

**Department of Computing**

**Algorithms and Data Structures**

**(55-508810-AF-202425)**

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# 1. Project 1

## Computational Complexity

A close up of text

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*Outer Loop*

*Middle Loop*

*Inner Loop*

**Find big O of above algorithm:**

**Points to note:**

* Print statement runs k number of times for every time the inner loop runs
* Inner loop runs j number of times for every time the middle loop runs
* middle loop runs i number of times for every time the outer loop runs
* outer loop runs n number of times

therefore:

=

=

Subbing in this:

Factoring out constants:

Separating into two series

Dealing with each series individually:

=

Subbing back in and simplifying:

)

)

)

)

)

n3 is dominant term therefore the algorithm has a Big O of O(n3)

## Observation of rate of growth

Let the two functions be known as:

F(n) = n2

G(n) = 2n/4

To observe the rate of growth of these functions so I can comment on them I have devised 2 methods.

Method 1: table of values

|  |  |  |
| --- | --- | --- |
| n | f(n) | g(n) |
| 1 | 1 | 0.5 |
| 5 | 25 | 8 |
| 10 | 100 | 256 |
| 15 | 225 | 8192 |
| 20 | 400 | 262144 |
| 25 | 625 | 8388608 |
| 30 | 900 | 2.68E+08 |

*Data generate by MS excel spreadsheet (LINK?) .*

Method2: graphics calculator application

*Using* [*https://www.geogebra.org/calculator*](https://www.geogebra.org/calculator) *:*

*A screenshot of a graph

Description automatically generated*

*Note: x is used as a substitute for n and is limited to the positive scale as negative complexity does not need to be considered.*

Analysis

As shown best by the graph g(n) is better for small values of n - up till n = 8 (see intersect point B) . Note I’m ignoring the first intercept point A as data sets normally consist of 1 or more items, not of ~ .062 of an item. However past a data set size of 8, as best shown by the table if values f(n) is significantly better than g(n) as the difference between f(n) and g(n) grows exponentially large.

## 1.3 Incorporation of formative feedback

Provide evidence of how you evaluated and acted on the formative feedback you received from your tutors, including the tutor’s name and the timestamp.

|  |  |  |  |
| --- | --- | --- | --- |
| Date and Time | Name of the Tutor | Feedback of the tutor | How the comment is addressed |
| 04/10/24 ~ 1040 | Mehemet | Excellent work | Kept doing what I was doing |
|  |  |  |  |

# 2. Project 2

## 2.1 Algorithms in an Algorithmic Language, such as ADL

I have designed two separate algorithms and corresponding data structures (A&DS) to solve the this problem, based on depth first and breadth first traversals of graphs to avoid confusion on which algorithms go with which data structures I will list common A&DS and then under separate headings the A&DS for each approach.

Common Data Structures.

**2D array – used for Maze Representation:**

* The maze doesn’t change, only accessed so the lack of dynamics doesn’t matter
* Space efficient
* Easily accessed
* *Note:* Though I represented the maze using a 2D array I treated the maze more like a graph in both solutions with adjacent 0s being connected and ignoring the 1s.

**Endless Stack – used to store chain of visited nodes/positions**

* Custom data type
* A dynamic stack as I would not be able to tell how big it need to be before running the algorithm and this size would change with different mazes and algorithms.
* Used as I wanted a data structure that preserved the order on which items where added to it so the route would not be compromised
* **Functions:**
  + **isEmpty()**
  + **push() – adds an item to the top of the stack**
  + **pop() – returns and removes the top item on the stack**
  + **convertToList() – returns in list form for display**
  + **Count() – returns integer value of number of item in stack.**

**List – Used to store visited nodes and then the chain of visited nodes after removal of endless stack from the depth first approach.**

* Dynamic for same reasons as endless stack
* Easily accessed

Common Algorithms

**InRange – checks if a position that algorithm was looking at was inside the map.**

* Used to avoid errors
* Used to recognize the exit.
* Implemented in a parent class of both approaches classes.
* *Note:* this was implemented during development after receiving feedback from lecturer hence no ADL

Depth First Data Structures

**Array – Used for Positions/ positions**

* The maze doesn’t change dimensions, so the lack of dynamics doesn’t matter
* Space efficient compared to an object approach
* Easily accessed

Depth First Algorithms

In a low level pseudo code :

function lookArround(array currentLocation, array maze ){

// returns an array of all coordinates 1 place away form currentLocation

int x <- currentLocation - 1

int y <- currentLocation + 1

array zerosLocation <- {}

for y to y + 3 {

for x to x + 3 {

if maze[x,y] == 0 and maze[x,y] != currentLocation {

zerosLocation.add({x,y})

} else if maze[x,y] != 1 {

zerosLocation.add({-1,-1}) // -1,-1 signifies end

}

x <- x + 1

}

x <- current location - 1 // resets x to end s

y <- y - 1

}

return zerosLocation

}

function findRoute(array currentPos, EndlessStack previous, list visited, array maze){

// returns to exits if found if not returns empty array.

array options <- lookArround(currentPos, maze)

previous.add(currentPos)

vistited.add(currentPos)

//check if there's not any options i.e. dead end

if (options == null){

return {}

} else{

// check if exit found

for each option in options {

if (option == {-1,-1} and previous != null){

previous.add(currentPos)

return previous

}

// if not check paths

for each option in options {

if( !visited.isIn(option)){

EndlessStack route <- findRoute(option, previous, visited maze)

if (route != null){

return route

}

}

}

if ( previous == null) {

print("no exit")

}esle{

return {}

}

}

}

Depth First Data Structures

**Queue – Used to store nodes to visit next**

* Dynamic for same reasons as Endless stack
* Use of First in First out to implement a breadth first solution.

**Node**

* Custom data structure
* Creates a kind of a linked list with its recursive definition
* **Used to:**
  + store positions of the nodes the algorithm will traverse to
  + to store positions of the nodes the algorithm will traverse to
  + store if end found
* **Has**
  + Array to store position of the node
  + Node to point to the node this was node was traversed to from
  + Boolean value to signify if this node is adjacent to the exit.

Breadth First Algorithms

In a high level pseudo code :

// a recursive function to traverse the linked list of Nodes

function traverseNodes(currentNode,stack):

if currentNode's previousNode is null:

return stack

else

stack.Push(currentNode)

traverseNode(currentNode's previousNode)

endif

declare startPosition, queue, visitedlist

// traversal of maze

loop:

if current location on edge:

set currentlocation’s endFound to true

else:

add nodes connected to current to queue

end if

add current location to visitedList

set current location to first node in queue

until queue is empty

// finding routes

declare routesList

loop for every node in visitedList:

if node's endFound is true:

set routeEndlessStack to return value of traverseNodes(node, stack)

add routeEndlessStack to routesList

endif

end loop

declare bestRouteLength, bestRouteIndex

loop for every route in routeList:

if route's length > bestRouteLength:

set bestRouteIndex to currentIndex

endif

end loop

## 2.3 Software and its Presentation, including testing (and video link)

[*https://youtu.be/nR\_NoYhzUIs*](https://youtu.be/nR_NoYhzUIs)

In your video recording, you will need to demonstrate how you tested the software and what results you obtained using the acceptance tests outlined in this section, e.g.,

Acceptance tests

| N.O | Acceptance test- *Green = Expected route; Blue = start Red = exit* | Expected result | Depth first Result | Breadth first Result |
| --- | --- | --- | --- | --- |
| 1 | 1,0,1,1,1,1,1,1  1,0,0,0,0,0,0,1  1,1,1,1,1,1,0,1  1,0,0,0,0,0,0,1  1,0,1,1,1,1,1,1  1,0,0,0,0,0,0,1  1,1,1,1,1,1,0,1  1,0,0,0,0,0,0,1  1,0,1,1,1,1,1,1  1,0,0,0,0,0,0,0  1,1,1,1,1,1,1,1 | (1,0), (1,1), (1,2), (1,3), (1,4), (1,5), (1,6), (2,6), (3,6) (3,5), (3,4), (3,3), (3,2), (3,1), (4,1), (5,1), (5,2), (5,3), (5,4), (5,5), (5,6), (6,6), (7,6) (7,5), (7,4), (7,3), (7,2), (7,1), (8,1), (9,1), (9,2), (9,3), (9,4), (9,5), (9,6), (9,7) | (0,1),(1,1), (1,2), (1,3), (1,4), (1,5), (1,6), (2,6), (3,5), (3,4), (3,3), (3,2), (3,1), (4,1), (5,1), (5,2), (5,3), (5,4), (5,5), (5,6), (6,6), (7,5), (7,4), (7,3), (7,2), (7,1), (8,1), (9,1), (9,2), (9,3), (9,4), (9,5), (9,6), (9,7), | (1,2),(1,3), (1,4), (1,5), (2,6), (3,5), (3,4), (3,3), (3,2), (4,1), (5,2), (5,3), (5,4), (5,5), (6,6), (7,5), (7,4), (7,3), (7,2), (8,1), (9,2), (9,3), (9,4), (9,5), (9,6), (9,7), |
| 2 | 1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1  1,0,1,0,0,0,1,1,0,0,0,1,1,1,1,1,1  1,1,0,0,0,1,1,0,1,1,1,0,0,1,1,1,1  1,0,1,1,0,0,0,0,0,1,1,1,0,0,1,1,1  1,1,0,1,1,1,1,1,1,0,1,1,1,1,1,1,1  1,1,0,1,0,0,1,0,1,1,1,1,1,1,1,1,1 1,0,0,1,1,0,1,1,1,0,1,0,0,1,0,1,1  1,0,1,1,1,1,0,0,1,1,1,1,1,1,1,1,1  1,0,0,1,1,0,1,1,0,1,1,1,1,1,1,0,1  1,1,0,0,0,1,1,0,1,1,0,0,0,0,0,0,1  1,0,0,1,1,1,1,1,0,0,0,1,1,1,1,0,1  1,0,1,0,0,1,1,1,1,1,0,1,1,1,1,0,0 1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1 | (1,1), (2,2), (1,3), (2,4), (2,5), (2,6) ,(1,6), (1,7), (1,8) (2,8), (2,9), (3,9), (4,9), (5,8), (6,7), (7,7), (8,8), (7,9), (8,10), (9,10), (10,10), (10,9), (11,9), (12,9), (13,9), (14,9), (15,9), (15,10), (15,11), (16,11) | (1,1), (2,2), (3,1), (4,2), (5,2), (6,1), (6,2), (7,1), (8,1), (8,2), (9,2), (9,3), (9,4), (8,5), (7,6), (7,7), (8,8), (9,7), (10,8), (10,9), (9,10), (9,11), (9,12), (9,13), (9,14), (8,15), (9,15), (10,15), (11,15), (11,16) | (2,2), (3,1), (4,2), (5,2), (6,1), (7,1), (8,2), (9,3), (9,4), (8,5), (7,6), (7,7), (8,8), (9,7), (10,8), (10,9), (9,10), (9,11), (9,12), (9,13), (9,14), (10,15), (11,16), |

Comments on acceptance tests

**Acceptance test 1**

* All routes are correct but different
* Because of the way arrays work in C# the x and y of the coordinates are flipped
* When I made my ‘expected route’ I forgot that the algorithms could move diagonally. Note how depth first only does this in places like – using (y,x) –(2,6) to (3,5) where as breadth first always cuts the corner. This is because of the way the algorithms work. They both start top left and work their way across left to right top to bottom. Depth first goes to the first zero it sees, hence why it only sometimes uses the diagonal whereas breadth first goes to all, and the shortest route is found after hence the consistent corner cutting. This would suggest that breadth first is better at finding the shortest route but depth first is better at finding a route fastest

## 2.4 Descriptive Report, including artefacts

In this section, you are required to elaborate on how you devised your algorithm and developed the corresponding implementation in C#. Specifically, we are interested in your description of how you transformed your algorithm(s) into a corresponding implementation in C# and what strategy you employed to address the issues in this project (see below).

### 2.4.1 Transitioning algorithms to implementation

*Writing the code from ADL to Java was very simple, it does include more print statements for the program, however the same implementation is there as shown in the ADL above. The main difference is the stack class has a member variable called ‘item’, which stores the last item that has been popped from the stack. Apposed to directly storing the item from the pop() method returning a value.*

*Here is a diagram of the StackClass that I have created. This is the main class, however in the coded version there is some extra print functions for visual purposes only in the console application, so I have not included them here.*

Table

Description automatically generated

*The entirety of the coded Stack class will be shown in the video presentation. However here is the implemented sort() method designed to sort the plates in order with the largest at the bottom and smallest on top.*

Text

Description automatically generated

*As well as the procedure of creating the randomised plates and checking the material and initial order.*

Text

Description automatically generated

### 2.4.2 Problem-solving strategy

*To reorder the plates, I had to take into consideration the Time-Space Trade which made me to choose stack for my data representation, apart from the choosing the right data structure I had to think of how I will represent the plates, the easiest way to do that is to refer to the plates as integers since we know that we only have 4 types of plates that are desirable we can go for 1, 2, 3, 4 and any other number is an undesired plate.*

*Solution 1:*

*The first solution that I came with is space efficient, my algorithm consists of using two stacks, the first will contain the hand of plates in any order, the second stack will be used to sort the plates in the right order, the sorting process is simple:*

*The first step is to move the plates from stack 1 to stack 2 and getting rid of the unwanted plate types.*

*The second step is to move back the plates from stack 2 to stack 1 but we will be following some rules:*

*When we move a plate from stack 2 to stack 1 we need to check either plate type that we are moving is bigger or equal to the top of the first stack if it is we just push it there, if the plate type is less than the top of the first stack we will move the top of the first stack to the second stack and compare again the top of the first stack with our plate, every time we push an item from stack 1 to 2 we are having a count that increase every time, until we fulfil the condition, when we do we are pushing back the plates from stack 2 to stack 1 that have been moved for the sorting using a for loop using the count. We are repeating the process if the second stack is not empty.*

*The complexity of our algorithms:*

*F(n) = n+ (n-j).2k*

*So, O(f(n)) = n + (n-j).2k*

*n = initial number of plates*

*j = is the number unwanted plates*

*k = is the number of plates inside stack 1 when we want to move a plate from stack 2 to stack 1, we multiply it by 2 because we are moving them twice: from stack 1 to stack 2 then from stack 2 to stack 1*

*We are taking k as the worst-case scenario.*

*Here is a diagram representing our sorting process:*

Diagram, engineering drawing

Description automatically generated

Solution 2:

*The second solution that I came with is a time efficient solution but that consumes space in parallel, I am basically using 5 different stacks an initial stack where the plates are placed in any order and four other temporary stacks which will be used to sort the plates, we have four type of plates that are acceptable so each temporary stack is responsible for storing a specific type of plates, so what the algorithm is doing is pushing the plates from the initial stack to the temporary stack for example, if the plate is type 1 it will be stored in temporary stack 1, if the plate type is 2 it will be stored in temporary stack 2 etc …, any undesirable plate will be popped out from the initial stack and won’t be stored anywhere, when there will be no more plates in the initial stack we will push back to the stack using while loops the plates type number 1 then number 2 then number and lastly number 4. The big O notation for this algorithm is:*

*n represents the initial number of plates in our stack*

*j represents the number of unwanted plates*

*We have the first while loop which will run for n number of time to store the plates in the temporary stacks and since we are not putting back the unwanted plates in our stack, we subtract it from the total number of plates*

## 2.5 Incorporation of formative feedback

Provide evidence of how you evaluated and acted on the formative feedback you received from your tutors, including the tutor’s name and the timestamp.

|  |  |  |  |
| --- | --- | --- | --- |
| Date and Time | Name of the Tutor | Feedback of the tutor | How the comment is addressed |
|  |  |  |  |
|  |  |  |  |

# 3. Project 3

## 3.1 **Data Structure selection**

This section describes the data structures used to represent the graph using xxxxx.

Provide a discussion on time-space trade-off of the data structures.

# 3.2 Developed Algorithms

# Algorithm1: Influencers in Unweighted Network

***// Methods for graph construction***

***// Write comment of what the next steps do***

*Procedure jjjjjj(IN aa, IN b)*

*declare j,jj,jjj…*

***// Algorithm1***

*CALL jjjjjj(\_,\_) // Prints direct cities of any given input*

*end*

### Time Complexity of Algorithm1: Discuss about the time complexity of Algorithm1 that you have developed.

## 3.2.2 Algorithm2: Influencers in Weighted Network

***// Methods for graph construction***

***// Write comment of what the next steps do***

*Procedure jjjjjj(IN aa, IN b)*

*declare j,jj,jjj…*

***// Algorithm2***

*CALL jjjjjj(\_,\_) // Prints direct cities of any given input*

*end*

### Time Complexity of Algorithm2: Discuss about the time complexity of Algorithm2 that you have developed.

# Implementation

## 3.3.1 Implementation details

Provide a paragraph explaining the implementation details

## 3.3.2 Publishing your project

Publish your project code in GitHub, make [JayaTangirala (github.com)](https://github.com/JayaTangirala) as collaborator and place the GitHub link of the project here for ready reference.

## 3.3.3 Evaluation

An evaluation of the implementation's scalability to the road network available at [euroroad | Road Networks | Network Data Repository (networkrepository.com)](https://networkrepository.com/road-euroroad.php) where Edges represent roads and nodes are intersections where roads meet.

# Reflection

## 3.4.1 Video

Make a video presentation explaining the working of the developed program in C# for not more than 10 minutes.

## 3.4.2 Feedback

Provide evidence of how you evaluated and acted on the formative feedback you received from your tutors, including the tutor’s name and the timestamp.

|  |  |  |  |
| --- | --- | --- | --- |
| Date and Time | Name of the Tutor | Feedback of the tutor | How the comment is addressed |
|  |  |  |  |
|  |  |  |  |

# 4. Project 4

## 4.1 Introduction to Bin Packing Problem

One dimensional bin packing is an NP-Hard problem meaning it cannot be verified quickly. It refers to a problem of packing varying sized items into fixed sized bins, with the aim of minimizing the number of bins required to pack all the items.

Worst Case scenario:

This is where every item is in its own bin, this would be forced to happen if every item is greater than the half the capacity of the bins.

A group of squares with numbers

Description automatically generated

*(Above) A visualisation of a worst case solution for a simple version of bin packing*

Best Case scenario:

The minimum number of bins. This is difficult to find as it depends on the size of the bins and the items; larger bins and smaller items means is the best case, and smaller bins and larger items is the worst.

The website <https://www.geeksforgeeks.org/bin-packing-problem-minimize-number-of-used-bins/> uses the formula:

Min no. of bins >= Ceil ((Total Weight) / (Bin Capacity)

Where:

* Total weight is the sum of the size( or weight as used in the article) of the items
* Ceil is a function that rounds to the next greatest integer

Note the >=, this is because this formula assumes that the items fit perfectly into each bin, this is not always the case, hence why the problem is NP-Hard however this formula could be a good Jumping off point for an estimate of the number of bins needed

A row of rectangular boxes with numbers

Description automatically generated

*(Above) A visualisation of a near optimum solution for a simple version of bin packing*

Complexity of the Problem

As Mentioned before Bin Packing is NP- Hard, this is because it is an optimisation problem, not a decision problem. It’s complexity also increases exponentially with the number of items. To Illustrate this I have used the previously mention formula to calculate the number of bins so I plot the number of possible combinations compared to the size of the data set.

A graph with a line

Description automatically generated

| Number of items to be Packed | Number of Possible combinations |
| --- | --- |
| 1 | 1 |
| 2 | 2 |
| 3 | 6 |
| 4 | 24 |
| 5 | 120 |
| 6 | 144 |
| 7 | 336 |
| 8 | 1920 |
| 9 | 12960 |
| 10 | 43200 |

Not all combinations are possible or optimal and this is using the optimal number of bins. This shows that large data sets are would be very hard to calculate using a non heuristic algorithm.

*See Annex for Spreadsheet link*

*Other Citations:* <https://scialert.net/fulltext/?doi=jas.2013.919.923>

## 4.2 Random Mutation Hill Climbing

*This section requires you to discuss your understanding of the method. You may conduct desk research for this section and must cite them.*

Random Mutation Hill Climbing is a greedy local search algorithm that uses a randomness to find solutions to a problem and a fitness function to determine how well the solution created solves the problem.

It works by generating an initial solution, evaluating its fitness, then making a small change and comparing it to the original solution’s fitness, if the fitness it higher than it chooses the small change if not it sticks with the initial solution, this is why it is called greedy – it only choses the solution with the best fitness. This is repeated until a solution with best fitness is found called an optima,

## 4.3 Algorithm Design

*In this section, you must explicitly explain the designed algorithm for solving the problem using Random Mutation Hill Climbing. You may add your own sub-sections under this section, such as:*

### 4.3.1 Solution Representation

Discuss how you are going to model or represent the problem’s solution. Use diagrams and explain them if necessary.

### 4.3.2 Fitness Function Analysis

This section should have discussed several (at least 2) proposed fitness functions for the problem. Provide evidence of which fitness function is the best/suitable for your work and explain it.

### 4.3.2 Small Change Strategy

Explain your strategy for small change. Use diagrams and elaborate on them.

### 4.3.4 Data Structure

Discuss the data structure you will use for the work. This should cover the data structure for the solution representation, the dataset itself, and the main program of the experiment.

### 4.3.5 Algorithm Pseudocode

Write the pseudocode for the algorithm you use for the work.

### 4.3.6 Experiment Strategy

Outline your experiment strategy for the work. This can be how many times you will run for the experiment. How many iterations will you use in the experiment, and how will you present the results? Will it be getting the average or only the best run result?

## 4.4 Results

*Tabulate the results and plot graphs in this section. Discuss them. You may add sub-sections in this section based on your content.*

## 4.5 Testing

*Provide evidence for testing, e.g., unit and system testing.*

## 4.6 Software and its Presentation, including testing (and video link)

*All you need is to attach a link for the video recording. Do not forget to ensure the video recording is accessible by us.* **If we cannot access your video recording, you will get zero marks for that section. Therefore, please ensure you test your video link by asking someone else to access your video recording.**

## 4.7 Incorporation of formative feedback

Provide evidence of how you evaluated and acted on the formative feedback you received from your tutors, including the tutor’s name and the timestamp.

|  |  |  |  |
| --- | --- | --- | --- |
| Date and Time | Name of the Tutor | Feedback of the tutor | How the comment is addressed |
| 15/11/24 | Ziarul | Discuss why the problem is so complex | Added complexity sub heading in 4.1 |
|  |  |  |  |