Algorithm, Pseudocode and Flowchart

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Introduction

Introduction

- Algorithms, flowcharts, and pseudocode are essential tools for problem - solving
- They provide a bridge between problem analysis and actual programming
- This lecture introduces their concepts, notations, and best practices

Control Structures

Control Flow and Structure of a Program

- Need to be familiar with control structure to be able to write algorithms
- Control flow or control structure can be divided into a few types:
    - **Sequence**: step by step execution of commands from top to bottom
    - **Selection** or **conditional execution**: exceuting a codeblock if certain conditions are met (if-else statement)
    - **Iteration** or **loop**: repeatedly executing a block of code or commands while a certain condition is true, stop the loop if the codition is no longer true
- Every program can be built using the three structures

Additionally, functions (collection of commands) with zero or more inputs can be defined.

Sequence

- Code or commands are executed step by step, or sequentially
- Example: Input a number, then calculate its square, then print the result

Selection or Conditional Execution

- **IF**: execute a block if condition is true
- **IF-ELSE**: choose between two alternatives
- **ELSE IF ladder**: multiple conditions
- Can have an **IF** statement inside another, this is called nested **IF** statements

Iteration or Loops

- **FOR loop**: repeatedly execute commands for a fixed number of times
- **WHILE loop**: repeatedly execute a block of code while a condition is true. Usually, the number of iteration required until the condition becomes false, is not in known advanced
- **DO-WHILE loop**: run the commands at least once, then repeat if condition holds
- Can have a loop inside another loop, it is known as nested looping

For the purpose of this slide, only **WHILE** loop shall be used to keep things simple for now.

Break and Continue

- **BREAK**: exit a loop immediately without any further iteration. When inside nested loops, it exits out of the loop in which the **BREAK** statement is called
- **CONTINUE**: skip the rest of the current iteration, proceed to the next iteration

Functions

- Collection of commands that perform a specific task
- Groups together logic or commands that needs to be written across multiple places in a program
- Usually given a name
- Can call a function with its name followed by its parameters in brackets
- Can have zero or more inputs. These inputs are known as parameter or arguments
- Since a function is only defined once and subsequently called only using its name, this reduces code duplication leading to better readability and maintainability of code

Recursion

- Function calling itself to solve smaller subproblems
- Example: factorial, Fibonacci
- Must have a base case to terminate
- A base case is a condition which when true, the function stops calling itself and returns the final result
- The function must be able to reach its base case, otherwise it will turn into an infinite loop

Algorithms

What is an Algorithm?

- A step-by-step procedure to solve a problem
- Unambiguous and finite sequence of instructions
- Example: A recipe for cooking is an algorithm in real life

Characteristics of a Good Algorithm

- Finiteness: must terminate after finite steps
- Definiteness: each step is clearly defined
- Input: specified set of inputs
- Output: specified set of outputs
- Effectiveness: steps can be performed with available resources

Examples of Simple Algorithms

- Finding the maximum of three numbers
- Calculating factorial of a number
- Linear search in an array

Example Algorithm: Finding the Area of a Triangle

1. Input base, b and height, h
2. Let area, $a = bh/2$
3. Output a

Before Designing an Algorithm

Before writing an algorithm, think carefully about the following:

- **Inputs**: What data is required to solve the problem?
- **Outputs**: What results should be shown?
- **Variables**: What values need to be stored and updated during execution?
- **Processing steps**: What operations or calculations are required?
- **Formulas**: What mathematical or logical formulas are needed?
- **Decision making**: Are conditional checks (IF-ELSE) required?
- **Repetition**: Are loops required, and should the output be shown once or repeatedly?
- **Loop control**: What condition starts and stops each loop?
- **Recursion**: If recursion is used, what is the base case and how does the problem reduce?

Example Algorithm: Factorial of a Number

```
1 Input an integer, n
2 Set result = 1
3 While n is larger than 1, repeat the following:
    i  result = result × n
    ii n = n - 1
4 Output the result
```

Note: In step 3, “While” is a looping construct.
The statements under the “While” key-word are executed repeatedly as long as the condition (n is larger than 1) is true.

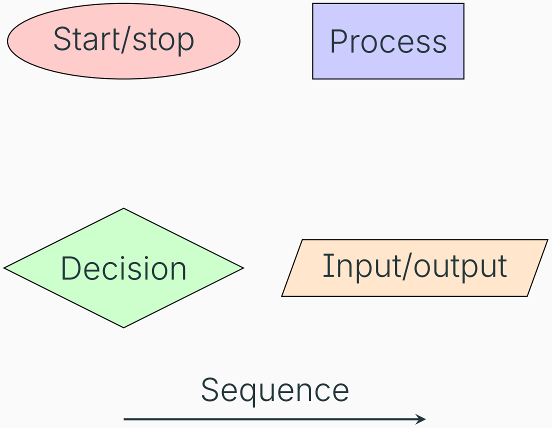
Flowcharts

Definition and Purpose

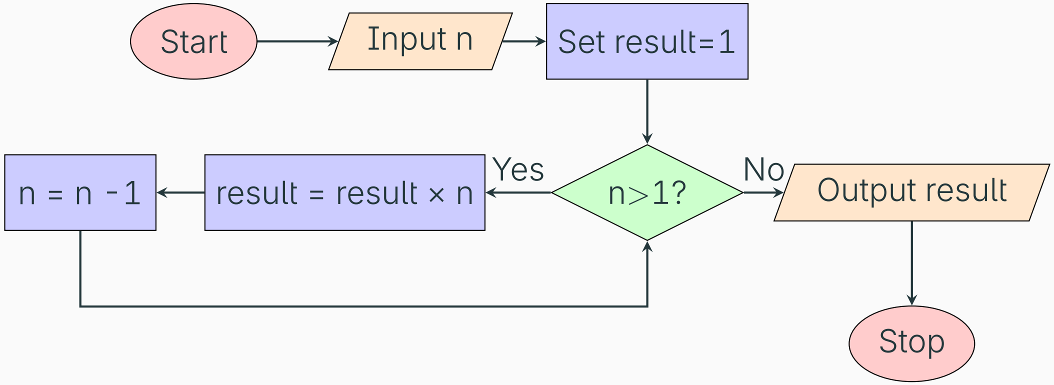
- Flowchart: graphical representation of an algorithm
- Uses standard symbols to show the flow of control
- Helps visualize program logic before coding

Flowchart Shapes

- **Start/Stop**: ellipse
- **Process**: rectangle
- **Decision**: diamond
- **Input/Output**: parallelogram
- **Sequence**: arrow



Example Flowchart: Factorial of a Number



Pseudocode

Purpose of Pseudocode

- Represents algorithms in structured, human-readable code
- Independent of programming language, but may include programming key-words
- Easier to understand and refine before coding

Conventions

- Use natural language mixed with structured logic
- Variable names should be consistent and meaningful
- Keywords like Input, If, While, For, Output, Function
- Indentation to show block structure
- Colons indicate the beginning of a block
- Keywords like EndIf, EndWhile, EndFor, EndFunction to indicate the end of a code block
- Pseudocode should be language-independent

Example pseudocode: Area of a Triangle

```
Start
Input base, height
Set area = base * height / 2
Output area
End
```

Example pseudocode: Factorial of a Number

```
Start
Input n
Set result = 1
While n>1:
    result = result * n
    n = n - 1
EndWhile
Output result
End
```

Example Pseudocode: Function for Finding Factorial

The following defines a function named `Factorial()` with a single input `n`.

```
Function Factorial(n):
    While n>1:
        result = result * n
        n = n - 1
    EndWhile
    Return result
EndFunction
```

The `Return` keyword indicates which value to return to the caller of the function. It also marks the end of execution of a function.

Example Pseudocode: Factorial of a Number using Recursion

A recursive function (function that calls itself) named `Factorial()` is defined that takes a single input:

```
Function Factorial(n):
    If (n==0):
        Return 1
    Else:
        Return n * Factorial(n-1)
    EndIf
EndFunction
```

Note: “a==b” checks whether a is equal to b, returns True if they are equal, otherwise, returns False.

Best Practices

- Keep flowcharts clean and uncluttered
- Use consistent symbols and indentation
- Pseudocode should be language-independent
- Algorithms should be logically ordered and unambiguous

Common Pitfalls

- Overcomplicating flowcharts with too many details
- Ambiguous pseudocode (mixing multiple languages)
- Ignoring edge cases in algorithms
- Writing unstructured logic

Examples

Putting It All Together

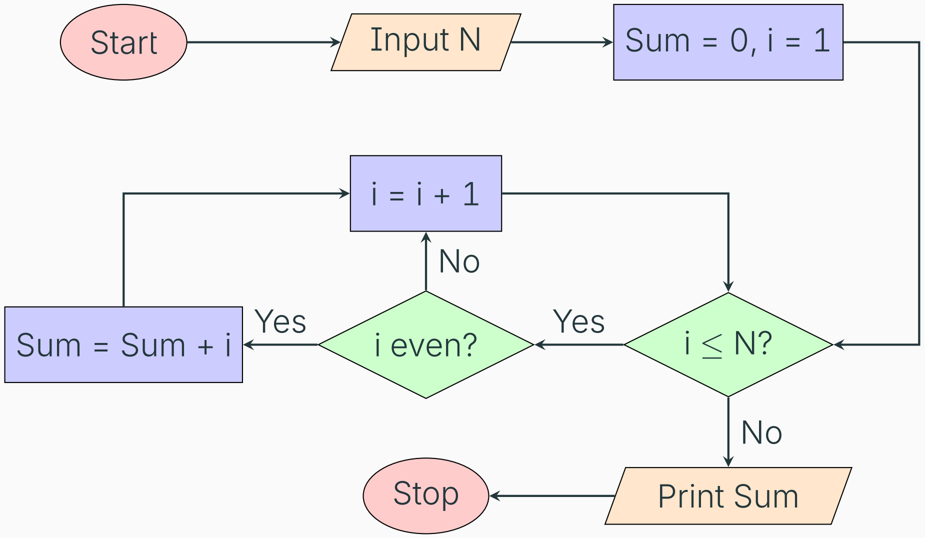
Example task

Compute the sum of all even numbers from 1 to N

Algorithm

```
1. Read n
2. Set sum = 0, i = 1
3. While i <= n:
    i. If i is even:
        ▸ add i to sum
    ii. Add 1 to i
4. Print sum
```

Flowchart


Start
Input N
Sum = 0, i = 1
i = i + 1
No
Yes
Yes
Sum = Sum + i
i even?
i ≤ N?
No
Stop
Print Sum

Pseudocode

```
Start
Input n
sum = 0
i = 1
While (i <= n):
    If (i is even):
        sum = sum + i
    EndIf
    i = i + 1
EndWhile
Output sum
End
```

Example: Find Whether a Number is Even or Odd

```
Start
Input num
If (num mod 2 == 0):
    Output Even
Else
    Output Odd
EndIf
End
```

Note: In the above, $x \bmod y$ returns the remainder when x is divided by y.

Example: Solution of Quadratic Equation

The equation is given as: $ax^2 + bx + c = 0$

```
Start
Input a, b, c
x1 = (-b + sqrt(b^2 - 4ac)) / 2a
x2 = (-b - sqrt(b^2 - 4ac)) / 2a
Output x1, x2
End
```

Note: In the above, `sqrt(p)` returns the square root of p.

Example: Quadratic Equation: Handling Edge-Case

Sometimes a quadratic equation may not have real-valued solutions.

```
Start
Input a, b, c
If (b^2 - 4ac) < 0:
    Output: No real-valued soltions
Else:
    x1 = (-b + sqrt(b^2 - 4ac)) / 2a
    x2 = (-b - sqrt(b^2 - 4ac)) / 2a
    Output: x1, x2
EndIf
End
```

Example: Quadratic Equation: Handling Edge-Case (cont.)

Sometimes, there might be only one real-valued solution.

```
Start
Input a, b, c
If (b^2 - 4ac) < 0:
    Output: No real-valued soltions
ElseIf (b^2 - 4ac) == 0:
    x = -b / 2a
    Output: x
Else:
    x1 = (-b + sqrt(b^2 - 4ac)) / 2a
    x2 = (-b - sqrt(b^2 - 4ac)) / 2a
    Output: x1, x2
EndIf
End
```

Exercises

Exercises

1. Design an algorithm and flow chart to find the largest of the three numbers
2. Develop pseudocode for computing the sum of the digits of a given integer
3. Write an algorithm and pseudocode to check whether a number is prime
4. Write a pseudocode for the Euclidean algorithm of finding GCD of two integers
5. Write a pseudocode for finding the LCM of two integers

Questions?