Graphics, classes, objects and program design

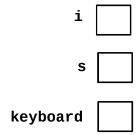
This lecture will

- Introduce the `EasyGraphics` class
- Cover the distinction between class **instance** methods and **static** methods
- Discuss the importance of **planning a solution** before writing a program
- Review a few simple **problem-solving strategies**

Objects and Values

- If you declare a variable of a basic type Java creates space to store the variables value
- If you declare a variable which is an object Java creates space to store a pointer to an object but doesn't create space for the object

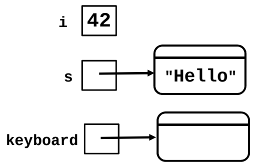
```
int i;
String s;
EasyReader keyboard;
```



Objects and Values

- You can't use variables until you assign values to them
- Generally if the declaration starts with a capital letter it is a reference to an object and anything you assign to it will need to have been created with the keyword **new**

```
int i = 42;
String s = "Hello";
EasyReader keyboard =
          new EasyReader();
```



`String` objects

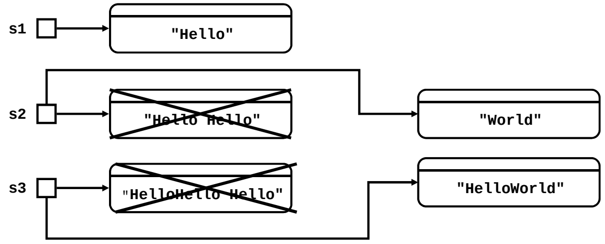
- Strings are unusual in that they are objects but can be created without **`new`**
- Once a **`String`** is created, its value cannot be changed – a **`String`** object is **immutable**
- A new **`String`** object is created when an assignment is made to a **`String`** variable

Creating new objects

- A new **`String`** object is created when an assignment is made to a **`String`** variable
- New memory space is allocated to store the new **`String`**s
- New memory space is allocated to store any other sort of object created with the reserved word **`new`**
- Old memory is reclaimed for future use in a process known as **garbage collection**

Garbage collection

```
String s1 = "Hello";
String s2 = "Hello Hello";
String s3 = s1+s2;
s2 = "World";
s3 = s1+s2;
```



The EasyGraphics class

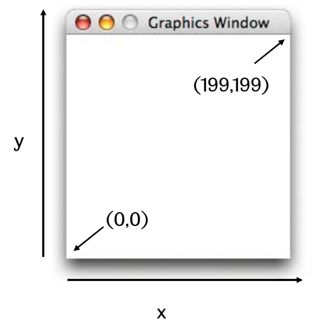
- The **`EasyGraphics`** class is part of the **`sheffield`** package
- An **`EasyGraphics`** object is created just like and **`EasyReader`** or **`EasyWriter`** object

```
EasyGraphics g = new EasyGraphics();
```

- This creates a window 200 pixels wide and 200 pixels high:

An EasyGraphics window

- For a 200 × 200 window the coordinate system runs from the origin (0,0) to (199,199)



The EasyGraphics class

```
EasyGraphics g = new EasyGraphics();
```

- Creates a window with 200 X 200 pixels
- The constructor is overloaded; it can be given parameters to create a window with a specific width and height:

```
EasyGraphics g =
            new EasyGraphics(520,384);
```

Colour and plotting

- The colour for graphics operations is set using the **`setColor`** method, which takes three parameters; the amount of red, green and blue in that order
- The colour values must be between 0 and 255 where the smaller the number the darker the colour is
- This sets the colour to bright red:

```
g.setColor(200,0,0);
```

Colour and plotting

- Having set the colour whatever command is obeyed next is in the colour you have set and that colour will remain in use until you reset it
- For instance the **`plot(x,y)`** method sets a pixel at coordinates (x,y) to the current colour so

```
g.setColor(200,0,0);
g.plot(100,100)
```

  creates a red dot at the coordinates (100,100)
- Black (0, 0, 0) is the default colour

Drawing lines

- There is an invisible **graphics cursor** at the current pixel, initially set to the origin
- We can move it to a new **`(x,y)`** position as follows:

```
g.moveTo(32,59);
```

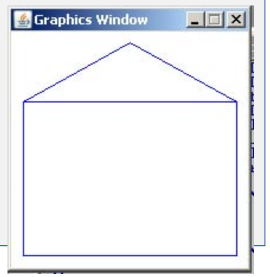
- Or move it and draw a line (in the current colour) from the current cursor position to its new one using the **`lineTo`** method

```
g.lineTo(45,96);
```

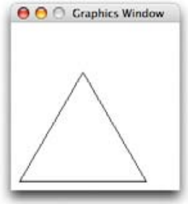
  which leaves the graphics cursor is at (45,96)

Example – a blue house

```
import sheffield.*;
public class House {
   public static void main(String[] args) {
      EasyGraphics g = new EasyGraphics(200,200);
      g.setColor(0,0,255);
      g.moveTo(10,140);
      g.lineTo(10,10);
      g.lineTo(190,10);
      g.lineTo(190,140);
      g.lineTo(10,140);
      g.lineTo(100,190);
      g.lineTo(190,140);
   }
}
```



Example – a triangle




```
import sheffield.*;
public class DrawTriangle {
   public static void main(String[] args)
     final double THETA= Math.PI/3.0;
     EasyReader keyboard = new EasyReader();
     int sideLen = keyboard.
          readInt("Enter the side length: ");
     EasyGraphics g = new EasyGraphics();
     g.moveTo(10,10);
     g.lineTo(
         10+(int)Math.round(sideLen*Math.cos(THETA)),
         10+(int)Math.round(sideLen*Math.sin(THETA)));
     g.lineTo(10+sideLen,10);
     g.lineTo(10,10);
   }
}
```

The **Math** class has trigonometric methods that work in radians

Other drawing methods

- The **moveTo** and **lineTo** methods can be combined using the method **drawLine**:

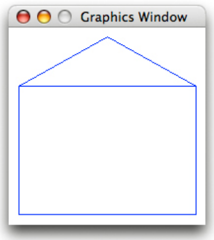
```
g.drawLine(x1,y1,x2,y2);
```

which draws a line from (x1,y1) to (x2,y2)

- This can be easier than using **moveTo** and **lineTo** if drawing a number of connected points

Example – house with drawLine

```
import sheffield.*;
public class HouseDrawLine {
   public static void main(String[] args) {
     EasyGraphics g = new EasyGraphics(200,200);
     g.setColor(0,0,255);
     g.drawLine(10,140,10,10);
     g.drawLine(10,10,190,10);
     g.drawLine(190,10,190,140)
     g.drawLine(190,140,10,140)
     g.drawLine(10,140,100,190)
     g.drawLine(100,190,190,140
   }
}
```



Drawing squares and rectangles

- These methods draw open or filled rectangles with the bottom left corner at coordinate (**x,y**), and with a width **w** and height **h**:

```
public void drawRectangle
     (int x, int y, int w, int h)
public void fillRectangle
      (int x, int y,int w, int h)
```

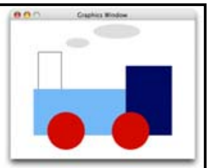
Drawing circles and elipses

- These methods draw open or filled ellipses with the bottom left corner at coordinate (**x,y**), and with a width **w** and height **h**:

```
public void drawEllipse
  (int x, int y, int w, int h)
public void fillEllipse
  (int x, int y, int w, int h)
```

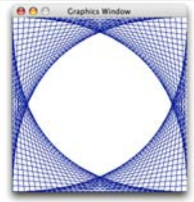
- You have to imagine where the bottom left hand corner of a circle is

A lovely choo-choo train



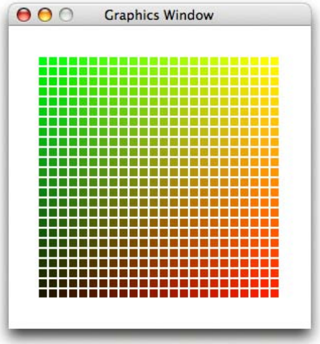
```
import sheffield.*;
public class Train {
   public static void main(String[] args) {
     EasyGraphics g = new EasyGraphics(400,300);
     g.drawRectangle(60,150,50,80); // funnel
     g.setColor(128,180,245);
     g.fillRectangle(50,50,200,100); // boiler
     g.setColor(0,0,100);
     g.fillRectangle(250,50,100,150); // cabin
     g.setColor(200,0,0);
     g.fillEllipse(80,20,80,80); // left wheel
     g.fillEllipse(220,20,80,80); // right wheel
     g.setColor(220,220,220);
     g.fillEllipse(120,240,50,20); // small puff
     g.fillEllipse(180,260,100,30); // big puff
   }
}
```

Making a spiders web



```
import sheffield.*;
public class WebMaker {
    public static void main(String args[]) {
       final int WIN_SIZE = 300; // size of window
       final int STEP_SIZE = 10; // step size between lines
       EasyGraphics g=new EasyGraphics(WIN_SIZE,WIN_SIZE);
       g.setColor(0,0,140);
       for (int x=0; x<WIN_SIZE; x+=STEP_SIZE) {
          g.drawLine(x,0,WIN_SIZE,x);
          g.drawLine(x,WIN_SIZE,0,x);
          g.drawLine(x,WIN_SIZE,WIN_SIZE,WIN_SIZE-x);
          g.drawLine(0,WIN_SIZE-x,x,0);
       }
    }
}
```

Output of the `Graticule` program



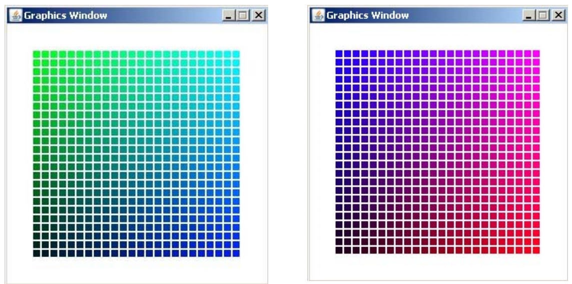
Nested loops – another example

```
// Graticule
final int WIN_SIZE = 300;  // window size
final int MARGIN = 30;     // margin around image
final int INCREMENT = 10;  // increment between squares
final int RECT_SIZE = 8;   // size of square

final int LAST_POSITION = WIN_SIZE-MARGIN-INCREMENT;
EasyGraphics g = new EasyGraphics(WIN_SIZE,WIN_SIZE);

for (int x=MARGIN; x<=LAST_POSITION; x+=INCREMENT)
  for (int y=MARGIN; y<=LAST_POSITION; y+=INCREMENT) {
    // choose some nice colours
    int red = (int)(x*255.0/LAST_POSITION);
    int green = (int)(y*255.0/LAST_POSITION);
    // draw a square at (x,y)
    g.setColor(red,green,0);
    g.fillRectangle(x,y,RECT_SIZE,RECT_SIZE);
  }
```

Output of variations on the Graticule program



Easy graphics methods

Method and Description
clear() Clear the EasyGraphics window
drawEllipse(int x, int y, int w, int h) Draw an empty ellipse
drawLine(int x0, int y0, int x1, int y1) Draw a line from (x0,y0) to (x1,y1)
drawRectangle(int x, int y, int w, int h) Draw an empty rectangle
drawString(java.lang.String s, int x, int y, int fontSize) Draw a string in the current foreground colour
fillEllipse(int x, int y, int w, int h) Draw a filled ellipse
fillRectangle(int x, int y, int w, int h) Draw a filled rectangle
getBlue(int x, int y) Get the blue RGB component of a given x,y coordinate
getGreen(int x, int y) Get the green RGB component of a given x,y coordinate
getRed(int x, int y) Get the red RGB component of a given x,y coordinate
lineTo(int x, int y) Draw a line from the current position to the given x,y coordinate
moveTo(int x, int y) Move the graphics cursor to the given x,y coordinate
plot(int x, int y) Plot a point at the given x,y coordinate
setColor(int r, int g, int b) Set the current drawing colour

- The list of methods effectively determines what we can do with the **`EasyGraphics`** class
- Or any class

Classes, objects and methods

- To use the **`EasyGraphics`** class we created an object, an instance of the class, using the word **`new`** and then called methods of the object
- In Java very little programming is done using the basic types **`byte, short, int, long, float, double, char`** and **`boolean`**
- Java is an object oriented language and most programming is done using classes, objects and their methods

Class methods and instance methods

- So far we have mainly used instance methods, methods that are invoked on an object, an instance of a class:

```
String s1 = "Sheffield";
String s2 = s1.replace('f','g');
```

- There are also methods that belong to the class, rather than to an instance of the class

```
double d = 3.14;
String s = String.valueOf(d);  //s = "3.14"
```

- This is a class method or a static method

More about class (static) methods

- A class method is usually invoked via the class name

```
import javax.swing.JOptionPane;

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

   String number =
      JOptionPane.showInputDialog("What number " +
             "would you like to multiply by two?");

    JOptionPane.showMessageDialog(null,
      "Two times "+number+
             " is "+Integer.valueOf(number)*2);
 }
}
```

How many class methods here?

Using static methods

- A class method is usually invoked via the class name

```
String s = "3.14";
double d = Double.valueOf(s);
```

Float, Long, Byte etc. also work

- We don't need an instance of the class in order to use a static method
- The **`Math`** class is entirely static and provides lots of useful class methods such as **`Math.abs(), Math.random(), Math.round(), Math.sin()`**

Writing programs

- Up to now we have been writing tiny little programs within the `main` method
- We are about to go on to writing more complicated programs creating our own classes with static and instance methods of their own and programming using objects of our own classes
- But we will start simply

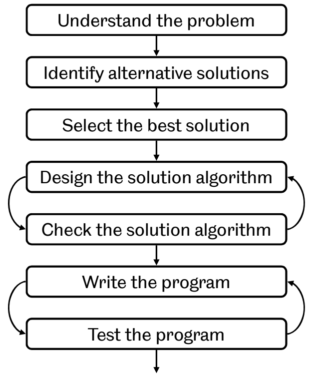
Simple programs

- We need a disciplined approach to developing programs, in which we identify the problem and plan a solution
- A **software design methodology** is usually followed – guidelines or rules that dictate the steps that should be taken in the software design process
- Later we will look at **object-oriented design**

Algorithms

- Currently we will focus on **top-down design**, a simple approach that is suitable for the design of small software systems
- A key stage in top-down design is writing a description of the steps needed to solve the problem – an **algorithm**

Solving a programming problem



Top-down design

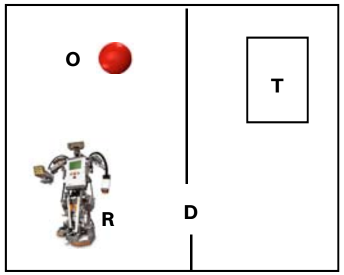
- The top-down approach to problem solving tries to decompose a large problem into subproblems
- This is also called **divide and conquer**
- We first list the steps needed to solve the problem
- Each step is then treated as a subproblem which is solved independently

Stepwise Refinement

- Each step on the route to a solution is then treated as a subproblem can be solved independently
- In turn, subproblems may give rise to sub-subproblems that must be solved, and so on
- This process of adding detail to a solution algorithm is called **stepwise refinement**

Example – moving a robot

- Starting from position **R**, a robot should collect an object **O** and then put it on the table **T**, moving via a doorway **D**



- The robot can turn to face any direction, move straight ahead and grasp or release an object

Developing the algorithm

- We assume that picking up and dropping an object are basic operations of the robot, so long as it is facing in the correct direction.
- The robot can achieve the goal with the following steps:
  1. Move from point **R** to point **O**
  2. Pick up the object at point **O**
  3. Move from point **O** to point **T**
  4. Put the object on the table at point **T**

Basic operations

Stepwise refinement

- Subproblem 1 was

  1. Move from point **R** to point **O**

- It can be refined to

  1.1 Turn to face point **O**

  1.2 Move from point **R** to point **O**

  and no farther because 1.1 and 1.2 are basic operations

Stepwise refinement

- Subproblem 3 was:

  3. Move from point **O** to point **T**

- It can be refined to

  3.1 Turn to face the doorway (point **D**)

  3.2 Move from point **O** to point **D**

  3.3 Turn to face point **T**

  3.4 Move from point **D** to point **T**

Moving the robot – complete algorithm

1. Move from point **R** to point **O**
   1.1 Turn to face point **O**
   1.2 Move from point **R** to point **O**
2. Pick up the object at point **O**
3. Move from point **O** to point **T**
   3.1 Turn to face the doorway (point **D**)
   3.2 Move from point **O** to point **D**
   3.3 Turn to face point **T**
   3.4 Move from point **D** to point **T**
4. Put the object on the table at point **T**

A real robot controller would have to be refined even further (e.g., to describe how sensor data is used to detect the doorway)

More about writing algorithms

- Algorithm is written in stylized English called **pseudocode**
- This can't be executed directly by the computer but uses the structural conventions of programming languages, whilst excluding language-specific details
- There is no 'correct' way to write pseudocode

More about writing algorithms

- There is no ‘correct’ way to write pseudocode but always use consistent numbering of pseudocode statements for sub-problems:

$2 \xrightarrow{\textit{refine}}$ 2.1, 2.2, 2.3

2.2 $\xrightarrow{\textit{refine}}$ 2.2.1, 2.2.2, 2.2.3

Selection and repetition in pseudocode

- We can also write simple decisions (selections) in pseudocode or repeat a step of the algorithm a number of times (looping), e.g.:

if the number is greater than one then
    add the number to the total
end

repeat
    ask the user for a letter
until the letter is ‘y’ or ‘n’

Understanding the problem

- An important part of understanding the problem is to identify the **inputs** to the problem, and the **outputs** that are produced.
- These can often be identified as **nouns** in the problem statement.

Example problem statement:

A program is required to prompt the computer user for the maximum and minimum temperature readings on a particular day, accept those readings as integers, and calculate and display the average temperature.

Identifying inputs and outputs

- The nouns are *program*, *computer user*, *maximum and minimum temperature*, *day*, *readings*, *integers*, *average temperature*.
- Some of these can be discounted, suggesting the following inputs and outputs:

Inputs:
maximum temperature
minimum temperature
Integers

Output:
average temperature
A real number

Verbs indicate processing steps

- Verbs in the problem description give an indication of the **processing steps** required in the algorithm
- The verbs in our example are *prompt*, *accept*, *calculate*, *display*

Algorithm

1. Prompt for temperatures
2. Get the maximum and minimum temperatures
3. Compute the average temperature
4. Display the average temperature

Stepwise refinement

- Complete algorithm:
  1. Prompt for temperatures
  2. Get the maximum and minimum temperatures
  3. Compute the average temperature
     3.1 Add the maximum and minimum temperatures and divide by two
  4. Display the average temperature

The temperature program

```
import sheffield.*;
public class AverageTemp {
  public static void main(String[] args) {
    EasyReader keyboard = new EasyReader();
    // Get the maximum and minimum temperatures
    int maxTemp = keyboard.readInt("Enter the maximum temperature: ");
    int minTemp = keyboard.readInt("Enter the minimum temperature: ");
    // Compute the average temperature
    double average = (maxTemp+minTemp)/2.0;
    // Display the average temperature
    System.out.println("The average temperature is " + average);
  }
}
```

Exercise

❓ **If Tom has three times as many apples as Susan and Susan has a quarter as many as Joe, how many does Mary have if Mary has two more than Tom and Joe has 4?**

The apples program

```
public class Apples {
  public static void main(String[] args) {
    int susan, tom, mary, joe=4;
    // susan has a quarter as many apples as joe
    susan=joe/4;
    // tom has three times as many apples as susan
    tom=3*susan;
    // mary has two more apples than tom
    mary=tom+2;
    // display the result
    System.out.println("Mary has "+mary+" apples.");
  }
}
```

```
>java Apples
Mary has 5 apples.
```

Problem solving strategies - analogy

- **Solution by analogy** – easier to adapt an existing solution than to start from scratch.
- Example: find the minimum value in a list of numbers.

set the minimum value to the first number in the list
for each successive number
If the number is less than the minimum then
set the minimum to that number
display the minimum value

- Now by analogy, write an algorithm to find the maximum value in a list of numbers.

Problem solving strategies - generalisation

- **Generalising a solution** – try to write general solutions to problems.
- What if we were asked the apples problem but Joe had 9 apples?
- We could – probably *should* – have written a more general version of the program that takes the number of apples as input from the keyboard.
- Many other approaches to problem solving, and it takes practice!

Summary of key points

- The **EasyGraphics** class provides simple commands for drawing
- Classes can have **static** methods that are not associated with any object of the class and **instance** methods that are associated with objects
- Plan your programs as **algorithms** before you write them
- Understanding the problem, **psudocode** and **stepwise refinement** are useful tools in designing your algorithms