Programming Design and Implementation

Lecture 5: Nesting, 2D Arrays and Methods

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COMP1007 - Unit Learning Outcomes

- Identify appropriate primitive data types required for the translation of pseudocode algorithms into Java;
- Design in pseudocode simple classes and implement them in Java in a Linux command-line environment;
- Design in pseudocode and implement in Java structured procedural algorithms in a Linux command-line environment;
- Apply design and programming skills to implement known algorithms in real world applications; and
- Reflect on design choices and communicate design and design decisions in a manner appropriate to the audience.

COMP5011 - Unit Learning Outcomes

- Develop and apply simple non-object oriented algorithms;
- Develop and implement simple classes in an object oriented language;
- Create object oriented designs consisting of classes connected by aggregation; and
- Communicate design and design decisions in a manner appropriate to the audience.

Outline

Nested Loops

Nested Loops

- Any control structure can be nested inside another control structure
  - `IF-THEN-ELSE` inside `IF-THEN-ELSE`
  - A `loop` inside a `loop`;
- Be careful of algorithm efficiency (inefficiency)
- Nesting a loop inside another exponentially increases the number of processing steps;
- Good use of indentation is essential for human readability.

Nested Loop Example

- Write an algorithm that will input a number between 1 and 12 (inclusive) from the user, then output all of the times tables (1 to 12) between 1 and the input number
  - i.e., If the user inputs 3, the program will output:

```
Enter a number in the range 1 to 12: 3
The 1 Times Table
1 x 1 = 1
...
1 x 12 = 12
The 2 Times Table
2 x 1 = 2
...
2 x 12 = 24
The 3 Times Table
3 x 1 = 3
...
3 x 12 = 36
```

Nested Loop Example: Algorithm

```
num = -1
WHILE(num < 1) OR (num > 12)
    OUTPUT 'Enter a number in the range 1 to 12'
    num = GET user input
ASSERTION: num in the range 1 to 12 inclusive

FOR table = 1 TO num CHANGEBY 1
    OUTPUT 'The ' table ' Times Table'
    FOR number = 1 TO 12 CHANGEBY 1
        OUPTUT table " x " number " = " (table * number)
    ENDFOR
    ASSERTION: table Times Table is output to the user
ENDFOR
ASSERTION: one to n Times Table is output to the user
```

Nested Loop Example: Java

```
import java.util.*;
public class NestedLoop
{
   public static void main(String[] args)
   {
      int num = -1;
      Scanner sc = new Scanner(System.in);
      while ((num < 1)||(num > 12))
      {
          System.out.print("Enter a number in the range 1 to 12: ");
          num = sc.nextInt ();
      }
      for (int table = 1; table <= num ; table ++)
      {
         System.out.println("The " + table + " Times Table ");
             for (int number = 1; number <= 12; number ++)
             {
                  System.out.println(table + " x " + number + " = " + (table * number ));
              }
       }
       sc.close();
    }
 }
```

Nested Loops and Algorithm Complexity

- Algorithm Complexity can indicate algorithm efficiency;
- It attempts to show the rate of increase in processing steps as a function of the amount of data being processed
- Algorithm complexity is covered in DSA (COMP1002);
- For the moment consider the previous example where two FOR loops were nested

Algorithm Complexity

```
1  for(int table = 1; table <= n; table++)
2  {
3      System.out.println("The " + table + " Times Table");
4      for(int number = 1; number <= 12; number++)
5      {
6          System.out.println(table + " x " + number + " = "
7                                  + (table * number));
8      }
9  }
```

- When the user inputs 6, how many times did the statement `System.out.println(table +... );` (*Line 6*) execute?
- How about when the user inputs 12?

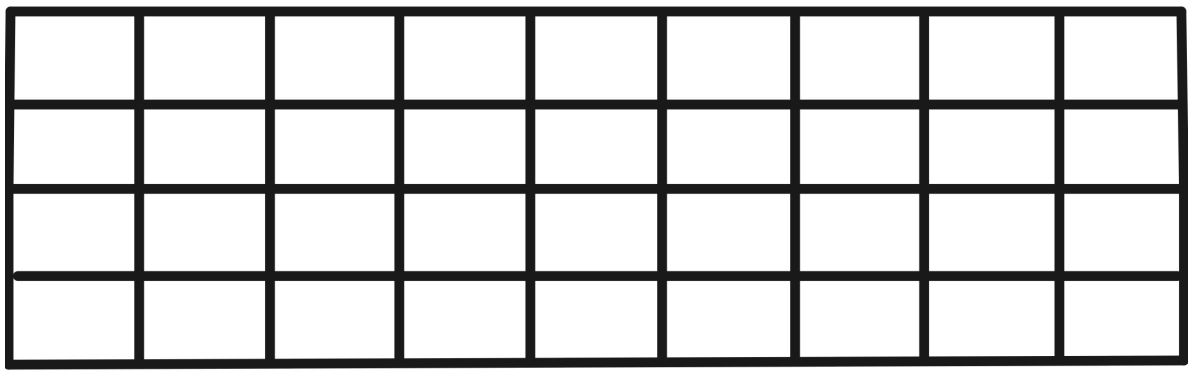
Live Demo

- In this live demo we will look at:
  - Nested loops;
  - Nested `for`;
  - Nested `while`.

Two-Dimensional Arrays

2D Arrays

- A 2D array expands the concept of the array;



- Access to array elements is still via an *index* or *subscript*;
- The *index* contains 2 numbers, one for the row, one for the column;
- Row numbering starts at 0;
- Column numbering starts at 0;

Creating a 2D Array in Java

- Creating a 2D array with 4 rows and 9 columns for integers:

```
int [][] twoDArray = new int [4][9];
```

0,0	0,1	0,2						
1,0								
2,0							2,7	2,8
3,0							3,7	3,8

- Above is the 2D array (with some *index* numbering);
- A way to access elements is via a nested `for` loop.

Java Code

```
import java.util.*;
public class UsingTwoDArrays
{
    public static void main(String[] args)
    {
        int [][] myTwoDArray;
        myTwoDArray = new int[10][10];

        for(int i = 0; i < 10; i++)
        {
            for(int j = 0; j < 10; j++)
            {
                myTwoDArray[i][j] = j;
            }
        }
        for(int i = 0; i < 10; i++)
        {
            for(int j = 0; j < 10; j++)
            {
                System.out.print(myTwoDArray[i][j]);
            }
            System.out.println();//Print on the next line
        }
    }
}
```

Live Demo

- In this live demo we will look at:
  - Creating 2D Arrays;
  - Accessing elements via Nested loops; and
  - Attempting to access data outside the array.

Methods and Design

Modularity

- Methods are used to break algorithms into smaller parts;
- Each method performs one task and one task only:
  - Ease of design;
  - Readability;
  - Code re-use;
  - Debugging.
- Methods **must** be useful:
  - A pointless method:

```
public static void printMyMethod()
{
    System.out.println("I wrote a method just to do this!");
}
```

The `main()` Method

- Java programs start at the `main()` method
- `main()` is the program's starting point
- Within `main()`:
  - Other methods are invoked;
  - Objects can be created;
  - Methods within objects can be invoked.

```
    public static          void      main   (String [] args) { .... }
|-method type/modifiers-| |-return-| |-name-| |- parameters -| |-code-|
```

- Parameters for `main()` will be covered in another Lecture.

Methods

- Java calls them methods (also known as functions)

```
public double multiplyTwoNumbers(double numOne, double numTwo)
{
      double product = 0.0;
      product = numOne * numTwo;
      return product;
}
```

- A method has a **header** consisting of:
  - Modifiers: public, private (there are others);
  - Data type the method returns (void if nothing returned);
  - Method name;
  - Parameter list;
  - Exception list (not shown & covered later);
- A method has a **body** enclosed in braces { }
  - The code that does all the computation.

Methods

- Plan and design your methods
  - Use pseudocode (especially in PDI)
- Look at the requirements
  - For each task in the requirement specification, ask yourself: *"Is there a method already written and tested for this task?"*
    - **Yes:** Use it
    - **No:** Design it
- See worked example at the end of this lecture

Designing Methods

- Think: what does the algorithm **supply** to the method?
- Think: what does the method `return` to the algorithm?
- When designing it, create it like this:
  - `IMPORT`: Information supplied to the method
  - `EXPORT`: Information `return`ed from the method to the calling method
  - `ASSERTION`: What is true after the method has executed
    - Assertions statements assist in debugging the algorithm
    - Sometimes no assertion can be made

Comments

- Comment blocks are used to describe methods;
- Generally contain:
  - Method Contract:
    - `IMPORT`, `EXPORT` and `ASSERTION`.
  - Purpose of the submodule (its job);
  - Authors;
  - Dates created and modified.
- Generally omitted from lecture notes due to space;
- Expectation is you use them in **all** your programs/classes.

Comment Blocks (1)

```
/************************************************
 * Author: Dr David A. McMeekin                 *
 * Date: 1/03/2021                              *
 * Purpose: To do something                     *
 ************************************************/
public class MyJavaApp
{
    public static void main(String[] args)
    {
      // Code
    } // End main
     ...
```

Comment Blocks (2)

```
...

    /*************************************************
     * Name: myMethod                                *
     * Date: 1/03/2021                                  *
     * Import: a (int), b (int)                      *
     * Export: val (double)                          *
     * Purpose: Do do a part of something            *
     *************************************************/
                        // Parameters declared individually
    public static double myMethod(int a, int b)
    {
        // Code
    } // End myMethod
} // End Class
```

void Methods

- do their job and pass control back to calling method;
- have no return value: i.e., no export.

Example void method: Pseudo Code

```
MAIN:
    sayHello <- "David"
END MAIN

METHOD: sayHello
IMPORT: aParam
EXPORT: none
ALGORITHM:
    DISPLAY "I'm saying hello to " aParam
END METHOD
```

Example void method: Java

```
import java.util.*;
public class MyWorldClass
{
    public static void main(String[] args)
    {
        sayHello("David"); //Calling sayHello() method
    }                      // "David" is the argument

    // METHOD: sayHello
    // IMPORT: aParam (String)
    // EXPORT: none
    public static void sayHello(String aParam)
    {
        System.out.println("I'm saying hello to " + aParam);
    }
}
```

Invoking or calling methods

- Two possibilities when calling methods:
  - The calling and called method are in the same class; or
  - The calling and called method are in different classes.
- Methods in the same class are invoked as in previous example;
- Non static methods in a different class are invoked via an `Object` variable:
  - `objectName.methodName();`
  - `sc.nextDouble();`
- Static methods in a different class are invoked by specifying the class name:
  - `Math.sqrt(9);`

Live Demo

- In this live demo we will look at:
  - Some basic method use.

More on Methods

Methods

- In Java methods can return a single piece of data to the calling method:
  - The return data type is shown in the method header:

```
public int calculateMyAge(String name)
```

- Remember `void` methods do not return anything:

```
public void sayHello(String aParam)
```

Functions and Methods

- Most non-trivial arithmetic uses various functions:
  - sin, log, sqrt, etc.
- Calculators have predefined functions that return a value when given argument(s):
  - Provide `x` and it returns `sin(x)`;
  - **Arguments** are passed to methods as **parameters.**
- In Java, functions are implemented as non-void methods;
- The Java `Math` class provides a library math methods;
- Predefined functions avoid "reinventing the wheel" & allow reusability of written and tested code:
  - If a function does not exist then write the method for it.
- **Values** are passed to a function in the **argument list**;
- A single result (value) is `return`ed from the function.

Java Math Class

- In maths a function maps a set of inputs to an output value:
  - `z = f(x, y);`
- Java `Math` class contains methods that perform non-trivial mathematical calculations;
- Is part of the "`package.java.lang`" which is automatically imported into every Java program;
- It is `final`, has no subclasses (see later), has no constructors and methods are `static`:
  - The class name must is always used before the method name (see slide 15);
  - e.g., `Math.sqrt(x);`
- Two constants:
  - `Math.E`
  - `Math.PI`

Some Math class methods

Function	Argument	Constraints	Result
abs(x)	int/long/float/double		Same as arg
ceil(x)	double		double
floor(x)	double		double
round(x)	float/double		int/long
rint(x)	double		double
os(x)	double	x in radians	double
exp(x)	double		double
log(x)	double	x > 0	double
pow(x,y)	double	x^y, x > 0	double
sqrt(x)	double	x >= 0	double
max(x,y)	int/long/float/double		Same as arg
min(x,y)	int/long/float/double		Same as arg

Examples

Expression	Result
`Math.round(2.6)`	`3`
`Math.round(-3.15)`	`-3`
`Math.rint(-3.7)`	`-4.0`
`Math.ceil(3.7)`	`4.0`
`Math.floor(3.7)`	`3.0`
`Math.pow(2.0, 3.0)`	`8.0`
`Math.sqrt(-9)`	`NaN`
`Math.abs(-4)`	`4`
`Math.abs(4.0)`	`4.0`

Method Example: Pseudo Code

```
MAIN:
    INPUT inches
    cms = convertInchesToCms <- inches
    OUTPUT "CMs are: " + cms
END MAIN

METHOD: convertInchesToCms
IMPORT: ins
EXPORT: cm
ALGORITHM:
    cm = ins * 2.54
END convertInchesToCms
```

Method Example: Java

```
import java.util.*;
public class InchesToCmConverter
{
    public static void main(String[] args)
    {
        double inches, cms;
        Scanner sc = new Scanner(System.in);
        System.out.print("Input inches: ");
        inches = sc.nextDouble();
        cms = convertInchesToCms(inches);
        System.out.println("CMs are: " + cms);
        sc.close();
    }
    private static double convertInchesToCms(double pIns)
    {
        double cm;
        cm = pIns * 2.54;
        return cm;
    }
}
```

Method Example (2): Pseudo Code

```
MAIN:
    INPUT x
    INPUT y
    average = calculateMean(x, y)
    OUTPUT average
END MAIN

METHOD: calculateMean
IMPORT: a, b
EXPORT: mean
ALGORITHM:
    mean = (a + b) / 2.0
END calculateMean
```

Method Example (2): Java

```
import java.util.*;
public class LectureFiveSlide25
{
    public static void main(String[] args)
    {
        int x, y;
        double avg;
        Scanner sc = new Scanner(System.in);

        System.out.print("Enter an integer: ");
        x = sc.nextInt();
        System.out.print("Enter another integer: ");
        y = sc.nextInt();
        avg = calculateMean(x, y);
        System.out.println("Mean " + x + " & " + y + " is: " + avg);
        sc.close();
    } // End main
      // Code continues on next slide
```

Method Example (2): Java

```
...
    /*********************************************************
     * METHOD: calculateMean                                 *
     * IMPORT: pA (int), pB (int)                              *
     * EXPORT: mean (double)                                 *
     *********************************************************/
     private static double calculateMean(int pA, int pB)
     {
         return (double)(pA + pB) / 2.0;
     } //End calculateMean
 } // End Class
```

Live Demo

- In this live demo we will look at:
  - the examples in the previous slides; and
  - some `Math` class methods.

Parameters

Method Parameters

- For some methods to work, they require data when called;
- Data used in the method call is an argument;
- This data arriving in the method is called a parameter;
- Parameters are local variables to the method;
- Parameters are initialised with the argument values;

```
public void exampleOfAMethod(int pParamOne, float pParamTwo)
{
    int localOne = 0;
    float localTwo = 0.0;
    ...;
}
```

- `pParamOne`, `pParamTwo`, `localOne` and `localTwo` are all local variables in the method `exampleOfAMethod()`.
- 'p' is the parameter's first letter indicating it's a parameter.

Modular Grade Example Pseudo Code

- 'p' is the parameter's first letter indicating it is a parameter.

```
METHOD: markGrade
IMPORT: pMark (Integer)
EXPORT: grade (Character)
ALGORITHM:
    newMark = pMark DIV 10
    CASE newMark OF
        8, 9 or 10
            grade = 'H'
        7
            grade = 'D'
        6
            grade = 'C'
        5
            grade = 'P'
        DEFAULT
            grade = 'F'
    ENDCASE
END markGrade
```

Modular Grade Example Java Code

```
public static char markGrade(int pMark)
{
    int newMark = pMark / 10; char grade;
    switch(newMark)
    {
        case 8: case 9: case 10:
            grade = 'H';
        break;
        case 7:
            grade = 'D';
        break;
        case 6:
            grade = 'C';
        break;
        case 5:
            grade = 'P';
        break;
        default:
            grade = 'F';
    }
    return grade;
}
```

Special/Interesting Cases

- Some programming languages pass parameters in a different manner:
  - It's called passing by reference (covered in UCP (COMP1000)).
- In Java, two data types are automatically passed by reference:
  - Objects; and
  - Arrays (a special type of object).
- A parameter which is of a particular class type will contain the object's address (a reference to the original object);
- Modification to the object are reflected in the original module;
- **RELAX**: Classes are covered in another lecture.

Live Demo

- In this live demo we will look at:
  - More on method use;
  - The use of parameters;
  - Return values.

A Worked Example

Modular Algorithm Design: Pseudocode

- A modular version of the Times Table Program

```
MAIN:
    OUTPUT 'Welcome to the Times Tables!'
    maxTable = userInput(1, 12)
    FOR table = 1 TO maxTable CHANGEBY 1
        outputTable(table)
    ENDFOR
    ASSERTION: 1 to maxTable times table output to user.
END MAIN

...
```

Modular Input Algorithm: Pseudocode

- A possible algorithm to get user input:

```
METHOD: userInput
IMPORT: pLower (Integer), pUpper (Integer)
EXPORT: number (Integer)
ASSERTION: value will be in the range of lower and upper
ALGORITHM:
START:
    WHILE((number <= pLower) OR (number => pUpper)) DO
        OUTPUT Enter a number in the range 'pLower' to 'pUpper'
        number = GET user input
    ENDWHILE
    ASSERTION: pLower <= value <= pUpper
END inputValueFromUser
```

Modular Output Table: Pseudocode

```
METHOD: outputTable
IMPORT: pTable (Integer)
EXPORT: none
ASSERTION: pTable is in the range of 1 to 12
ALGORITHM:
    OUTPUT 'The ' pTable ' Times Table'
    FOR number = 1 TO 12 CHANGEBY 1
        OUPTUT pTable ' x ' number ' = ' (pTable x number)
    ENDFOR
    ASSERTION: pTable Times Table is output to the user
END outputTable
```

Modular Algorithm Design in Java: main()

```
import java.util.*;
public class TimesTable
{
    public static void main(String[] args)
    {
        int maxTable;
        System.out.println("Welcome to the times tables!");
        maxTable = userInput(1, 12);
        for(int table = 1; table <= maxTable; table++)
        {
            outputTable(table);
        }
    }
...
```

Modular Algorithm Design in Java: userInput()

```
...

    public static int userInput(int pLower, int pUpper)
    {
        int number = -1;
        Scanner sc = new Scanner(System.in);

        while((number <= pLower) || (pUpper <= number))
        {
            System.out.print("Enter a value between "
                             + pLower + " and " + pUpper + ":");
            number = sc.nextInt();
        }
        sc.close();
        return number;
    }
...
```

Modular Algorithm Design in Java: outputTable()

```
...
    public static void outputTable(int pTable)
    {
        System.out.println("The " + pTable + " Times Table");
        for(int number = 1; number <= 12; number++)
        {
            System.out.println(pTable + " x " + number + " = "
                               + (pTable * number));
        }
    }
}
```