Green VRP with genetic algorithm

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GREEN VRP

- Considers environmental constraint

1) Minimize carbon emissions
2) Minimize Fuel consumption
3) Consider charging(should transit depot or charging station when it has insufficient fuel)

Neccesity

- More practical case of Vehicle routing problem
- Most of vehicle with green fuels only can be charged in specific place
- Cost saving proble -> Fuel consumtions

Description

- Should transport objects to customers(C_i)

(means visit each city at least once and return to depot)

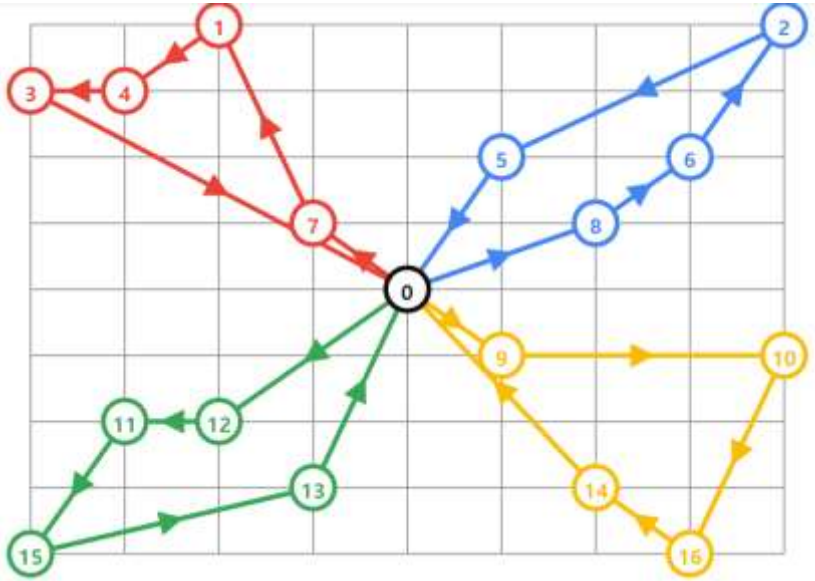
- Should visit Charging station(F_i) to charge when we have no fuel
- A green Vehicle Routing Problem(2012, sevgi Erdogan, Transportation Research Part E: 100-114)

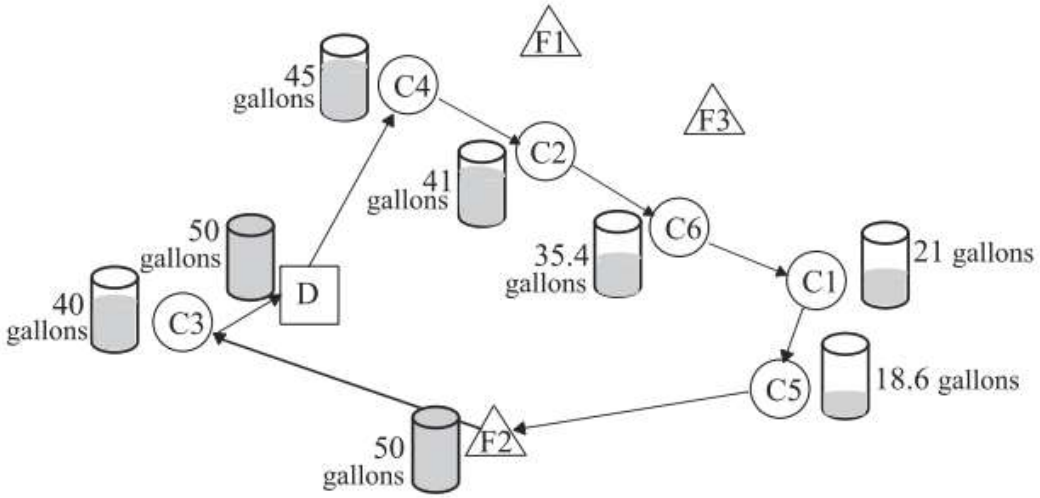
- Do parallel genetic algorithm and SGA

(How it performs in green vrp)

Fuel constraint

- Assume Fuel capacity is proportional with Euclidean distance
- When we visit charging station, fuel of veihicle become maximum
- Our goal is save fuel as much as possible(means it should minimize ditnace in given shap





Other conditions

Load capacity : inf(assume we can always transport whole objects at once)
No deadline, Incoming or outcoming time
All routes are available(every nodes are connected each other in straight)

-> focused on condtions about fuel and recharge

- Chromosome : length N(cities we visit(order based))
- Fitness evaluation : fuel consumption(distance) + penalty
- Selection : Tournament selection
- Crossover : one point simple crossover
- Mutation : swap mutation
- Penalty function : do experiment with extra fuel capacity

Penalty function & goals

- If we cannot proceed with given capacity, We assume we have more capacity of fuels and progress experiment

- Finess Value :

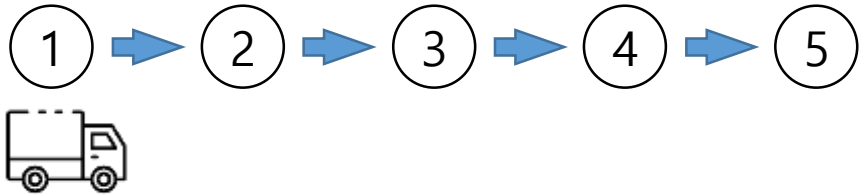
(sum of distance we travel) + λ* (additional fuel capacity)

λ = 1000 in this experiment -> make high penalty(to give lower fitness value when it keeps the fuel capacity)

Details in chromosomes

1	2	3	4	5

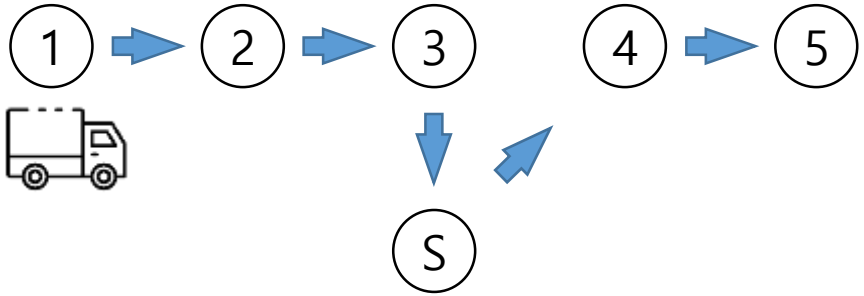
We travel in order of chromosome



1	2	3	S	4	5

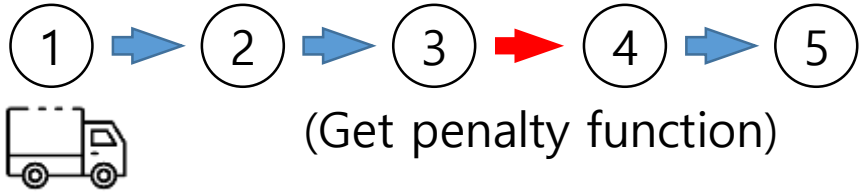
1	2	3	4	5

We will visit nearest charging station when We don't have efficient fuel



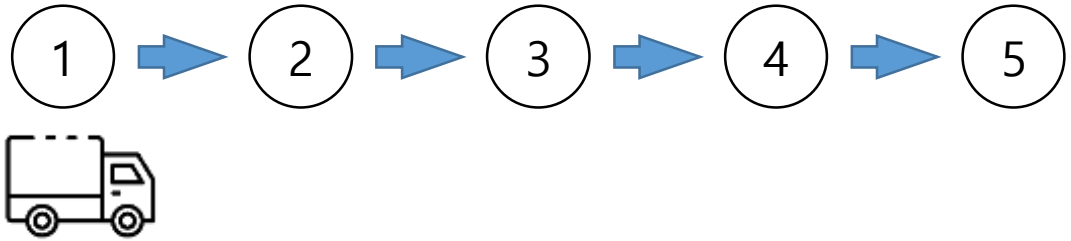
1	2	3	4	5

Even Can't visit charging station with present fuel, increasing fuel capacity(present fuel) and progress experiment



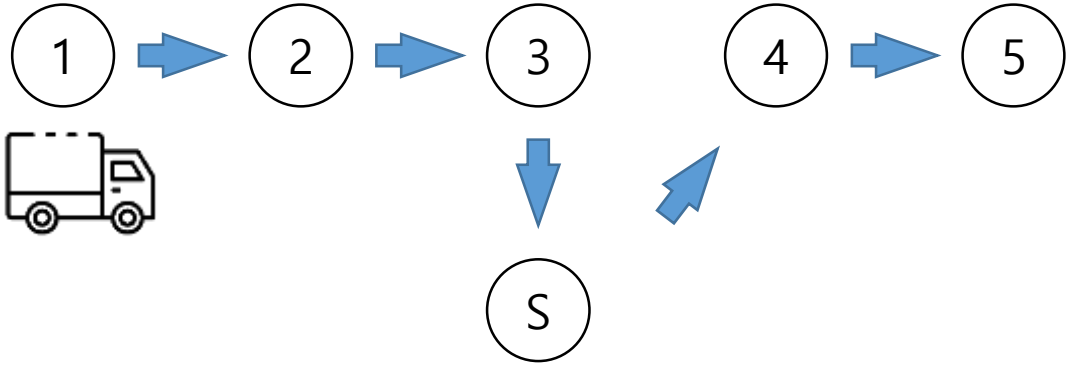
(Get penalty function)

Fitness value



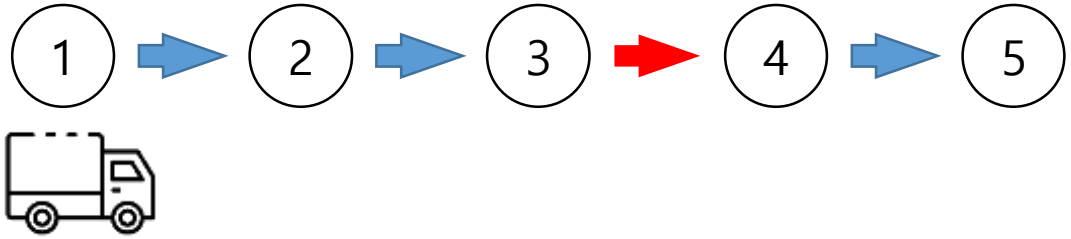
(sum of distance we travel)

$$d_{12} + d_{23} + d_{34} + d_{45}$$



(sum of distance we travel)

$$d_{12} + d_{23} + d_{3s} + d_{s4} + d_{45}$$



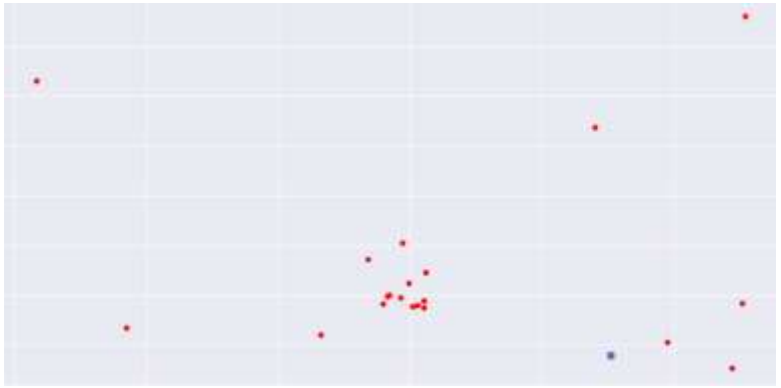
(sum of distance we travel) + λ^* (additional fuel capacity)

$$d_{12} + d_{23} + d_{34} + d_{45} + \lambda(\text{additional fuel need})$$

condtion

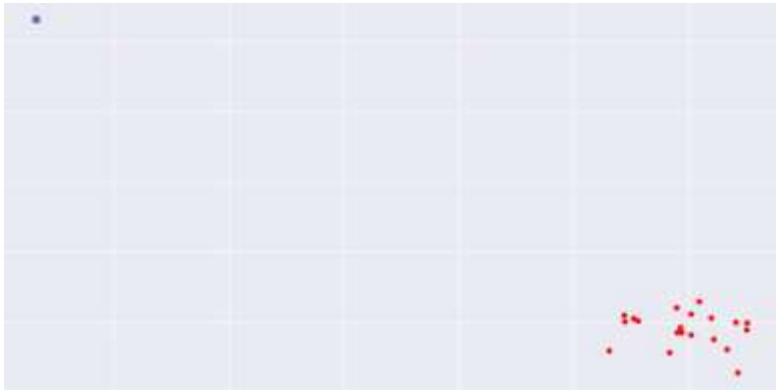
- Generation : 1000
- Population : 200
- Crossover rate : 0.4
- Mutation rate : 0.6
- Vehicles : 4
- Fuel capacity: 1000 (means distance 1000 can go without charge)
- Lamda(penalty coefficient) : 1000
- Map : 100*200
- 20/50 cities are random/clustered distributed, charge stations are regulary distributed

Maps

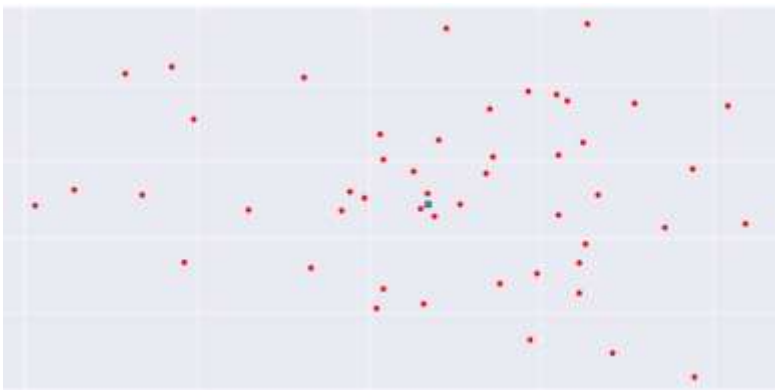


10 clustered, 10 random point

20 random point



20 clustered point



50 random point

Experiment details

- Do SGA and PSGA to solve vehicle routing problem
- In 1000 generations, it will find optimal value and repeat 10 time for same type of map

- Compare performance of 2 algorithm by fitness value

Result & colcusions

- Best fitness after 1000 generations

Average	**20 random**	**10 random 10 custered**	**20 clsutered**	**50 random**
SGA	521.04	476.54	365.2	4786.5
Parallel sga	467.26	455.13	358.1	2985.4

- Parallel algorithm find more optimal method in same generations
- In clustered distribution, both algorithm make similar performance
- The difference get bigger in more comlex situation

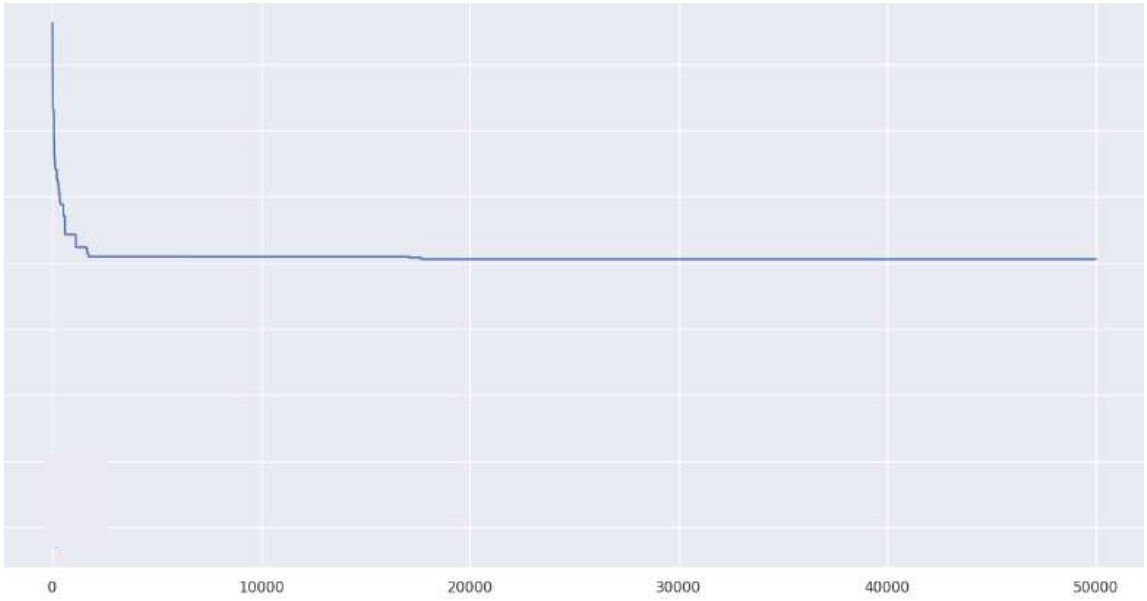
(Due to Penalty function activated more frequently)

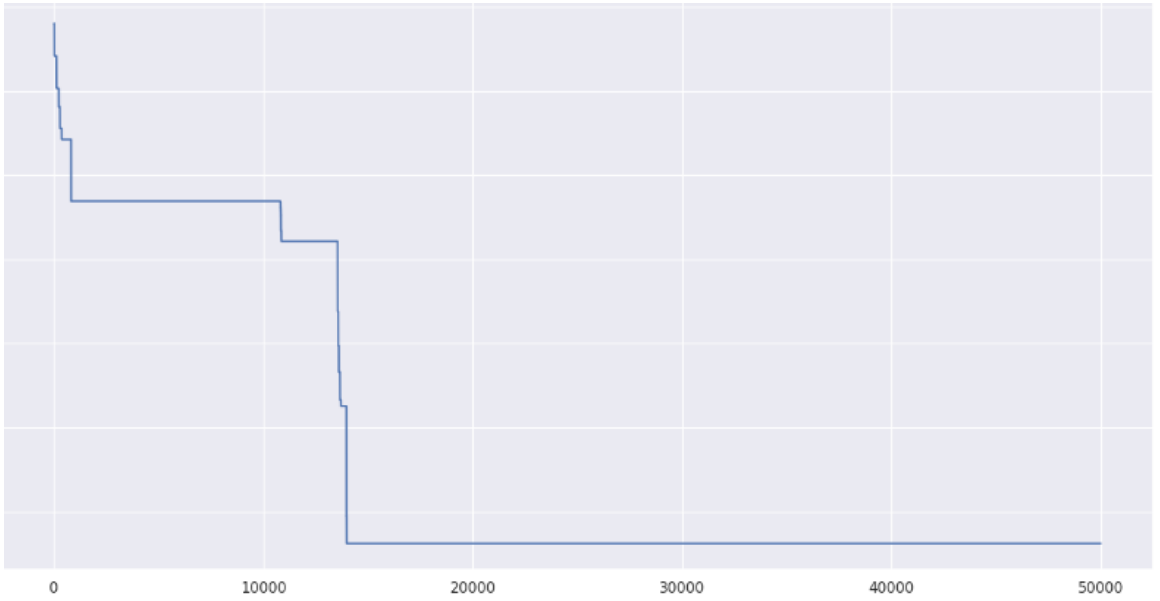
Additional experiment

- Tests for 20 random cities

Average	**1000**	**5000**	**10000**	**50000**
SGA	521.04	511.11	511.11	510.81
PSGA	467.26	456.21	456.21	443.54

- Is it converged or can attach better solution at the end?
- Did more iteration to see algorithms converges or improved





Simple genetic algorithm even not improved after 1000 generations
-> simple genetic algorithm easy to fall into local optima in green-VRP

Due to parallel genetic algorithm have more diversity in solutions and its robust, it's more effective in green-VRP

If the problem become more complicated or more factors -> parallel algorithm performs better

Complementary point

- Time-related variables : deadline of sipply, income time, charging time of fuels(due to charge of green vehicles takes long time)

- Fuels are not proportional to Euclidean distance practically

- Did not found real global optima(MILP)
- > These can make my researches more practical

References

- A green Vehicle Routing Problem(2012, sevgi Erdogan, Transportation Research Part E: 100-114)
- A Genetic Algorithm for Unmanned Aerial Vehicle Routing(2005,Russell,Matthew A.)
- Design and Development of a Genetic Algorithm for the Distance Constrained Vehicle Routing Problem with Environmental Issues(2015, Fatnassi, Ezzeddine)
- Research of the Time-dependent Electric Vehicle Routing Problem(2019, Liu, Kaiji ye, Peng Hong, Tao li, Bo)
- Genetic Programming for electric vehicle routing problem with soft time windows(2022, Gala, Fransicso Javier Gil)
- Towards Optimized schedules for charging electric vehicles on Austrian Highways using genetic algorithms(2023, Christian stipple, Benjamin Scwendinger, Gecco 23 companion)