Introduction to Java (cs2514)

Lecture 3 & 4: Classes and Objects

M. R. C. van Dongen

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Monday 4–5 in WGB G24

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Objects and Classes

- Programmers construct their Java program from *objects*.
- Similar to a builder building a house from parts:
  - Doors;
  - Windows;
  - Walls;
  - ...
- Each part has its own function.
- The parts work together to form the house:
  - The house is the *sum* of the parts.
- The builder doesn't have to construct the parts.
- All he does is composing them.

Using Objects

- □ Objects are the first citizens of Java programs.
- □ You make an object work by calling its methods.
- □ Each method is a sequence of instructions.
- □ You can call a method even if you don't know its instructions.

Java

```java
System.out.println( "Hello world!" );
```

- □ Each method provides a service.
  - □ The method performs the service if you call the method.
- □ Different methods may provide different services:
  - □ Draw a picture;
  - □ Print text;
  - □ Set up a connection with another computer;
  - □ Compute something and return it;
  - □ …

Classes

- Each object belongs to a unique class.
- Different objects may belong to different classes.
  - `System.out`
  - `"Hello world!"`
- An object that belongs to a class is called an *instance* of the class.
- A class may have more than one instance:
  - `"Hello world!"`
  - `"What's up Doc?"`
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Classes (Continued)

- Each class has its own *Application Programming Interface* (API).
- The API describes how to use the class:
  - The names of the methods;
  - The types of the arguments;
  - The purpose of the arguments;
  - The return value;
  - Side effects;
  - ...
- The API defines a common protocol:

Java

```
System.out.println( "Hello world!" );
System.err.println( "Fatal error." );
```

- Different classes may have different APIs.
  - E.g. an instance of the String class cannot print.

Don't Try This at Home

```
"Hello world!".println( "What's up Doc?" );
```

Variables

- Most programs require computations.
  - Add 13% VAT to the price;
  - Add 2 penalty points;
  - Determine the maximum input value;
  - ...
- A single computation may require many sub-computations.
- You (usually) store the results of a computation in a *variable*.
- A variable has several properties:
  - A name;
  - A memory location to store its value;
  - Its current value.
- To change a variable's value, you *assign* it a new value.

Java

```
⟨variable's name⟩ = ⟨expression that determines the value⟩;
```

Variables

- □ Before you can use a variable, you must *declare* it.
- □ A variable declaration determines:
  - □ The variable’s name;
  - □ The variable’s type (the kind of its values);

Java

```java
int counter;
double interest;
```

- □ A variable declaration may also determine the initial value;

Java

```java
String greetings = "Hello world!";
```

Assignment and Equality

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- In Java you use = for assignment.

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- □ However, you can’t write the following in Java:

Don’t Try This at Home

```
1 = a; // ?
```

Introduction to Java

M. R. C. van Dongen

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Wrapper Classes

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About this Document

Assignment and Equality

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Don’t Try This at Home

```
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- □ In mathematics $a = a + 1$ is impossible.

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```
1 = a; // ?
```

- □ In mathematics $a = a + 1$ is impossible.
- □ However, writing the following is valid in Java.

Java

```
counter = counter + 1;
```

Types

- Java has different numeric types.

whole numbers	□ `byte`; □ `short`; □ `int`; □ `long`.
floating point	□ `float`; □ `double`.

- For whole numbers, `int` is usually a good choice.
- For floating point numbers, use `double`.

Operations on Numbers

unary plus	+ ⟨operand⟩;
unary minus	- ⟨operand⟩;
adding	⟨operand #1⟩ + ⟨operand #2⟩;
subtracting	⟨operand #1⟩ - ⟨operand #2⟩;
multiplying	⟨operand #1⟩ * ⟨operand #2⟩;
dividing	⟨operand #1⟩ / ⟨operand #2⟩;
...	

- Multiplicative operators bind more tightly:
  - a * b + c equals c + a * b equals (a * b) + c.
  - a / b + c equals c + a / b equals (a / b) + c.

Primitive Types and Object Reference Types

- A type starting with a lowercase letter is a *primitive* variable.
  - `int`, `bool`, `char`, `float`, ...
- A type starting with an uppercase letter is an *object/reference* variable.
  - `Integer`, `Boolean`, `Character`, `Float`, ...
  - Object variables have objects (primitive variables don't).

Java

```
Integer number = new Integer( 1 );
String string = number.toString( );
```

- Best view these types as wrapper classes for primitive type values.

Wrapper Classes

- Java has a *wrapper class* for each primitive type.

  `Integer` For ints:
  - `final Integer iObject = new Integer( 42 );`
  - `final int val = iObject.intValue( );`

  `Double` For doubles:
  - `final Double dObject = new Double( 3.14 );`
  - `final double val = dObject.doubleValue( );`

  `Boolean` For booleans:
  - `final Boolean bObject = new Boolean( true );`
  - `final boolean val = bObject.booleanValue( );`

  ....

Autoboxing and Unboxing

- Writing code to convert to and from wrapper classes is tedious.
  - You must type more.
  - It increases the code size.
- That’s why Java automates (some) conversions.
  - Automatic conversion to the wrapper class is called *autoboxing*.
  - Automatic conversion from the wrapper class is called *unboxing*.
- The conversion is done at runtime.

Autoboxing

- Let `val` be an value with primitive type type.
    - If you use `val` and `Java` expects an object, `Java` will autobox `val`.
- The type of `val` determines the wrapper class:
    - `int` ↦ `Integer`;
    - `double` ↦ `Double`;
    - `boolean` ↦ `Boolean`;
    - ...

Unboxing

- Unboxing turns wrapper class objects to primitive type values.
- The wrapper class type determines the primitive type.
  - `Integer` ↦ `int`;
  - `Double` ↦ `double`;
  - `Boolean` ↦ `boolean`;
  - ...
- The conversion is done at runtime.

Caching

- □ `Java` *caches* a limited number of wrapper class values.
- □ Guarantees shallow equality for small number of boxed values.
  - □ If `o1.equals( o2 )` then `o1 == o2`.
- □ For example, `new Integer( 0 ) == new Integer( 0 )`.
- □ In general this may not always work:
  - □ Almost always: `new Integer( 666 ) != new Integer( 666 )`.
- □ Caching is implemented because it saves memory.
- □ In general caching works for “small” primitive values.

  `boolean`: `true` and `false`.

  `byte`: 0–255.

  `char`: `\u0000`–`\u007f`.

  `short`: -128, -127, ..., 127.

  `int`: -128, -127, ..., 127.

Constant Variables

- □ A *constant* (variable) can only be assigned a value once.
- □ You declare a constant by adding the keyword `final`.

Java

```
final int ANSWER = 42;
```

- □ Making a variable constant is a form of documentation.
- □ It lets the compiler help you detect logic errors:

Java

```
final int ACCELLERATION = 9.8;
...
ACCELLERATION = 9.9;
```

Using Variables in Methods

- You cannot use an unassigned variable in a method.

Don't Try This at Home

```
int number;
int square = number * number;
```

Comments

- A *comment* is text that is ignored by the compiler.
- Comments have several purposes:
  - They describe the purpose of a variable or a method.
  - They describe a relationship between two or more variables.
    - This is called an invariant.
  - They are used to create API documentation.
- You should always document your programs.

One Line Comments

Java

```
// number of centimetres per inch
final double CENTIMETRES_PER_INCH = 2.56;
```

Multi-Line Line Comments

Java

```
/* Encrypted user password.
 * Use the changePassword( ) method to change the password.
 */
String password;
```

JavaDoc Comments

Java

```
/**
 * ...
 */
```

Variable Names

- Use names that are meaningful.
- The name should describe the variable's purpose.
- By convention each variable name should be a noun.
  - non-constant
    - Each name should start with a lowercase letter.
    - The rest should be letters and digits.
    - At word boundaries, you use an uppercase letter.
    - All other letters should be lowercase.
    - E.g. `sum`, `currentColour`, ...
  - constant
    - Use sequences of words, digits, and underscores.
    - Each word is spelt with uppercase letters.
    - At word boundaries, you use an underscore.
    - E.g. `CENT`, `CENTIMETRES_PER_INCH`, ...

Choosing Variable Names

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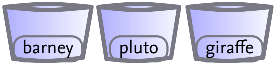
  - It helps you remember what the variable does.
  - It helps others understand the purpose of the variable.
- Choosing a good name helps you understand the purpose.
  - If you can't find a good name, do you really know the purpose?

Java Cares about its Types

Java

```
Dog barney = new Dog( );
Dog pluto = new Dog( );
Giraffe giraffe = new Giraffe( );
```



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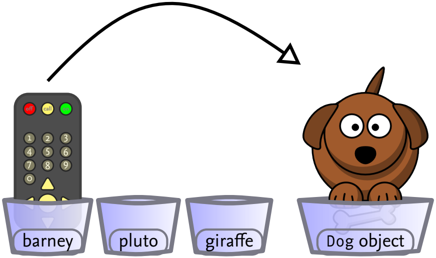

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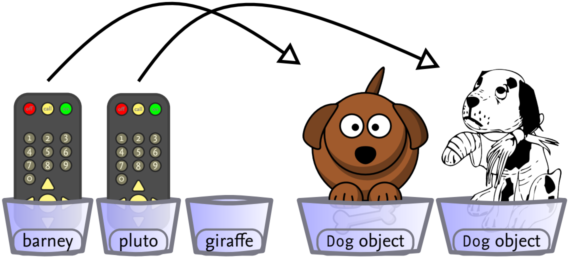

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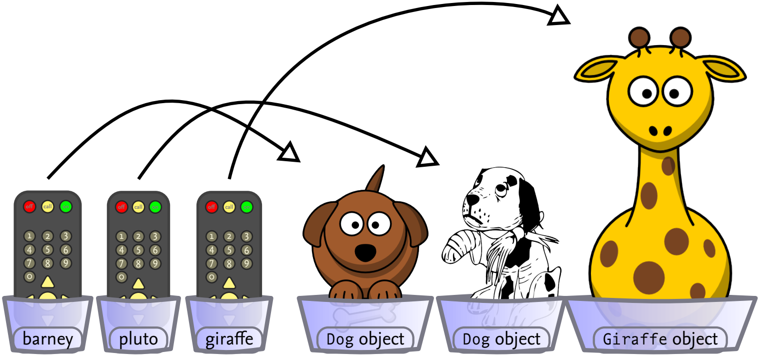

Types Really Matter

Don’t Try This at Home

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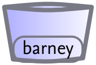

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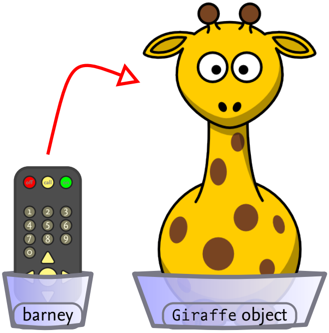

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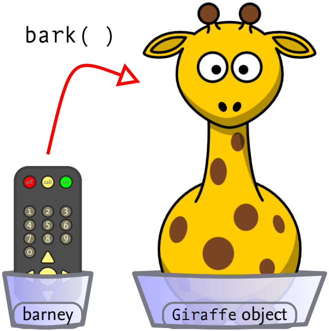
```
Dog barney = new Giraffe( );
barney.bark( );
```



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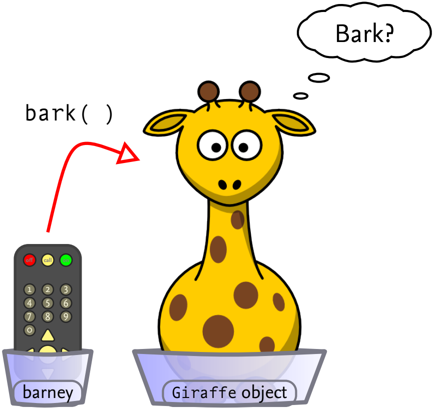
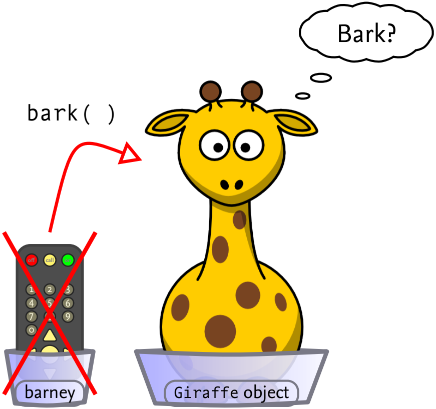
```
Dog barney = new Giraffe( );
barney.bark( ); // ???
```



Types Really Matter

Don’t Try This at Home

```
Dog barney = new Giraffe( ); // Impossible
barney.bark( ); // ???
```



Working with Objects

- Before you can use an object, you must construct (create) it.
- To construct an object, you call its constructor.
    - The constructor constructs and initialises the object.
- There may be different ways to construct an object.

Java

```java
final Rectangle bar = new Rectangle( x, y, width, height );
```

Constructing the Rectangle

Java

```
Rectangle bar = new Rectangle( x, y, width, height )
```

1. The new operator creates memory to represents the object;
2. The constructor uses its arguments to initialise the object;
3. The constructor returns a *reference* to the object;
4. The reference is assigned to the object reference value bar.
5. The reference may be used to call the object's instance methods.

Method Declarations

- To define/declare a method you provide:
  - The name of the method;
  - The return type;
  - The names and types of the formal parameters;
  - The types of the formal parameters.

Java

```
public int getWidth( ) { /* Implementation omitted. */ }
```

- You use `void` for a method without return value.

Java

```
public void println( String output ) { /* Implementation omitted. */ }
```

- If the argument types are different, the names may overlap.
  - This is called *overloading*:

Java

```
public void println( int output ) { /* Implementation omitted. */ }
```

Accessor and Mutator Methods

- A method that returns information about an object without modifying the object is an *accessor method.*
  - `double width = rectangle.getWidth( );`
- A method that modifies an object’s instance variables is a *mutator method.*
  - `rectangle.setWidth( 4.0 );`

Implementing a Tally Counter Class

- Let's implement a tally counter object class.
- The name of the class should be a noun.
  - The name should start with an uppercase letter.
  - The name should continue with letters and digits.
  - At each word boundary, you use an uppercase letter.
  - All other letters should be lowercase.
  - The name should describe the instances of the class.
  - For example, `StringBuilder`, `FullAdder`, ...

State and Behaviour

- Let's use `Counter` for our class name.
- How do we implement the class?
- We must determine what the `Counter` instances do and know.
- What the instance does is its *behaviour*.
  - Object behaviour is implemented as *instance methods*.
- What the instance knows is its *state*.
  - Object state is implemented as *instance variables*.

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  - Start thinking about the behaviour.
  - If behaviour requires state, you implement the st
  - Otherwise, you don't.

Behaviour

What Should a `Counter` Object Do?

Behaviour

What Should a `Counter` Object Do?

- Compute its next counter value:
  - `public void incrementValue( )`
- Return its current counter value:
  - `public int getValue( )`

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Behaviour

What Should a Counter Object Do? This indicates its state.

- Compute its next counter value:
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- Return its current counter value:
  - `public int getValue( )`

What Should a `Counter` Object Know?

What Should a `Counter` Object Know?

- Its counter value:
  - `private int value;`

The Class

Class Definition

Java

```
// Class for representing tally counter objects.
public class Counter {
    // The current tally counter value.
    private int value;

    // Returns the current counter value.
    public int getValue( ) {
        return value;
    }

    // Increment the counter value.
    public void incrementValue( ) {
        value = value + 1;
    }
}
```

The Class

Instance Attribute Declaration

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The Class

Instance Method Declarations

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Access/Visibility Specifiers

Java

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// Class for representing tally counter objects.
public class Counter {
    // The current tally counter value.
    private int value;

    // Returns the current counter value.
    public int getValue( ) {
        return value;
    }

    // Increment the counter value.
    public void incrementValue( ) {
        value = value + 1;
    }
}
```

The Class

Types

Java

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The Class

Comments: You should use JavaDoc Here

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}
```

Instance Variables

- Each `Counter` object has its own `value` variable.
- Let’s assume `tally` is a `Counter` object reference (variable):
  - To access its `value` you write `tally.value`.
- The `Counter` object owns the variable.
- Different `Counter` objects may have different values for `value`.

Instance Methods

- `Counter` objects can call `Counter` instance methods.
- Calling them is similar to accessing the instance variable:
  - `tally.incrementValue( );`
  - `int current = tally.getValue( );`

Encapsulation

- Objects should be self-governing.
- They should control their own instance variables.
- An object is self-governing if its instance variables are `private`.
- This is called *hiding* the instance variables.
  - Variable hiding prevents direct variable access by external clients.
- Hiding the instance variables makes the object self-contained.
  - It's as if the object's instance variables are in a capsule.
  - This is why instance variable hiding is usually called *encapsulation*.

Why Do We Need Encapulation?

- Direct attribute access is unsafe/dangerous.
    - A malicious external agent may corrupt the attribute’s value.
- Encapsulation simplifies the complexity of the API.
    - Makes learning the API easier.
    - Makes using the API easier.
    - Makes desiging the API easier.
    - Makes reasoning about the API easier.
    - Makes testing the API easier.
- Prevents clients from *depending* on the implementation.
    - Allows implementation changes without breaking clients.

Contract

- We hide all instance variables.
- We hide all methods that aren't/shouldn't be part of the API.

Hiding Methods

- Java also lets you hide method declarations.

Java

```
public int squareOfAnswer( ) {
    return answer( ) * answer( );
}

private int answer( ) {
    return 42;
}
```

- Hiding methods has similar advantages as hiding attributes.

Automatic Variables

- A variable that is declared in a method is called *automatic.*
  - It only lives for the lifespan of its block during its method call.

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Automatic Variables

- A variable that is declared in a method is called *automatic*.
  - It only lives for the lifespan of its block during its method call.
- Use automatic variables for intermediate computations.
- Don’t use instance attributes for intermediate computations.

Introduction

- Arrays are a special data type in `Java`.
- Arrays are objects that contain other things.
- There are two kinds of arrays:
  1. Arrays consisting of primitive data type values;
  2. Arrays consisting of object reference values;
- The type of the array determines the type of its values.
- Before you can use an array you must create it (it's an object).
  - When doing this, you must specify the array's length.
  - The length remains fixed.
- You can put things into the array.
- You can retrieve things from the array.
- You can only access arrays with index values:
  - Only `int` index values are allowed.
  - They must be non-negative;
  - They must be smaller than the length of the array.

Initialisation

Java

```
final int[] numbers = new int[ 10 ];
System.out.println( "length of numbers: " + numbers.length );

final String[] words = new String[ 5 ];
System.out.println( "length of words: " + words.length );
```

Initialisation

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```

Getting Stuff from the Array

- An array is best viewed as a tray/sequence with cups.
- Each cup has a number: 0, 1, ...
- The cups contain what's in the array:
    - `Object` references.
- The number of cups is the length of the array.
- Let `array` be a `Java` array.
- Then `array[ i ]` is the ith cup of `array`.

Java

```
final int[] numbers = new int[ 10 ];
...
System.out.println( "The first value is " + numbers[ 0 ] );
System.out.println( "The last value is " + numbers[ 9 ] );
```

Getting Stuff from the Array

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Writing Stuff to the Array

- The notation `array[ index ]` works just as with getting.
- Cups in the arrays work just like variables, so
  - `array[ index ] = value` assigns a `value` to the “`indexth`” cup.

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Java

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

numbers[ 0 ] = 1;
numbers[ 9 ] = 42;
System.out.println( numbers[ 0 ] + " == 1" );
System.out.println( numbers[ 9 ] + " == 42" );
```

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```

Default Values

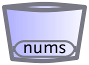
- When the JVM creates an array, it initialises the array's contents.
- Each cup in the array is filled with the same value.
- This value depends on the type of the array.

Numeric	`0;`
`boolean`	`false;`
`char`	`'\u0000';`
Object	`null.`

Arrays with Primitive Type Values

Java

```
byte[] nums = new byte[ 5 ];
nums[ 1 ] = 4;
nums[ 4 ] = 17;
```



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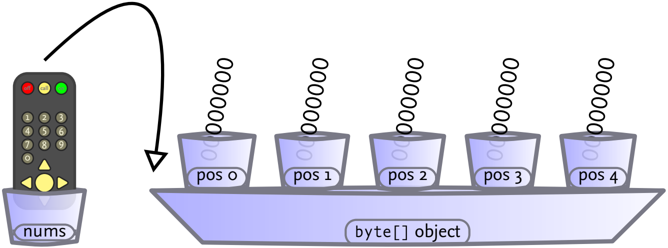

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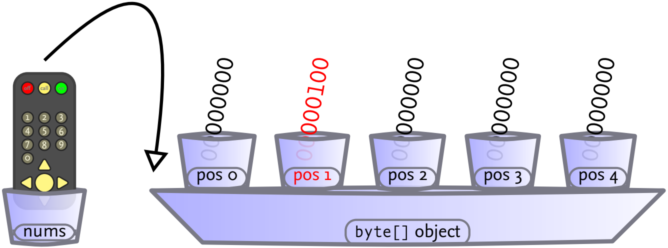

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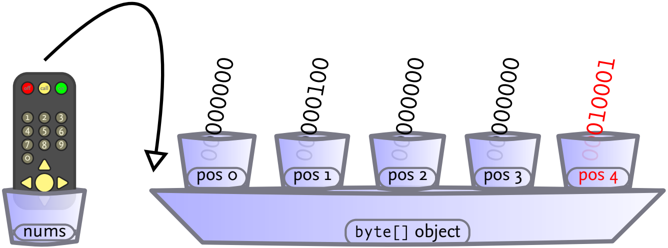
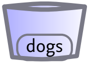


Arrays with Objects

Java

```
Dog[] dogs = new Dog[ 3 ];
dogs[ 1 ] = new Dog( );
dogs[ 1 ].bark( );
dogs[ 0 ].bark( );
```



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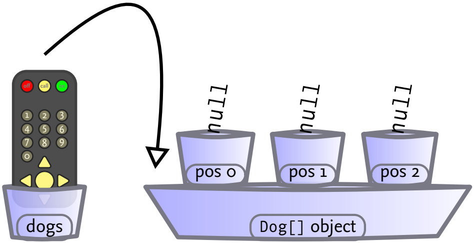

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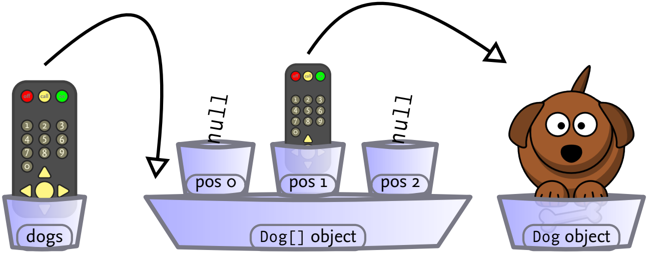

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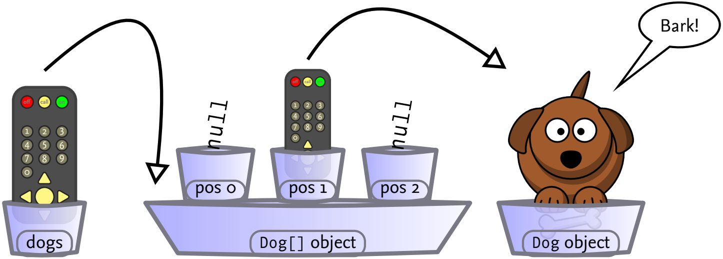

Arrays with Objects

Java

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Dog[] dogs = new Dog[ 3 ];
dogs[ 1 ] = new Dog( );
dogs[ 1 ].bark( );
dogs[ 0 ].bark( ); // Run-time error!
```

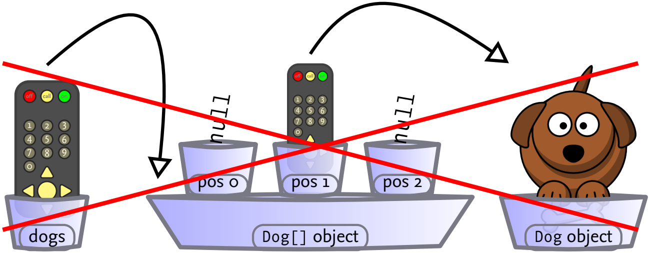

Arrays do Not Grow

- The length attribute of a Java array is final.
- So you cannot assign values to ⟨array⟩.length.
- The minimum size of any array is 0.
- The maximum size of any array is Integer.MAX_VALUE.

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Types Matter
Working with Objects
Encapsulation
Arrays
Introduction
Initialisation
Getting & Putting
Arrays do Not Grow
Partially Filled Arrays
Common Errors
Question Time
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Acknowledgements
References
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Partially Filled Arrays

- □ You must fill the array before you can use it.
- □ You usually start filling at the bottom (index 0).
- □ Then fill the next position (index 1).
- □ And so on.
- □ You need a counter to keep track of the current index.

Java

```java
final Scanner scanner = new Scanner( System.in );
final int[] values = new int[ scanner.nextInt( ) ];

int size = 0;
int next = 0;
while ((size != values.length) && (next >= 0)) {
    System.err.println( "Next value (negative value to stop): " );
    next = scanner.next( );
    if (next >= 0) {
        values[ size++ ] = next;
    }
}

final double percentage = 100.0 * size / values.length );
System.out.println( "Percentage filled is " + percentage );
```

Partially Filled Arrays

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- □ And so on.
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final Scanner scanner = new Scanner( System.in );
final int[] values = new int[ scanner.nextInt( ) ];

int size = 0;
int next = 0; // We need this to enter the loop.
while ((size != values.length) && (next >= 0)) {
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    next = scanner.next( );
    if (next >= 0) {
        values[ size++ ] = next;
    }
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final double percentage = 100.0 * size / values.length );
System.out.println( "Percentage filled is " + percentage );
```

Common Errors

Index too Large

Don’t Try This at Home

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

values[ 10 ] = 1;
```

Common Errors

Index too Small

Don't Try This at Home

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

values[ -1 ] = 1;
```

Common Errors

Uninitialised Values

Don’t Try This at Home

```
String[] words = new String[ 10 ];

if (words[ 0 ].equals( "yes" )) {
    System.out.println( "This isn’t printed." );
} else {
    System.out.println( "This also isn’t printed." );
}
```

Representing Bank Accounts

- Consider a bank account application.
- Each account has an owner and a balance.
  - We could represent the owners using a `String` array;
  - We could represent the balance using a `double` array.

Parallel Array Implementation

The for Loop Declares Its Own index Variable

Java

```
public class AccountManager {
    private final String[] owners;
    private final double[] balances;

    public AccountManager( final int size ) {
        final Scanner scanner = new Scanner( System.in );
        owners = new String[ size ];
        balances = new double[ size ];
        for (int index = 0; index != size; index++) {
            owners[ index ] = scanner.next( );
            balances[ index ] = scanner.nextDouble( );
        }
    }

    ...
}
```

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    ...
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```

Class-Based Implementation

Java

```
public class AccountManager {
    private final Account[] accounts;

    public AccountManager( final int size ) {
        final Scanner scanner = new Scanner( System.in );
        accounts = new Acount[ size ];
        for (int index = 0; index != size; index++) {
            final String owner = scanner.next( );
            final double balance = scanner.nextDouble( );
            accounts[ index ] = new Account( owner, balance );
        }
    }

    ...
}
```

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Comparison

Stability The parallel array implementation is "unstable:"

- □ If we need addresses we must change the constructor.

Security The parallel array implementation is not safe:

- □ Parallel array clients need access to all arrays:
  - □ `withdraw( owners, balances, nr, amount );`
  - □ This gives the client access to all account details.
  - □ They can even modify the array.
  - □ It violates encapsulation.
- □ Direct access for `Account` clients:
  - □ `account.withdraw( amount ).`
- □ Perhaps better to add service at `AccountManager` level:

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```
public void withdraw( final Account account, final double amount ) {
    if (⟨conditions are right⟩) {
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Question Time

Questions Anybody?

For Next Monday

- Study Chapters 2 and 3.

Acknowledgements

- This lecture is partially based on
  - [Sierra, and Bates 2004].
  - [Horstmann 2013].

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Sierra, Kathy, and Bert Bates [2004]. *Head First Java.* O'Reilly. ISBN: 978-0-596-00712-6.

About this Document

- This document was created with `pdflatex`.
- The LaTeX document class is `beamer`.