FINAL PROJECT FOR MODERN OPTIMIZATION METHODS
FALL SEMESTER 2021

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The main goal of this final project is to learn new algorithms on top of those learnt from the lecture, and to gain the ability to judge and compare these new algorithms to the existing ones. Here is a list of components that will be required in the final project.

1. **A Revision on Traveler Salesman Problem.** *(10 points)* The first part of this project needs you to review the famous Traveler Salesman Problem (TSP). It is a classic optimization problem that many metaheuristic algorithms try to implement. In this section, please write down the following:

   (a) What is TSP?

   (b) What are the difficulties in TSP?

   (c) What are the applications of TSP in real life?

(a) 給定一系列城市和每個城市之間的距離，求解旅行推銷員訪問每一座城市一次，並回到起始城市的最短路徑(最小成本)。

(b) 旅行推銷員問題的可行解是所有頂點(城市)的全部排列，隨著頂點數(城市數量)的增加，會產生組合爆炸。

(c) UberEats/foodpanda 外送路線規劃、物流宅配貨車配送路線規劃

2. **Data Collection.** *(10 points)* It is well-known that 7-Eleven is the most abundant convenient store in Taiwan. The logistic among all stores is always very complicated. Now we only focus on all 36 7-Eleven stores in Nangang District, Taipei City, and look for the optimal path through these 36 stores, so that the delivery van can ship the goods in the shortest path. First, we need to collect the data. Follow the following steps below.

   (a) Go to the following website: https://emap.pcsc.com.tw/emap.aspx. Gather all addresses of Nangang 7-Eleven stores.

   (b) Go to Google Map and measure the pairwise store distances, and form a distance matrix.

   (c) Consider a complete graph with 36 nodes, each is a convenient store and the edge between two nodes contains the distance information.

   Then the question becomes how to draw a line to pass through all 36 nodes on this graph, so that the distance is the shortest.

Please check my code "**dist.ipynb**" in the file and the result of distances is in "**dist.csv**".

3. **An Implementation of Known Metaheuristic Methods.** *(40 points)* In this course, we learn many metaheuristic algorithms and all these methods can be implemented in TSP. In this section, please implement the following algorithms in TSP.

   (a) Hill Climbing.
   (b) Random Walk.
   (c) Genetic Algorithm.
   (d) Simulated Annealing.
   (e) Tabu Search.
   (f) Particle Swarm Optimization (the standard one, not the SIB).
   (g) Ant Colony Optimization.

   For each algorithm, remember to state all necessary information, including the particle definition, objective function, goal, constraints, etc.

Please Check my code "**algorithm.ipynb**" in the file. There are titles of the 8 algorithms.

4. **Method Comparison.** *(30 points)* Now each of you will have 7 methods on hand. Please run them in TSP of 7-Eleven convenient stores in Nangang and answer the following questions.

   (a) Write down all parameters of 7 methods and state why you choose these values (so please choose reasonable values).
   (b) Provide the results of 7 methods on TSP of 7-Eleven convenient stores. You need to provide 7 lists of store names in order, and provide 7 maps with the routes.
   (c) Draw the progress plot by overlapping the results of all 7 methods. Note: some are single-state methods and some are population-based methods.

(a) **Parameters lists**:

(a) Hill Climbing. : iteration time = 60

(b) Random Walk. : iteration time = 60

(c) Genetic Algorithm. : iter = 60, n_population = 12, selectivity = 0.15, p_cross = 0.3, p_mut = 0.3

(d) Simulated Annealing. : iteration time = 60

(e) Tabu Search. : iteration time = 60, max length of tabu list = 10

(f) Particle Swarm Optimization. : iteration time = 60, w = 1, c1 = 5, c2 = 5,

(g) Ant Colony Optimization. : numant = 40, alpha = 1, beta = 5, rho = 0.1, Q = 1, iter = 60

(b) **Results**:

(a) Hill Climbing. :

最佳路線： [8, 12, 19, 22, 30, 32, 28, 6, 34, 25, 7, 26, 23, 16, 9, 13, 14, 1, 2, 11, 18, 27, 35, 17, 8, 15, 31, 10, 5, 4, 21, 29, 3, 33, 24, 20]

最佳路線長度： 80.5

(b) Random Walk. :

最佳路線： [8, 14, 9, 26, 2, 15, 30, 29, 13, 25, 6, 31, 11, 12, 22, 32, 8, 16, 3, 28, 27, 18, 35, 7, 34, 24, 33, 4, 23, 19, 20, 17, 21, 5, 10, 1]

最佳路線長度： 105.49999999999999

(c) Genetic Algorithm. :

最佳路線： [2, 3, 18, 16, 10, 31, 8, 29, 22, 5, 12, 35, 7, 1, 14, 25, 11, 33, 23, 34, 4, 9, 20, 30, 21, 32, 27, 17, 26, 28, 15, 0, 6, 13, 24, 19]

最佳路線長度： 70.7

(d) Simulated Annealing. :

最佳路線： [0 3 29 21 31 19 28 23 1 17 12 35 6 25 5 15 34 9 14 13 11 27 16 18 30 26 8 7 10 20 4 24 22 33 2 32]

最佳路線長度： 103.5

(e) Tabu Search. :

最佳路線： [0, 21, 27, 16, 4, 13, 23, 29, 14, 11, 19, 6, 18, 7, 3, 22, 32, 24, 5, 31, 33, 10, 30, 9, 8, 17, 28, 20, 2, 12, 34, 15, 26, 1, 25, 35]

最佳路線長度： 103.5

Tabu List： [[33, 34], [23, 30], [13, 28], [15, 22], [15, 20], [24, 30]]

(f) Particle Swarm Optimization (the standard one, not the SIB). :

最佳路線： [0 5 7 6 2 4 1 3 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35]

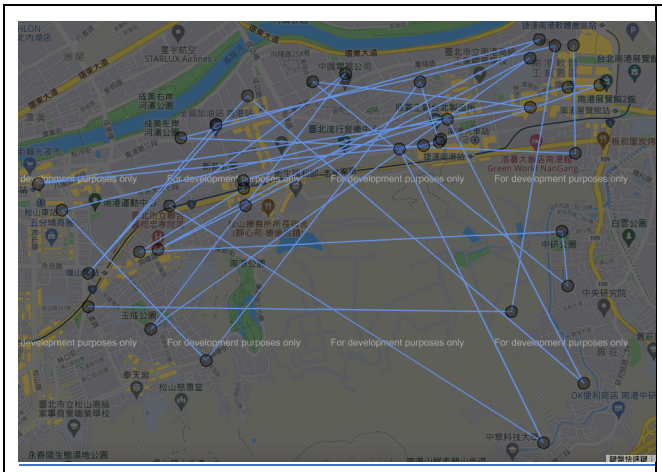
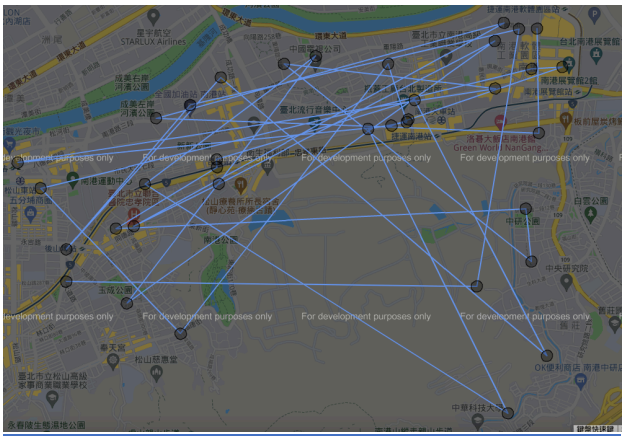
最佳路線長度： 120.96000000000004

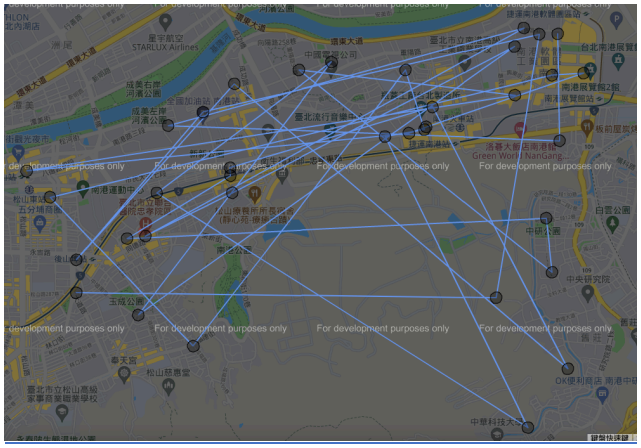
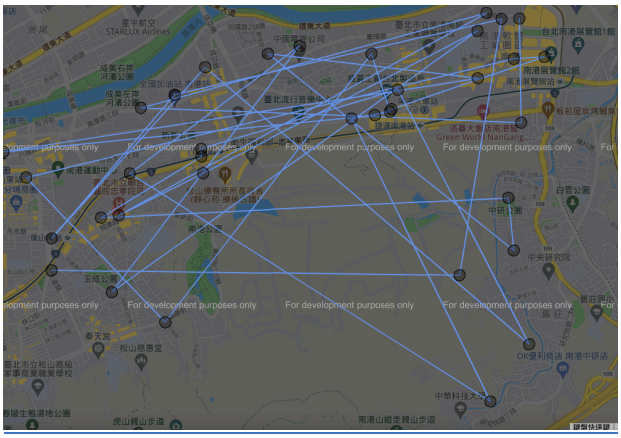
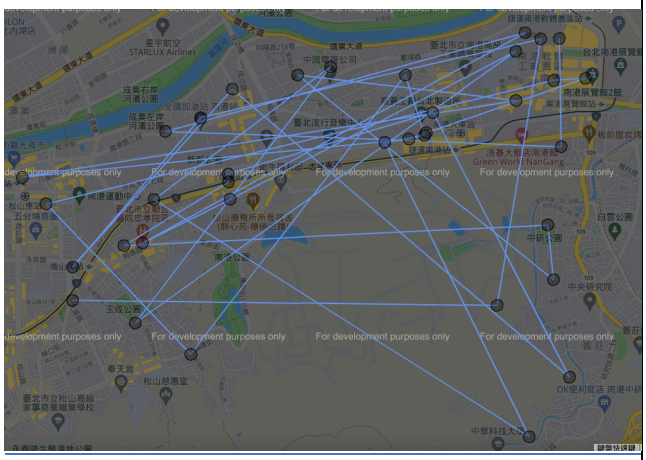
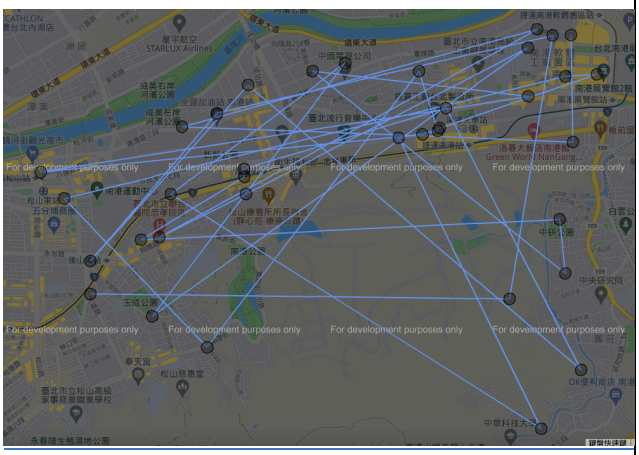
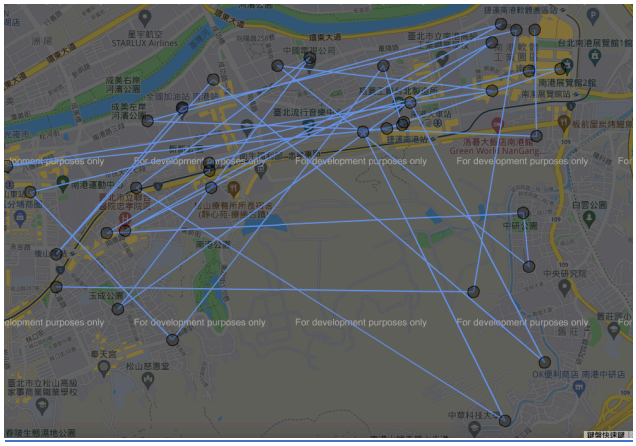
(g) Ant Colony Optimization. :

最佳路線： [3. 10. 31. 8. 9. 20. 28. 26. 0. 21. 4. 30. 13. 17. 19. 23. 29. 16. 14. 12. 25. 11. 1. 6. 34. 32. 7. 18. 24. 5. 22. 2. 35. 27. 33. 15.]

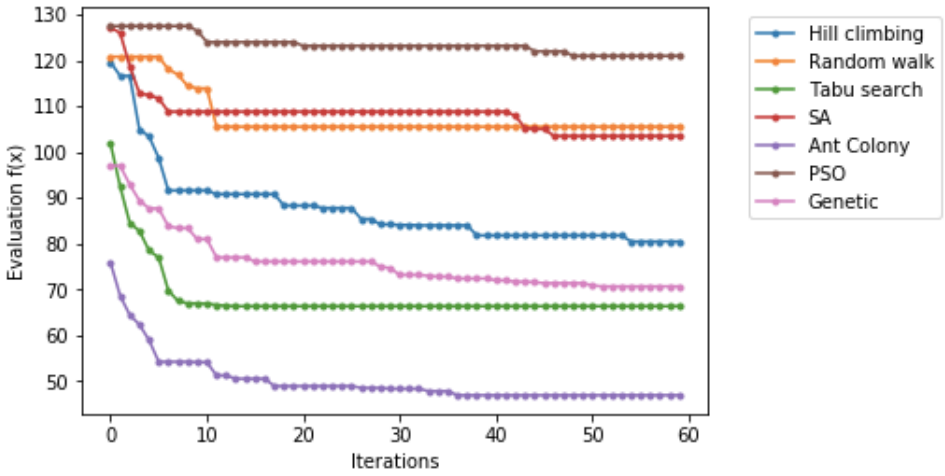
最佳路線長度： 46.959999999999994

- **MAPS:**

	
Hill Climbing	Random Walk

	
Tabu Search	SA
	
Ant Colony	PSO
	
Genetic Algorithm	

(c)



5. **Conclusion.** *(10 points)* In the last part of this final project, please provide the following information:

   (a) Summarize your comparison results on 7 methods.

   (b) State the advantages and disadvantages of all 7 methods shown in this application to TSP.

   (c) State at least one potential improvement on the best method to make the algorithm even better on this TSP application.

   (d) Suggest a potential memetic algorithm by combining two good methods from the 7 methods that is suitable for improving the result of TSP.

(a) 從實驗結果來看，Ant Colony 為所有方法中表現最好的演算法。而 Tabu Search 和 Genetic Algorithm 也因為參數的設定，可以讓演算法計算並考慮更多的可能解，從而找尋全域中的最佳解為何。例如：Tabu list 的長度設定、Genetic Algorithm 的子代設定數量等等。而在實驗過程中，我發現 PSO 起點對於演算法來說非常重要，選到一個好的起始點能夠有明顯較佳的結果，因為 PSO 對於局部最佳解的尋找非常有優勢。Hill Climbing 也是類似的情況，很容易被侷限在所謂局部最佳解的地方。而 Random Walk 雖然較 Hill Climbing 不易被侷限在區域最佳解中，但很看 Random 選擇的運氣，否則就是迭代次數要更多才會使演算法更有機率找到全域最佳解的位置。因此綜合上述與實驗結果，Ant Colony 與 Genetic Algorithm 為我認為較推薦的 TSP 解決方法。

(b) **(a) Hill Climbing.**

→ Advantages: 避免窮舉，只選擇部分節點搜索，提高搜索效率。

→ Disadvantages: 1.有時候會陷入區域最佳解，而不一定能找到全域最佳解。2.到達山頂或是山脊，無法確定最佳搜尋方向，會產生隨機走動使得搜索效率降低。

(b) Random Walk. 關鍵在步長的取值

→ Advantages: 給定每次行走步長越大，可找尋的解空間越大，較容易找到全域最佳解。

→ Disadvantages: 步長越大，總迭代次數越多，運算時間會越長。

(c) Genetic Algorithm.

→ Advantages: 全域搜索能力強，透過多點搜尋，比較不會陷入局部最佳解，

→ Disadvantages: 1.運算成本高，每個世代交替都要進行運算。2.手動設定適應值(Fitness Value)，不當假設下可能會得到區域最佳解而非全域最佳解。

(d) Simulated Annealing.

→ Advantages: 搜索效率比窮舉法高，如果參數設置得當，可以快速找到最佳解。

→ Disadvantages: 參數難以控制，若參數假設不好，容易陷入局部最佳解。

(e) Tabu Search. 取決於禁忌名單長度

→ Advantages: 透過禁忌名單，避開一部分的區域最佳解，獲得更多的搜尋區域，更容易找到全域最佳解。

→ Disadvantages: 仰賴禁忌名單長度。1.禁忌長度過短，一但陷入區域最佳解就無法跳出。2.禁忌長度過長，造成計算時間較大，也可能造成計算無法運行。

(f) Particle Swarm Optimization (the standard one, not the SIB).

→ Advantages: 搜尋速度快、效率高，容易結合其他演算法進行優化。

→ Disadvantages: 容易陷入區域最佳解。

(g) Ant Colony Optimization.

→ Advantages: 1.搜尋的過程同時修正原來的路線，搜索過程不斷收斂，最後逼近最佳解。2.不容易陷入局部最佳解。

→ Disadvantages: 搜尋路徑不是最優、搜索時間冗長。

(c) Ant 為所有方法中表現最佳的方法。我認為加上 GA 的演算法可以優化 Ant Colony 的表現。因為 GA 演算法的特點是可以快速從全域中找到哪些是解空間，而後再使用 Ant 去搜尋最佳解為何，計算時間上也會縮短許多。

(d) 起始點的位置為何對於 PSO 演算法的計算成效影響非常大。因此我認為 PSO 與 GA 結合是一種非常有優勢的方法。因為 PSO 在找局部最佳解非常強，而且速度很快，加上 PSO 是個容易結合其他演算法的方法；而 GA 雖然計算結果很不錯，但若子代過多，會迭代太多次，也就是把解空間內所有的可行解都包含在計算過程內了，但裡面其實很多都是區域最佳解而非全域最佳解，加上「適應值」應如何訂定較佳的問題也很難被定義。因此透過兩者演算法的結合可以互補各自的缺點，已達到更優的計算結果。

6. **Find New Method by Yourself.** *(Bonus 20 points)* A bonus score will be given if you do the following:

   (a) In fact, there exists many metaheuristic optimization methods nowadays, see Wikipedia for the complete list. Among them, try to pick one method that is not learnt from the course.

   (b) Write your own program code for the new metaheuristic method you picked.

   (c) Apply the new metaheuristic method to TSP. Provide its result on TSP of 7-Eleven convenient stores like those in Q4.

   (d) Add the result of new metaheuristic method to the progress plot. Note: the new method you pick is not necessarily the best method among all, but it cannot be the worst method.

(a) 布穀鳥搜索（Cuckoo Search，CS）

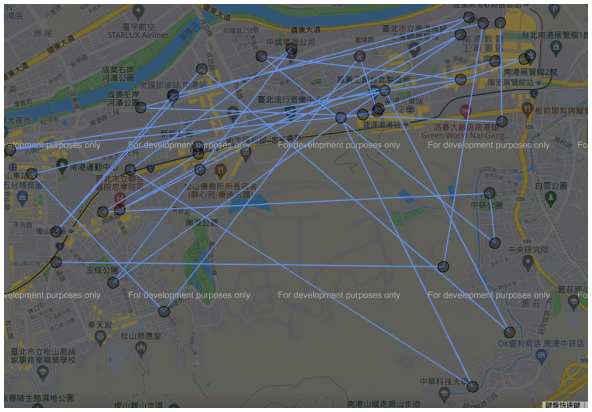
(b) Please Check my code "**algorithm.ipynb**" in the file. There is a part of bonus with the title "Bonus-Cuckoo Search Algorithm"

(c) **Parameter lists**: numNests = 80, pa = 40, pc = 48, maxGen = 60

Result: **最佳路線**： [2, 3, 4, 5, 6, 15, 8, 9, 10, 11, 1, 12, 13, 33, 24, 30, 17, 18, 19, 20, 21, 22, 35, 7, 25, 26, 27, 28, 29, 16, 31, 32, 14, 34, 23, 0]

最佳路線長度： 91.75999999999999

MAP：



(d) Progress Plot：