1. Task 3: Methodology, Results and Discussion
   1. Methodology

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| In task 3, our goal is to find out the path that has the lowest cost by designing a 16m2 minus cost area. We defined the best minus cost area is that the area is capable to help us greatly reduce the cost or conduct a path that has the lowest cost. We think that design the minus cost area as a line is more effective and more suitable to decline the cost because the PolyU-A380 can has a full use of the minus cost area. Otherwise, the PolyU-A380 cannot has full use of the minus cost area if we make in to square or rectangular. We will conduct this project by using the formula “C = 𝐶𝐹 ∙ ∆𝐹 + 𝐶𝑇 ∙ ∆𝑇 + 𝐶𝑐 + 𝐶𝑃 ∙ ∆P”.  We assume that the minus cost area is placed along the original path because the original path is the path that has the lowest cost calculated by the python A-star. Meanwhile, we try not to increase the total distance that the PolyU-A380 travels, so we think the minus cost area should be placed along the original path in order to cut the cost as much as we can. |
| Figure 1 (The Original Cost Without Minus Cost Area) |
| After that, we will try to figure out the possible minus cost area outside the original path in order to gain all possible results and prevent losing the potential minus cost area that gives us the best cost reduction.  Finally, we will also try to put the minus cost area next to the time consuming area and fuel consuming area in order to find out the path that make the increasing cost to be recovered by the minus cost area. For an exmple, place the minus cost area on the one side of the cost adding areas to recover the cost. It should a method to to gain all possible results. |

* 1. Results

This is the original PolyU-A380 travelling path calculated by Python A-star in Task 1. The cost in this path is 2941.417. The below picture shows the path of PolyU-A380 in Task 1.

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| Figure 1 (The Original Cost Without Minus Cost Area) |

* + 1. Designing Minus Cost Along the Original Path

The numbers are the minus cost area locations in the pictures below.

|  |  |
| --- | --- |
| The Location of Minus Cost Area | Cost |
| Location 1 | 2068.832 |
| Location 2 | 1354.041 |
| Location 3 | 1267.332 |
| Location 4 | 1131.498 |
| Location 5 | 355.203 |

Chart 1 (The results of designing minus cost along the original path)

|  |  |  |  |
| --- | --- | --- | --- |
| Figure 2 (Location 1 in Part7.2.1) | | Figure 3 (Location 2 in Part7.2.1) | |
| Figure 4 (Location 3 in Part7.2.1) | | Figure 5 (Location 4 in Part7.2.1) | |
| Figure 6 (Location 5 in Part7.2.1) | |

* + 1. Designing Minus Cost Outside the Original Path

The numbers are the minus cost area locations in the pictures below.

|  |  |
| --- | --- |
| The Locations of Minus Cost Area | Cost |
| Location 1 | 1981.215 |
| Location 2 | 1741.624 |
| Location 3 | 1723.415 |
| Location 4 | 956.830 |
| Location 5 | 1039.791 |
| Location 6 | 792.958 |

Chart 2 (The results of designing minus cost outside the original path)

|  |  |
| --- | --- |
| Figure 7 (Location 1 in Part7.2.2) | Figure 8 (Location 2 in Part7.2.2) |
| Figure 9 (Location 3 in Part7.2.2) | Figure 10 (Location 4 in Part7.2.2) |
| Figure 11 (Location 5 in Part7.2.2) | Figure 11 (Location 6 in Part7.2.2) |

* + 1. Designing Minus Cost Next to the Cost Adding Areas

The numbers are the minus cost area locations in the pictures below.

|  |  |
| --- | --- |
| The Locations of Minus Cost Area | Cost |
| Location 1 | 2038.494 |
| Location 2 | 2382.230 |
| Location 3 | 2382.230 |
| Location 4 | 264.043 |

Chart 3 (The results of designing minus cost next to the cost adding areas)

|  |  |
| --- | --- |
| Figure 12 (Location 3 in Part7.2.3) | Figure 13 (Location 4 in Part7.2.3) |
| Figure 14 (Location 5 in Part7.2.3) | Figure 15 (Location 6 in Part7.2.3) |

* + 1. Sorting the Data from Part 7.2.1 to 7.2.3

|  |  |
| --- | --- |
| The Location of Minus Cost Area | Cost |
| Location 1 in 7.2.1 | 2068.832 |
| Location 2 in 7.2.1 | 1354.041 |
| Location 3 in 7.2.1 | 1267.332 |
| Location 4 in 7.2.1 | 1131.498 |
| Location 5 in 7.2.1 | 355.203 |

Chart 1 (The results of designing minus cost along the original path)

|  |  |
| --- | --- |
| The Locations of Minus Cost Area | Cost |
| Location 1 in 7.2.2 | 1981.215 |
| Location 2 in 7.2.2 | 1741.624 |
| Location 3 in 7.2.2 | 1723.415 |
| Location 4 in 7.2.2 | 956.830 |
| Location 5 in 7.2.2 | 1039.791 |
| Location 6 in 7.2.2 | 792.958 |

Chart 2 (The results of designing minus cost outside the original path)

|  |  |
| --- | --- |
| The Locations of Minus Cost Area | Cost |
| Location 1 in 7.2.3 | 2038.494 |
| Location 2 in 7.2.3 | 2382.230 |
| Location 3 in 7.2.3 | 2382.230 |
| Location 4 in 7.2.3 | 264.043 |

Chart 3 (The results of designing minus cost next to the cost adding areas)

After placing different minus cost area locations into the map, we can get the data above. In order to find the best potential minus cost area location, we decide to place the minus cost area next to the location which is location 4 in 7.2.3 has the minimum cost in the above chart. Hope to find out the minimum cost.

|  |  |
| --- | --- |
| The Locations of Minus Cost Area | Cost |
| Location 1 in 7.2.4 | 320.375 |
| Location 2 in 7.2.4 | 19 |
| Location 3 in 7.2.4 | 94.042 |
| Location 4 in 7.2.4 | 26.042 |

Chart 4 (The results of further designing minus cost area from the location 4 in 7.2.3)

The numbers are the minus cost area locations in the pictures below.

|  |  |
| --- | --- |
| Figure 16 (Location 1 in Part7.2.4) | Figure 17 (Location 2 in Part7.2.4) |
| Figure 18 (Location 3 in Part7.2.4) | Figure 19 (Location 4 in Part7.2.4) |

* 1. Discussion
  2. Data Sorting

From the above part, we can observe that the paths having relatively low cost are located nearby the original path. In the above charts, we can see that chart 1 which is the results of designing minus cost area along the original path, its average cost is 1235. In comparison to the average cost in chart 2 and 3, the average cost in chart 1 is 138 lower than the that in chart 2 and 532 lower than that in chart 3. Hence, this reflect that the putting the minus cost area nearby the original path probably help us get the minimum cost.

In part chart 3, one of the results records the minimum cost, 264.043. In order to get the greater reduction on cost, we design part 7.2.4 to find out the potential result by setting the minus cost area nearby the minimum cost location 4 in chart 3.

Nevertheless, the result in part 7.2.4 is too small after conducted the part 7.2.4. In chart 4 in part 7.2.4, the biggest result is 320.375, another three data are lower than 10. We think the data in chart 4 is not suitable for the reality situation because some of the results reflect a near zero cost. So, it is reasonable that the data in chart 4 need to be analyzed to get more certain and accurate result. After that, choosing the result from the other charts instead of chart 4 may be needed.

* 1. Possible Error Analysis

Although the minimum cost observed on the above charts is 19 produced in location 2 in part 7.2.4, it could not be considered as the best location to put the minus area. It may be an error data generated by the a-star programme, because the cost should not be that small. After having a discussion, we have our explanation of why the data in part 7.2.4 is considered as error.

The factor of making these error is that the code pattern itself has some weakness that does not show the greatest path. The code used in the project is called AStarPlanner which is a basic path planning model. It calculates the cost by using the equation, “cost fuctionF(x) + HeuristicG(x)”. As the code shown in the file, “open\_set[o].cost + self.calc\_heuristic (self, goal\_node, open-set[o])”, the first function “set[o].cost” is F(x) and the second function “self.calc\_heuristic(self, goal\_node, open-set[o])” is G(x). When too many nodes have the same cost, the codes’ weakness exposed. It does not know which way is the best and the cost calculation become inaccurate. The F(x)+G(x) gives a bigger weighting for heuristic function G(x) in the equation. Eventually, the shorter distance between the minus cost area and the end point, the lower the cost is.

* 1. Choosing the Suitable Result from the Charts

Moreover, all the data conducted in part 7.2.4 should be rejected because of its uncertainty. Now, the data conducted from part 7.2.1 to 7.2.3 should be considered to make further decision.

From the part 7.2.1 to part 7.2.3, the minimum cost can be observed in location 5 in part 7.2.1 in chart 1 which is 355.203 and is decided to be our result on task 3. In figure 6, the minus cost area is placed along the original path. When PolyU-A380 pass through the time-consuming area, then it enters the minus cost area immediately. This result is suitable and reasonable in the situation of figure 6. There are some possible factors that make this result is acceptable and the best.

For the first reason, the chosen result utilizes the shortest distance belong to original path. As the original path calculated by the programme has the shortest travel distance, so we can utilize this characteristic to have further cost reduction by setting the minus cost area along the original path. When the travel distance remains no change, the minus cost area can have a significant effective on total cost reduction. Then, the PolyU-A380 does not travel longer, it means it does not increase any cost by travelling a distance to enter the minus cost area. In this situation, the cost is reduced dramatically. As a result, the cost is reduced dramatically because of the minus cost area.

For the second reason, minus cost area recovers the increase of cost caused by consuming areas after PolyU-A380 entering the minus cost area. As we can see the time related cost per minute of flight (𝐶𝑇) in time-consuming area is 2, the trip time (∆𝑇) is 5 and the additional time cost (∆𝑇𝑎) is 0.2. The cost of fuel per kg (𝐶𝐹) is 1, the trip fuel (∆𝐹) is 1 and the additional fuel cost (∆𝐹𝑎) is 0.2. However, the coefficient of minus cost area (𝐶p) is -2 and the reduced cost (∆P) is 2. Also, the PolyU-A380 travelled 16 m2 of minus cost area and travelled 15m2 in fuel-consuming area which is shown in figure 6. By observing the formula “C = 𝐶𝐹 ∙ (∆𝐹 + ∆𝐹𝑎(𝑥, 𝑦)) + 𝐶𝑇 ∙ (∆𝑇 + ∆𝑇𝑎(𝑥, 𝑦)) + 𝐶p ∙ (∆P) + 𝐶c”, the cost reduction is greater than the cost increase by the fuel consuming area, 𝐶p ∙ (∆P) > 𝐶𝐹 ∙ (∆𝐹 + ∆𝐹𝑎(𝑥, 𝑦)). We can know that the cost reduction eliminates most of the cost increased by fuel-consuming area, although time cost is a heavy burden towards the cost. Consequently, both of cost recovery and cost reduction happens during PolyU-A380 is travelling through this path. So, the cost is reduced.

In conclusion, there are two main factors including the total travel distance remains no change and the fuel cost is eliminated by the cost reduction. Consequently, we think the result in the location 5 in chart 1 in part 7.2.1 is our answer in task 3. Yet, we agrees that the programme needs to be improved to get more accurate and certain answer.