Introduction

- Array is the simplest way to store a collection of data of the same type (homogeneous)
- It stores its elements in contiguous memory
  - Array index begins from zero
  - Example of a 5-element integer array  $A$  with elements filled

A

24	7	-3	15	9
$A[0]$	$A[1]$	$A[2]$	$A[3]$	$A[4]$

# Array in C (1/2)

```
#include <stdio.h>
#define MAX 6

int scanArray(double [], int);
void printArray(double [], int);
double sumArray(double [], int);

int main(void) {
    double list[MAX];
    int size;

    size = scanArray(list, MAX);
    printArray(list, size);
    printf("Sum = %f\n",
           sumArray(list, size));

    return 0;
}
```

```
// To read values into arr and return
// the number of elements read.
int scanArray(double arr[], int max_size) {
    int size, i;

    printf("How many elements? ");
    scanf("%d", &size);
    if (size > max_size) {
        printf("Exceeded max; you may only enter");
        printf(" %d values.\n", max_size);
        size = max_size;
    }
    printf("Enter %d values: ", size);
    for (i=0; i<size; i++) {
        scanf("%lf", &arr[i]);
    }
    return size;
}
```

sum\_array.c

# Array in C (2/2)

sum\_array.c

```
// To print values of arr
void printArray(double arr[], int size) {
    int i;

    for (i=0; i<size; i++)
        printf("%f ", arr[i]);
    printf("\n");
}

// To compute sum of all elements in arr
double sumArray(double arr[], int size) {
    int i;
    double sum = 0.0;

    for (i=0; i<size; i++)
        sum += arr[i];
    return sum;
}
```

# Array in Java (1/2)

- In Java, **array is an object**.
- Every array has a **public length** attribute (it is not a method!)

```
public class TestArray1 {  
  
    public static void main(String[] args) {  
        int[] arr; // arr is a reference  
  
        // create a new integer array with 3 elements  
        // arr now refers (points) to this new array  
        arr = new int[3];  
  
        // using the length attribute  
        System.out.println("Length = " + arr.length);  
  
        arr[0] = 100;  
        arr[1] = arr[0] - 37;  
        arr[2] = arr[1] / 2;  
        for (int i=0; i<arr.length; i++)  
            System.out.println("arr[" + i + "] = " + arr[i]);  
    }  
}
```

TestArray1.java

Declaring an array:  
`datatype[] array_name`

Constructing an array:  
`array_name = new datatype[size]`

Accessing individual  
array elements.

Length = ?  
arr[0] = ?  
arr[1] = ?  
arr[2] = ?

# Array in Java (2/2)

- Alternative loop syntax for accessing array elements
- Illustrate `toString()` method in `Arrays` class to print an array

```
public class TestArray2 {  
    public static void main(String[] args) {  
        // Construct and initialise array  
        double[] arr = { 35.1, 21, 57.7, 18.3 };  
  
        // using the length attribute  
        System.out.println("Length = " + arr.length);  
  
        for (int i=0; i<arr.length; i++) {  
            System.out.print(arr[i] + " ");  
        }  
        System.out.println();  
  
        // Alternative way  
        for (double element: arr) {  
            System.out.print(element + " ");  
        }  
        System.out.println();  
        System.out.println(Arrays.toString(arr));  
    }  
}
```

TestArray2.java

```
Length = 4  
35.1 21.0 57.7 18.3  
35.1 21.0 57.7 18.3  
[35.1, 21.0, 57.7, 18.3]
```

Syntax (enhanced for-loop):  
`for (datatype e: array_name)`

Go through all elements in the array. "e" automatically refers to the array element sequentially in each iteration

Using `toString()` method  
in `Arrays` class

# Array as a Parameter

- The reference to the array is passed into a method
  - Any modification of the elements in the method will affect the actual array

```
public class TestArray3 {  
    public static void main(String[] args) {  
        int[] list = { 22, 55, 33 };  
  
        swap(list, 0, 2);  
  
        for (int element: list)  
            System.out.print(element + " ");  
        System.out.println();  
    }  
  
    // To swap arr[i] with arr[j]  
    public static void swap(int[] arr, int i, int j) {  
        int temp = arr[i]; arr[i] = arr[j]; arr[j] = temp;  
    }  
}
```

TestArray3.java



# Detour: String[] in main() method

- The main() method contains a parameter which is an array of String objects
- We can use this for command-line arguments

```
public class TestCommandLineArgs {  
    public static void main(String[] args) {  
        for (int i=0; i<args.length; i++)  
            System.out.println("args[" + i + "] = " + args[i]);  
    }  
}
```

TestCommandLineArgs.java

```
java TestCommandLineArgs The "Harry Potter" series has 7 books.  
args[0] = The  
args[1] = Harry Potter  
args[2] = series  
args[3] = has  
args[4] = 7  
args[5] = books.
```

# Returning an Array

- Array can be returned from a method

```
public class TestArray4 {  
    public static void main(String[] args) {  
        double[] values;  
  
        values = makeArray(5, 999.0);  
  
        for (double value: values) {  
            System.out.println(value + " ");  
        }  
    }  
  
    // To create an array and return it to caller  
    public static double[] makeArray(int size, double limit) {  
        double[] arr = new double[size];  
  
        for (int i=0; i < arr.length; i++)  
            arr[i] = limit/(i+1);  
  
        return arr;  
    }  
}
```

TestArray4.java

```
999.0  
499.5  
333.0  
249.75  
199.8
```

Return type:  
datatype[]

# Common Mistakes (1/3)



- **length** versus **length()**
  - To obtain length of a **String** object **str**, we use the **length()** method
    - Example: **str.length()**
  - To obtain length (size) of an array **arr**, we use the **length** attribute
    - Example: **arr.length**
- Array index out of range
  - Beware of **ArrayIndexOutOfBoundsException**

```
public static void main(String[] args) {  
    int[] numbers = new int[10];  
    . . .  
    for (int i = 1; i <= numbers.length; i++)  
        System.out.println(numbers[i]);  
}
```

## Common Mistakes (2/3)

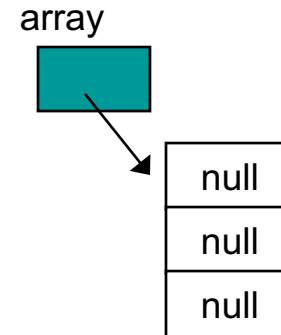


- When you have an **array of objects**, it's very common to forget to instantiate the array's objects.
- Programmers often instantiate the array itself and then think they're done – that leads to `java.lang.NullPointerException`
- Example on next slide
  - It uses the `Point` class in the API
  - Refer to the API documentation for details

# Common Mistakes (3/3)



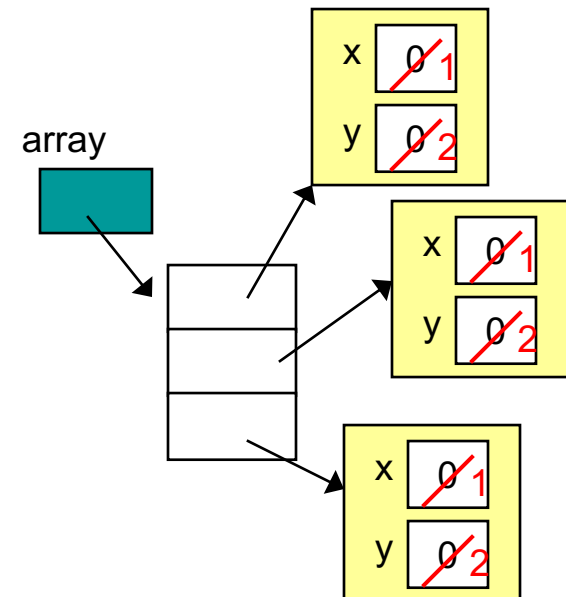
```
Point[] array = new Point[3];  
for (int i=0; i<array.length; i++) {  
    array[i].setLocation(1,2);  
}
```



There are no objects referred to by array[0], array[1], and array[2], so how to call setLocation() on them?!

Corrected code:

```
Point[] array = new Point[3];  
for (int i=0; i<array.length; i++) {  
    array[i] = new Point();  
    array[i].setLocation(1,2);  
}
```

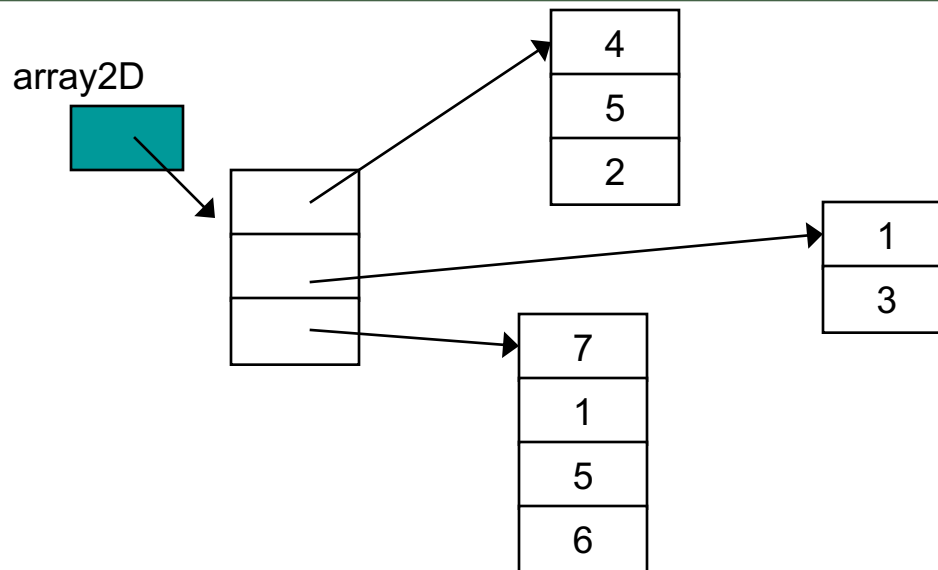


## 2D Array (1/2)

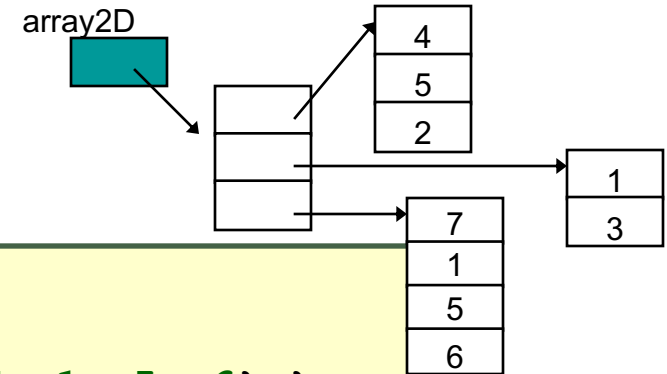
- A two-dimensional (2D) array is an array of array.
- This allows for rows of **different lengths**.

```
// an array of 12 arrays of int  
int[][] products = new int[12][];
```

```
int[][] array2D = { {4,5,2}, {1,3},  
                   {7,1,5,6} };
```



# 2D Array (2/2)



```
public class Test2DArray {
    public static void main(String[] args) {
        int[][] array2D = { {4, 5, 2}, {1, 3}, {7, 1, 5, 6} };

        System.out.println("array2D.length = " + array2D.length);
        for (int i = 0; i < array2D.length; i++)
            System.out.println("array2D[" + i + "].length = "
                               + array2D[i].length);

        for (int row = 0; row < array2D.length; row++) {
            for (int col = 0; col < array2D[row].length; col++)
                System.out.print(array2D[row][col] + " ");
            System.out.println();
        }
    }
}
```

Test2DArray.java

```
array2D.length = 3
array2D[0].length = ?
array2D[1].length = ?
array2D[2].length = ?
?
?
?
```

## Drawback

- Array has one major drawback:
  - Once initialized, the array size is **fixed**
  - Reconstruction is required if the array size changes
  - To overcome such limitation, we can use some classes related to array
- Java has an **Array** class
  - Check API documentation and explore it yourself
- However, we will not be using this **Array** class much; we will be using some other classes such as **Vector** or **ArrayList**
  - Differences between **Vector** and **ArrayList** are in slide 41
- Before doing Vector/ArrayList, we will introduce another concept called **Generics**



## **2 Generics**

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Allowing operation on objects of various types

# Motivation

- There are programming solutions that are applicable to a wide range of **different data types**
  - The code is exactly the same other than the data type declarations
- In C, there is no easy way to exploit the similarity:
  - You need a separate implementation for each data type
- In Java, you can make use of **generic programming**:
  - A mechanism to specify solution without tying it down to a specific data type

## Eg: The **IntPair** Class (non-generic)

- Let's define a class to:
  - Store a pair of integers, e.g. (74, -123)
  - Many usages, can represent 2D coordinates, range (min to max), height and weight, etc.

IntPair.java

```
class IntPair {  
  
    private int first, second;  
  
    public IntPair(int a, int b) {  
        first = a;  
        second = b;  
    }  
  
    public int getFirst() { return first; }  
    public int getSecond() { return second; }  
}
```

# Using the **IntPair** Class (non-generic)

```
// This program uses the IntPair class to create an object
// containing the lower and upper limits of a range.
// We then use it to check that the input data fall within
// that range.
```

```
import java.util.Scanner;
public class TestIntPair {
```

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

```
        IntPair range = new IntPair(-5, 20);
```

```
        Scanner sc = new Scanner(System.in);
```

```
        int input;
```

```
        do {
```

```
            System.out.printf("Enter a number in (%d to %d): ",
                               range.getFirst(), range.getSecond());
```

```
            input = sc.nextInt();
```

```
        } while( input < range.getFirst() ||
                 input > range.getSecond() );
```

```
    }
```

```
}
```

```
Enter a number in (-5 to 20): -10
```

```
Enter a number in (-5 to 20): 21
```

```
Enter a number in (-5 to 20): 12
```

TestIntPair.java

# Observation

- The **IntPair** class idea can be easily extended to other data types:
  - **double**, **String**, etc.
- The resultant code would be almost the same!

```
class StringPair {  
    private String first, second;  
  
    public StringPair( String a, String b ) {  
        first = a;  
        second = b;  
    }  
  
    public String getFirst() { return first; }  
    public String getSecond() { return second; }  
}
```

Only differences are the  
data type declarations

# The Generic **Pair** Class

```
class Pair <T> {  
    private T first, second;  
  
    public Pair(T a, T b) {  
        first = a;  
        second = b;  
    }  
  
    public T getFirst() { return first; }  
    public T getSecond() { return second; }  
}
```

Pair.java

- Important restriction:
  - ❑ The generic type can be substituted by **reference data type only**
  - ❑ Hence, **primitive data types are NOT allowed**
  - ❑ Need to use wrapper class for primitive data type

# Using the Generic **Pair** Class

TestGenericPair.java

```
public class TestGenericPair {  
  
    public static void main(String[] args) {  
  
        Pair<Integer> twoInt = new Pair<Integer>(-5, 20);  
        Pair<String> twoStr = new Pair<String>("Turing", "Alan");  
  
        // You can have pair of any reference data types!  
        // Print out the integer pair  
        System.out.println("Integer pair: (" + twoInt.getFirst()  
                           + ", " + twoInt.getSecond() + ")");  
  
        // Print out the String pair  
        System.out.println("String pair: (" + twoStr.getFirst()  
                           + ", " + twoStr.getSecond() + ")");  
  
    }  
}
```

- The formal generic type **<T>** is substituted with the actual data type supplied by the user:
  - The effect is similar to generating a new version of the **Pair** class, where **T** is substituted

# Autoboxing/unboxing (1/2)

- The following statement invokes **autoboxing**

```
Pair<Integer> twoInt = new Pair<Integer>(-5, 20);
```

- **Integer** objects are expected for the constructor, but -5 and 20, of primitive type **int**, are accepted.
- **Autoboxing** is the automatic conversion that the Java compiler makes between the primitive types and their corresponding object wrapper classes
  - The primitive values -5 and 20 are converted to objects of **Integer**
- The Java compiler applies autoboxing when a primitive value is:
  - Passed as a parameter to a method that expects an object of the corresponding wrapper class
  - Assigned to a variable of the correspond wrapper class



# Autoboxing/unboxing (2/2)

- Converting an object of a wrapper type (e.g.: **Integer**) to its corresponding primitive (e.g: **int**) value is called **unboxing**.
- The Java compiler applies unboxing when an object of a wrapper class is:
  - ❑ Passed as a parameter to a method that expects a value of the corresponding primitive type
  - ❑ Assigned to a variable of the corresponding primitive type

```
int i = new Integer(5); // unboxing
Integer intObj = 7;      // autoboxing
System.out.println("i = " + i);
System.out.println("intObj = " + intObj);
```

```
i = 5
intObj = 7
```

```
int a = 10;
Integer b = 10;      // autoboxing
System.out.println(a == b);
```

```
true
```

# The Generic **NewPair** Class

- We can have more than one generic type in a generic class
- Let's modify the generic pair class such that:
  - Each pair can have two values of **different data types**

```
class NewPair <S,T> {  
    private S first;  
    private T second;  
  
    public NewPair(S a, T b) {  
        first = a;  
        second = b;  
    }  
  
    public S getFirst() { return first; }  
    public T getSecond() { return second; }  
}
```

You can have multiple generic data types.  
**Convention:** Use single uppercase letters for generic data types.

NewPair.java

# Using the Generic **NewPair** Class

TestNewGenericPair.java

```
public class TestNewGenericPair {  
  
    public static void main(String[] args) {  
  
        NewPair<String, Integer> someone =  
            new NewPair<String, Integer>("James Gosling", 55);  
  
        System.out.println("Name: " + someone.getFirst());  
        System.out.println("Age: " + someone.getSecond());  
    }  
}
```

```
Name: James Gosling  
Age: 55
```

- This **NewPair** class is now very flexible!
  - Can be used in many ways

# Summary

- Caution:
  - ❑ Generics are useful when the code remains unchanged other than differences in data types
  - ❑ When you declare a generic class/method, make sure that the code is valid for all possible data types
- Additional Java Generics topics (not covered):
  - ❑ Generic methods
  - ❑ Bounded generic data types
  - ❑ Wildcard generic data types

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## **3** Vector class

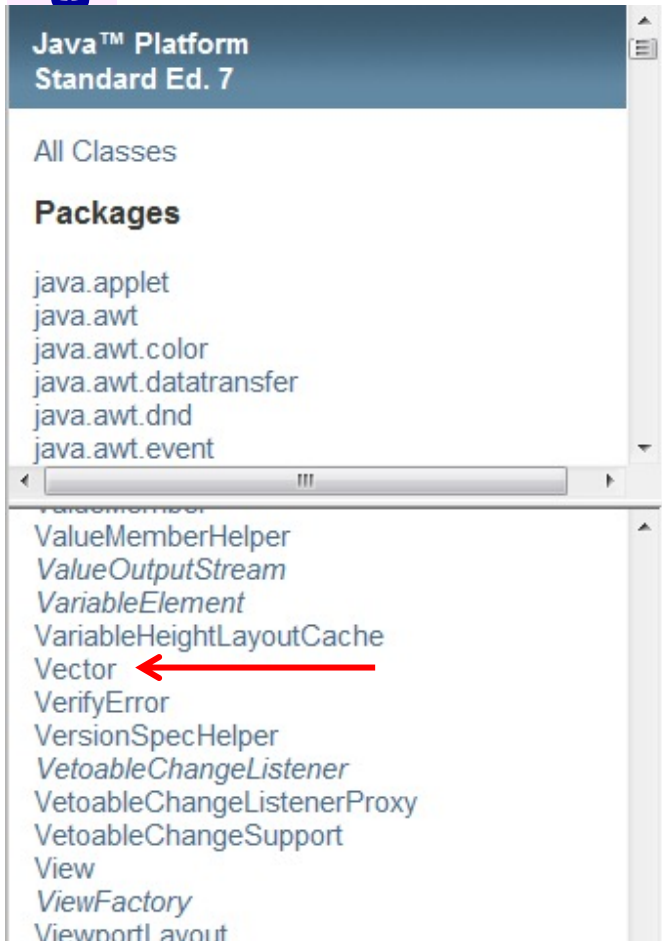
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Class for dynamic-size arrays

# Motivation

- Java offers a **Vector** class to provide:
  - Dynamic size
    - expands or shrinks automatically
  - Generic
    - allows any reference data types
  - Useful predefined methods
- Use array if the size is fixed; use **Vector** if the size may change.

# API documentation (1/3)



## Method Summary

### Methods

Modifier and Type	Method and Description
boolean	<b>add</b> ( <b>E</b> e) Appends the specified element to the end of this collection.
void	<b>add</b> (int index, <b>E</b> element) Inserts the specified element at the specified position in this collection.
boolean	<b>addAll</b> ( <b>Collection</b> <? <b>E</b> > c) Appends all of the elements in the specified collection to the end of this collection, using the iterator to traverse the collection.
boolean	<b>addAll</b> (int index, <b>Collection</b> <? <b>E</b> > c) Inserts all of the elements in the specified collection into this collection at the specified position.
void	<b>addElement</b> ( <b>E</b> obj) Adds the specified component to the end of this vector.
int	<b>capacity</b> () Returns the current capacity of this vector.
void	<b>clear</b> () Removes all of the elements from this vector.

# API documentation (2/3)

PACKAGE

```
import java.util.Vector;
```

SYNTAX

```
//Declaration of a Vector reference  
Vector<E> myVector;
```

```
//Initialize a empty Vector object  
myVector = new Vector<E>;
```

## Commonly Used Method Summary

boolean

*isEmpty()*

Tests if this vector has no components.

int

*size()*

Returns the number of components in this vector.



# API documentation (3/3)

## Commonly Used Method Summary (continued)

<b>boolean</b>	<i>add</i> ( <b>E</b> o) Appends the specified element to the end of this Vector.
<b>void</b>	<i>add</i> ( <b>int</b> index, <b>E</b> element) Inserts the specified element at the specified position in this Vector.
<b>E</b>	<i>remove</i> ( <b>int</b> index) Removes the element at the specified position in this Vector.
<b>boolean</b>	<i>remove</i> ( <b>Object</b> o) Removes the first occurrence of the specified element in this Vector If the Vector does not contain the element, it is unchanged.
<b>E</b>	<i>get</i> ( <b>int</b> index) Returns the element at the specified position in this Vector.
<b>int</b>	<i>indexOf</i> ( <b>Object</b> elem) Searches for the first occurrence of the given argument, testing for equality using the equals method.
<b>boolean</b>	<i>contains</i> ( <b>Object</b> elem) Tests if the specified object is a component in this vector.

# Example

TestVector.java

```
import java.util.Vector;
public class TestVector {

    public static void main(String[] args)

        Vector<String> courses;

        courses = new Vector<String>();

        courses.add("501043");
        courses.add(0, "501042");
        courses.add("502043");

        System.out.println(courses);
        System.out.println("At index 0: " + courses.get(0));

        if (courses.contains("501043"))
            System.out.println("501043 is in courses");

        courses.remove("501043");
        for (String c: courses)
            System.out.println(c);
    }
}
```

**Output:**

```
[501042, 501043, 502043]
At index 0: 501042
501043 is in courses
501042
502043
```

Vector class has a nice **toString()** method that prints all elements

The enhanced for-loop is applicable to **Vector** objects too!

---

## **4 ArrayList class**

---

Another class for dynamic-size arrays

# Introduction (1/2)

- Java offers an **ArrayList** class to provide similar features as **Vector**:
  - Dynamic size
    - expands or shrinks automatically
  - Generic
    - allows any reference data types
  - Useful predefined methods
- Similarities:
  - Both are index-based and use an array internally
  - Both maintain insertion order of element
- So, what are the differences between **Vector** and **ArrayList**?
  - This is one of the most frequently asked questions, and at interviews!

# Introduction (2/2)

- Differences between **Vector** and **ArrayList**

Vector	ArrayList
Since JDK 1.0	Since JDK 1.2
Synchronised * (thread-safe)	Not synchronised
Slower (price of synchronisation)	Faster ( $\approx 20 - 30\%$ )
Expansion: default to double the size of its array (can be set)	Expansion: increases its size by $\approx 50\%$

- **ArrayList** is preferred if you do not need synchronisation
  - Java supports multiple threads, and these threads may read from/write to the same variables, objects and resources. Synchronisation is a mechanism to ensure that Java thread can execute an object's synchronised methods one at a time.
- When using **Vector** / **ArrayList**, always try to initialise to the largest capacity that your program will need, since expanding the array is costly.
  - Array expansion: allocate a larger array and copy contents of old array to the new one

# API documentation (1/3)

Java™ Platform  
Standard Ed. 7

All Classes

## Packages

java.applet  
java.awt  
java.awt.color  
java.awt.datatransfer  
java.awt.dnd  
java.awt.event

ArrayIndexOutOfBoundsException  
ArrayList  
Arrays  
ArrayStoreException  
ArrayType  
ArrayType  
AssertionError  
AsyncBoxView  
AsyncHandler  
AsynchronousByteChannel  
AsynchronousChannel  
AsynchronousChannelGroup  
AsynchronousChannelProvider  
AsynchronousCloseException  
AsynchronousFileChannel

## Method Summary

### Methods

Modifier and Type	Method and Description
boolean	<b>add</b> ( <b>E</b> e) Appends the specified element to the e
void	<b>add</b> (int index, <b>E</b> elemen Inserts the specified element at the spe
boolean	<b>addAll</b> ( <b>Collection</b> <? ext Appends all of the elements in the spec iterator.
boolean	<b>addAll</b> (int index, <b>Colle</b> Inserts all of the elements in the specifi
void	<b>clear</b> () Removes all of the elements from this
<b>Object</b>	<b>clone</b> () Returns a shallow copy of this Array
boolean	<b>contains</b> ( <b>Object</b> o) Returns true if this list contains the s
void	<b>ensureCapacity</b> (int minC

# API documentation (2/3)

PACKAGE	<pre>import java.util.ArrayList;</pre>
SYNTAX	<pre><i>//Declaration of a ArrayList reference</i> ArrayList&lt;E&gt; myArrayList;  <i>//Initialize a empty ArrayList object</i> myArrayList = new ArrayList&lt;E&gt;;</pre>

## Commonly Used Method Summary

<b>boolean</b>	<b><i>isEmpty()</i></b> Returns <b>true</b> if this list contains no element.
<b>int</b>	<b><i>size()</i></b> Returns the number of elements in this list.

# API documentation (3/3)

Commonly Used Method Summary (continued)	
<b>boolean</b>	<b><i>add(E e)</i></b> Appends the specified element to the end of this list.
<b>void</b>	<b><i>add(int index, E element)</i></b> Inserts the specified element at the specified position in this list.
<b>E</b>	<b><i>remove(int index)</i></b> Removes the element at the specified position in this list.
<b>boolean</b>	<b><i>remove(Object o)</i></b> Removes the first occurrence of the specified element from this list, if it is present.
<b>E</b>	<b><i>get(int index)</i></b> Returns the element at the specified position in this list.
<b>int</b>	<b><i>indexOf(Object o)</i></b> Returns the index of the first occurrence of the specified element in this list, or -1 if this list does not contain the element.
<b>boolean</b>	<b><i>contains(Object elem)</i></b> Returns <b>true</b> if this list contains the specified element.



# Example

TestArrayList.java

```
import java.util.ArrayList;
import java.util.Scanner;

public class TestArrayList {
    public static void main(String[] args) {
        Scanner sc = new Scanner(System.in);
        ArrayList<Integer> list = new ArrayList<Integer>();

        System.out.println("Enter a list of integers, press ctrl-d to end.");
        while (sc.hasNext()) {
            list.add(sc.nextInt());
        }

        System.out.println(list); // u

        // Move first value to last
        list.add(list.remove(0));

        System.out.println(list);
    }
}
```

**Output:**

Enter a list ... to end.

31

17

-5

26

50

*(user pressed ctrl-d here)*

[31, 17, -5, 26, 50]

[17, -5, 26, 50, 31]

# Summary

## Java Elements

### **Array:**

- Declaration and common usage

### **Generics:**

- Allowing operation on objects of various types

### **Vector and ArrayList:**

- Dynamic-size arrays
- Declaration and useful methods

# Missing Digits (1/2)

- *[This is adapted from a 501042 exercise in C]*  
Write a program `MissingDigits.java` to read in a positive integer and list out all the digits that do not appear in the input number. (Assume input value has no leading zeroes.)
- You are to use primitive array, not Vector, ArrayList or any other related classes.
- You should use a `boolean` array.
- Sample run:

```
Enter a number: 73015
```

```
Missing digits in 73015: 2 4 6 8 9
```

## Missing Digits (2/2)

- What is the **boolean** array for? Idea?



# Detecting Duplicates (1/4)

- Using `ArrayList` class and random number generation.
  - You may use the `Math.random()` method or the `Random` class
- Write a program `DetectDuplicates.java` to read the following values:
  - The number of unique random integers to generate; and
  - Limit of the values: each random number generated should be in the range from 0 (inclusive) to limit (exclusive), or  $[0, \text{limit} - 1]$ .
  - (Certainly, the second input value must not be smaller than the first)
- Each time a random integer is generated, you must check if it is a duplicate of an earlier generated value. If it is, it must be discarded. The program goes on to generate the required number of unique random integers.
- You are to count how many duplicates were detected.

## Detecting Duplicates (2/4)

- Sample run
  - ▣ (In testing your code, each time a random number is generated, you may want to print it to check that the computation is correct)

```
Enter number of unique integers to generate: 10
Enter limit: 20
List: [16, 3, 15, 17, 2, 10, 18, 5, 12, 14]
Duplicates detected: 8
```

# Detecting Duplicates (3/4)

DetectDuplicates.java

```
import java.util.*;

public class DetectDuplicates {

    public static void main(String[] args) {

        Scanner sc = new Scanner(System.in);
        ArrayList<Integer> list = new ArrayList<Integer>();

        System.out.print("Enter number of unique ...: ");
        int numUnique = sc.nextInt();

        System.out.print("Enter limit: ");
        int limit = sc.nextInt();

        Random rnd = new Random();
        int countUnique = 0;
        int countDuplicates = 0;
        int num; // the random number
```

# Detecting Duplicates (4/4)

DetectDuplicates.java

```
System.out.println("List: " + list);  
System.out.println("Duplicates detected: "  
                    + countDuplicates);  
}  
}
```



---

End of file

---

- Sử dụng Array/Vector để thực hiện các bài toán sau:
  - Nhập/xuất mảng
  - Liệt kê âm, dương
  - Tìm kiếm phần tử x đầu tiên trong mảng
  - Tìm kiếm phần tử âm đầu tiên trong mảng
  - Tìm số nguyên tố đầu tiên trong mảng.
  - Tìm max âm/dương, chẵn/lẻ
  - Tính tổng các phần tử, phân tử dương, trung bình cộng, trung bình cộng các phần tử dương

- ❑ Thêm phần tử  $x$  vào cuối, đầu, vị trí bất kỳ trong mảng.
- ❑ Xóa phần tử cuối, đầu, phần tử  $x$  đầu tiên trong mảng, xóa tất cả phần tử  $= x$  trong mảng.
- ❑ Sắp xếp mảng tăng dần.