

**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.**

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 {}

}

}

}

Breadth 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

### 2.4.1 Transitioning algorithms to implementation

During implementation I changed from the ADL significantly to simplify the program. I realised for both solutions I didn’t need a look around function if I was just going to loop through again. So instead of ‘looking around’ then processing I process as I ‘look around’ this reduces the time complexity of both algorithms and means there are less function calling.

I also decided to wrap both solution’s code in a class so I can take advantage of encapsulation and inheritance. I created a common class routingAlgorithm that stores the inRange function and originally the look around function. inRange(), is a function that I realised need to make because of how C# handles out of range accessing that I overlooked when designing the algorithms in ADL.

Depth first has a findRoutePt2 function as I wanted to have the solutions return the same data structure but still wanted to use and Endless stack in the recursion element so in the Depth first code findRoute acts as wrapper function that formats the output of the recursive findRoutePt2.

### 2.4.2 Problem-solving strategy

When considering this problem, I saw each 0 in the maze as a node of a graph, and thus I was able to use Algorithms associated with graphs. Despite these algorithms I decided to store the maze as matrix as this was the closest representation to the mazes given and my relative experience at using matrices to graphs in C#. When designing the two algorithms, I focused on three things: time complexity, space complexity and the length of the route found.

Solution 1 Depth first:

I designed this algorithm to be the leanest and fastest so low time and space complexity; the route’s length wasn’t important just that it worked. I would imagine that this style of algorithm would be used in a game pathing situations where the speed of the operation was a priority to ensure the program ran smoothly.

It could almost be called a greedy algorithm as it takes the first path it sees. It ‘looks around’ by using two nested for loops to first check the three nodes above, then the three nodes on the same row as it then the three nodes below.

A black background with numbers and red arrows

Description automatically generated

*Above: diagram of how the algorithm ‘looks around’*

I use recursion to handle the repetitive nature, in this way little code is used implementing a loop and little space is wasted storing information that isn’t used. When a node is traversed to, it pushes it to the Endless Stack. When the end node is found it returns the Endless Stack; if it can’t find a node to traverse to that hasn’t been traversed to yet, it returns null.

**time complexity (worst case):** O(n)

**time complexity (best case):** O(s)

Where:

n = number of nodes in the matrix.

s = the number of nodes in the most optimal route.

**Explanation:**

Though I do use nested for loops they are of constant time complexity as combined they run 9 times for every node visited, the only loop that depends on the input size is the loop created by the recursion - so for every node visited - which in the worst case would be all nodes in the matrix.

Solution 2 Breadth first:

I designed this algorithm to be one that prioritised the shortest route regardless of the time or space complexity. I would imagine that this style of algorithm would be used in a mapping solution like Google Maps where the route distance is the priority.

The algorithm works by ‘looking around’ the current node (in the same way as depth first) and adding any possible traversable nodes to a queue if they haven’t already been visited. To do this I employ a custom data structure node to store the node’s position in the matrix, whenever it’s the end node, and the node it would be visited by, this is used as a pseudo linked list to find the most optimal route. Once this is finished the next node in the to visit queue is dequeued and added to the visited list, this becomes the current node, and the process starts over again. The loop ends when there are no more items in the to visit queue. The route is found by following the linked list created by the node data structure starting with the node that where the end found value is true.

**time complexity (worst case):** O(n\*v)

**time complexity (best case):** O(n\*v)

Where:

n = number of nodes in the matrix.

v = number of nodes in visited list; from 0 to n

**Explanation:**

The algorithm will traverse to every node in the matrix and in looking for new nodes will perform a linear search through every node in the visited list, whose length starts at 0 but ends up at n.

**Improvements:**

To remove the v value from the complexity, I could use a hash map to access a node in constant time. This was suggested to me by Mehemet after implementation, hence why I have not included it in the code.

I did think if I could use heuristics to optimise the algorithm by stopping it traversing to nodes that don’t lead in the direction of the end and make it more akin to something like A\* or Dijkstra’s but as the target node’s position is not known I could not see a way of making it make a prediction and know which paths to stop.

## 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 |
| 18/10/24 1130 | Mehemet | Good work | N/A |
| 21/11/24 1115 | Mehemet | Good work – consider the time/space trade off when using the visited data structure |  |

# 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***

***// for non weighted***

***class unweightedGraph:***

***let nodes be a adjacency list of all nodes in graph and their connections***

***// function to traverse to all other nodes using a breadth first technique***

***function findRoutes(startNode):***

***let toVist be a queue of nodes in order of next to visit***

***let visited be a dictionary of edges from one node to another stored as nodeTo, nodeFrom***

***add startNode to toVist***

***add startNode : null to visited***

***foreach node in toVist:***

***foreach adjacentNode in node's connections***

***if adjacentNode is not in visited:***

***add adjacentNode to toVist***

***add adjacentNode : node to visited***

***end if***

***end foreach***

***end foreach***

***return visited***

***endFunction***

***function findRoute(start, routes)***

***let route be a list of nodes***

***let nextNode = start***

***add start to route***

***while nextNode is not null:***

***add routes[nextNode] to route***

***set nextNode = routes[nextNode]***

***end while***

***return route***

***endFunction***

***function calcScore(scoreNode, graph):***

***let distanceToNode = []***

***let routes = call findRoutes(scoreNode)***

***foreach node in graph:***

***if node is not score node:***

***add (call length(findRoute(node, routes)) ) to distanceToNode***

***endif***

***end foreach***

***return numNodes-1 / sum of distanceToNode***

***endFunction***

***function findBestScore()***

***let bestScore = 0***

***let bestNode = Null***

***foreach node in graph:***

***let newScore = call calcScore(node)***

***if newScore > best score:***

***bestscore = newScore***

***bestNode = node***

***end if***

***end foreach***

***endFunction***

***endClass***

### 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***

***// for weighted***

***class weightedGraph:***

***let nodes be a adjacency list of all nodes in graph and their connections with weights// I.E. A : {{B, 1},{C, 1}, {E, 5}}***

***// function to traverse to all other nodes using a breadth first technique***

***function findRoutes(startNode):***

***let toVist be a queue of nodes in order of next to visit***

***let visited be a dictionary of edges from one node to another stored as nodeTo, nodeFrom***

***add startNode to toVist***

***add startNode : null to visited***

***foreach node in toVist:***

***foreach adjacentNode in node's connections***

***if adjacentNode is not in visited:***

***add adjacentNode to toVist***

***add adjacentNode : node to visited***

***end if***

***end foreach***

***end foreach***

***return visited***

***endFunction***

***function findRoute(start, routes)***

***let route be a list of nodes***

***let nextNode = start***

***add start to route***

***while nextNode is not null:***

***add routes[nextNode] to route***

***set nextNode = routes[nextNode]***

***end while***

***return route***

***endFunction***

***function calcScore(scoreNode, graph):***

***let distanceToNode = []***

***let routes = call findRoutes(scoreNode)***

***foreach node in graph:***

***if node is not score node:***

***add (call length(findRoute(node, routes)) ) to distanceToNode***

***endif***

***end foreach***

***return numNodes-1 / sum of distanceToNode***

***endFunction***

***function findBestScore()***

***let bestScore = 0***

***let bestNode = Null***

***foreach node in graph:***

***let newScore = call calcScore(node)***

***if newScore > best score:***

***bestscore = newScore***

***bestNode = node***

***end if***

***end foreach***

***endFunction***

***endClass***

### 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.

<https://github.com/Omagar1/ADS/tree/main/Project%203/Project3>

## 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.

| 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 would be very hard to calculate using a non-heuristic algorithm.

[*Spreadsheet link*](Project%204/Complexity%20Finder.xlsx)

*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(RMHC) 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 of the small change is higher 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 better fitness. This is repeated until a solution with best fitness is found called an optima.

<https://www.geeksforgeeks.org/introduction-hill-climbing-artificial-intelligence/>

lists the pros of RMHC as:

* Simplicity and Ease of Implementation
* Versatility
* Efficiency in Finding Local Optima:
* Customizability

However there are Problems with RMHC. Local optima is the most apparent; this is where the algorithm finds an optima, but this might not be the most optimal optimum hence why it’s called a local optimum. And since the algorithm is greedy it won’t move from the local optimum to find a better optimum.

A Plateau is a similar in that is caused by the greedy nature, but the surrounding solutions are of the same fitness as each other.

There are many ways top combat these problems, including random restarting and how the fitness value is calculated.

A diagram of a graph

Description automatically generated with medium confidence

*(Above) A visualisation of the local optima and plateau problems*

These problems can be overcome by a multitude of methods the two most common ones are:

* Random Start RMHC – once local optima is found restart and see if the new local optima is better that the current local optima for x number of times
* Stochastic hill climbing is a non-greedy version of RMHC where it accepts a degree of worse fitness (determined by a tolerance value) in the hope of finding a better optima past the decline

## 4.3 Algorithm Design

### 4.3.1 Solution Representation

I plan on using an array of equal length to the data set; this array will contain the bin number I am assigning that index to. I am mapping the index of the solution to the data set – giving each item a bin.

A black and white picture of a number grid

Description automatically generated with medium confidence

### 4.3.2 Fitness Function Analysis

For All Equations:

* n is number of bins
* b is a set of items in each bin
* c is the capacity of a bin
* is fitness

**Fitness eq 1:**

Mean average of the percentage of the bin used or negative integers for number of bins overflowing:

OR for all times >1: f –

I designed this fitness function to create a steady linear progression from worst case to best case in this way fitness should be steady.

**Fitness eq 2: from:** [**https://scialert.net/fulltext/?doi=jas.2013.919.923**](https://scialert.net/fulltext/?doi=jas.2013.919.923)

Mean average of the squared percentage of the bin used or negative integers for number of bins overflowing:

OR for all times >1: f --

A more exponential growth in the fitness value(FV). “This [fitness function] will avoid large plateaus in the search space around the best solutions” it provides a larger difference between the FVs of the best solutions though it gives less of a difference of FVs with worst solutions which may cause it to get stuck if the initial solutions is bad.

**Fitness eq 3:**

A logarithmic approach accounting for the number of bins normalised to produce same range of values as previous equations:

OR for all times >1: f –

Does the opposite of eq2, aimed at getting out of the worst-case scenario into a better scenario, is likely to plateau at higher values.

*data based on a small set of 3 bins*

A table of numbers and symbols

Description automatically generated

**Evaluation:**

Fitness 3 is more likely than the others to find a maxima in the in the mid ranges of the so will like to find a solution but not the best solution because of this I believe fitness 1 will out perform it.

Fitness 2 is more likely to find a better solution one it passed the midpoint but would struggle to get out of a band starting value. As the start is random it would likely need many restarts to find a good starting point to get the higher values.

Fitness 1 is constant and thus will have the same probability of improving from any starting solution which is good as the starting solution is random. Because of this I will choose fitness 1.

### 4.3.2 Small Change Strategy

I have a value called numChaneges that is determined as the integer above 20% the size of the data set. For numChaneges number of times I take a randomised index in the current solution and replace this value with a randomised number from 1 to the number of bins that I am using. I did consider swapping two randomised values but reasoned that this method as a lower potential ceiling in fitness as it only used bins generated by the initial solution. And if the number of bins was increased, as my algorithm does, then the swapping method couldn’t take advantage of that.

A diagram of a number

Description automatically generated with medium confidence

### 4.3.4 Data Structure

I will use arrays to store the data set and solution (of type double and int respectively) as their sizes can be fixed and arrays allow for quick random access. I will use their indexes to map the solution to the data set.

So the user can have a less abstract view on the way the bins are packed I will use as dictionary with the bin number as the key and the total of the items packed in each bin as the value to display the bins.

The output of the program will be a custom structure containing, the fitness of the solution as a double, the number of iterations the program took in an integer, the solution, and the bins both in the data structures previously mentioned

### 4.3.5 Algorithm Pseudocode

|  |  |
| --- | --- |
| Line N.O. | Code |
| 1 | Input dataset |
| 2 | Input binCapasity |
| 3 | Let numChaneges = length(dataset) \* 0.2 |
| 4 | Let numBins = sum(dataset)/ binCapasity rounding up |
| 5 | Let S be an array of random intigers |
| 6 | Let F be S’s fitness |
| 7 | While(noChangeCount > tolerance): |
| 8 | Let newS be an s with numChaneges number of random changes |
| 9 | Let newF be newS’s Fitness |
| 10 | If newF > F: |
| 11 | Let S = new S and F = newF |
| 12 | Set noChangeCount to 0 |
| 13 | Else If fitness > 0 and noChangeCount >= tolerance -1 |
| 14 | Increment numBins |
| 15 | Set noChangeCount to 0 |
| 16 | Else |
| 17 | Increment noChangeCount |
| 18 | End If |
| 19 | End While |
| 20 | OUT S and F |

### 4.3.6 Experiment Strategy

My experiment strategy works by using a tolerance value that is the number of times the program will run until it outputs a result. However, if there is an overflow, represented by a negative integer value of fitness the program will increase the number of bins available by one and reset the no change count to zero. I do this to encourage the finding of valid solutions are produced as I expect the more iterations the better solution will be found. I generally set the tolerance value to 100,000 though the optimal number would need to be determined, this would be based on the convergence value of the algorithm .

I present the results in a custom data structure called a BinPackingSolution which contains, the best solution found, the fitness of the solution, the iterations and the bins as they are filled by the solution. This can be written to a file.

## 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.*

*Find attached* [*Spreadsheet*](Project%204/results.xlsx) *as data too large to present here*

This graph ended up a lot more discrete than I expected: I was expecting a more of a bell curve from 0 fitness value (FV) to near 1. In fact I got only 4 different FVs: -1, 0.776307692, 0.841 and 0.917454545 see Pi chart to see numbers of each FV.

I initially Believed this discreet nature is caused by my Experiment Strategy of how I increment the number of bins if there in an overflow and reset the counter. My expectation was that if I did not do that the results towards the higher number of iterations would be in the negatives. This is supported by the outliers of FV -1 which all have hight iteration numbers. However, when I plotted the Number of iterations against the number of bins it showed no correlation:

As such I don’t know why I have such discrete number of FVs

The first graph shows the number of iterations needed to get to a high solution (known as the convergence value) is around 300,000.

## 4.5 Testing

### 4.5.1 Unit testing:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Data Set: |  |  |  |  |  |
| index: | 0 | 1 | 2 | 3 | 4 |
| Data: | 4 | 2 | 3 | 1 | 2 |
| bin capacity: | 5 |  |  |  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Function | Test Solution | Expected Result | Actual result | Passed | fix if necessary | Note index |
| GetBins |  |  |  |  |  |  |
|  | 1,2,2,1,3 | 1:5,2:5,3:2 | 1:5,2:5,3:2 | TRUE | N/A |  |
|  | 2,1,3,2,3 | 1:2,2:5,3:5 | 2:5,1:2,3:5 | TRUE | N/A |  |
|  | 1,2,3,4,5 | 1:4,2:2,3:3,4:1,5:2 | 1:4,2:2,3:3,4:1,5:2 | TRUE | N/A |  |
|  | 1,1,1,1,1 | 1:12 | 1:12 | TRUE | N/A |  |
| CalcFitness |  |  |  |  |  |  |
|  | 1,2,2,1,3 | 0.8 | 0.8 | TRUE | N/A |  |
|  | 2,1,3,2,3 | 0.8 | 0.8 | TRUE | N/A |  |
|  | 1,2,3,4,5 | 0.48 | 0.48 | TRUE | N/A |  |
|  | 1,1,1,1,1 | -1 | -1 | TRUE | N/A | 1 |
| SmallChange |  |  |  |  |  | 2 |
|  | 1,2,2,1,3 | N/A | 1,2,2,1,3 | TRUE | N/A |  |
|  | 2,1,3,2,3 | N/A | 2,1,2,2,3 | TRUE | N/A |  |
|  | 1,2,3,4,5 | N/A | 1,2,3,4,5 | TRUE | N/A |  |
|  | 1,1,1,1,1 | N/A | 2,1,1,1,1 | TRUE | N/A |  |

**Notes:**

1. *– 1 is an overflow as 12 > 5*
2. *No expected solution as small change is random; pass defined as true if the sum off all elements of result is within the range of the original solutions sum +- number change \* number of bins*
3. *There is no erroneous data as all data is generated by the program an not by a user thus no need to test a case that wouldn’t come up.*

### 4.5.1 System testing:

*Find attached* [*Spreadsheet*](Project%204/results.xlsx) *as data too large to present here*

## 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 |
| 21/11/24 | Ziarul | Good fitness function; add file reading; | Added file reading |