Metaheuristic Based Fire Fighting and Scheduling Framework

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MOTIVATION

In recent years, with the effects of climate change and global warming, the number of forest fires has increased significantly, causing tremendous economic and ecological damage.

With **improper** scheduling of the resources and wrong predictions, the wildfires have destroyed millions of hectares every year.

PROBLEM DEFINITION

Constraints:

- All fire points shall be **visited** and **extinguished.**
- Number of vehicles used in a fire station shall not **exceed** its capacity.
- Fire points with high priority shall be served **first.**

Objectives:

- **Minimizing Weighted Extinguishing Time:** The sum of the completion of extinguishing time of all fire points weighted by their priorities.
- **Minimizing Total Travel Time:** The total travel time of all vehicles.
- **Minimizing Total Number of Vehicles:** The sum of the vehicles used in each fire station.
- **Unified Objective:** Weighted linear combination of all the objectives.

EXPERIMENTAL SETUP

Dataset Generation:

3 types of map generation methods are utilized for the experiments:

- **Random:** Placing points into 2D plane totally randomly.
- **Grid:** Placing points into grids for more scattered settlement.
- **Perlin Noise:** Placing points to weighted 2D map generated by Perlin Noise.

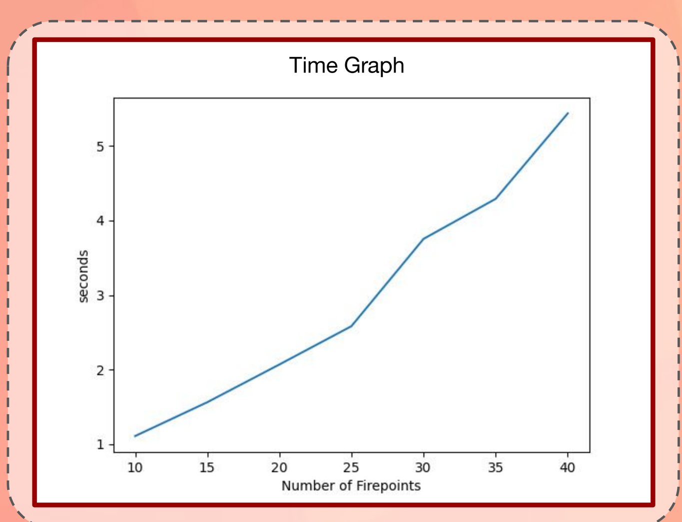
- **Spread speed** of each fire point is taken randomly between 5-19 m^2/min
- **Priority** of each fire point is selected from one of the values (1,10,100)
- **Fire-fighting speeds** are taken randomly between 20-30 m^2/min.
- **Vehicle speeds** are taken randomly between 30-80 km/h.

x30 For Each Case

RESULTS

Performance:

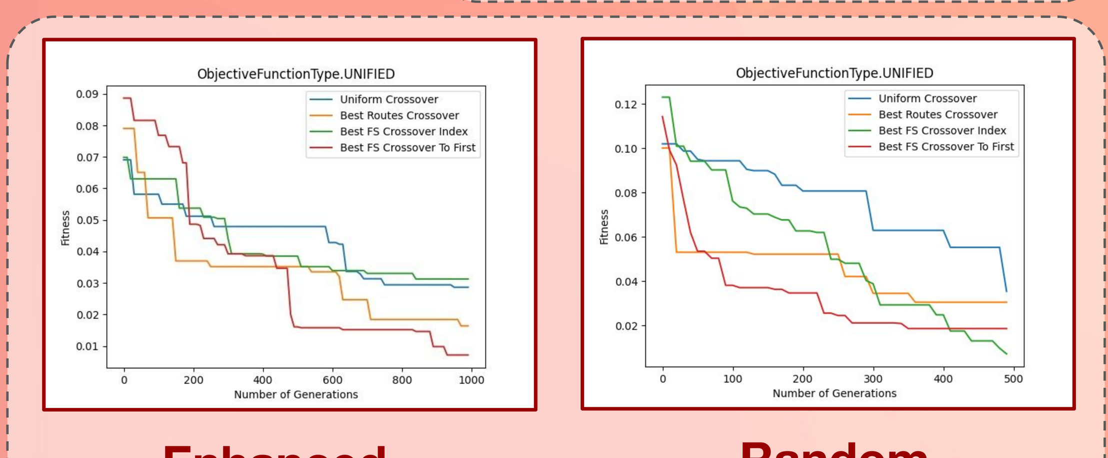
- Experimental study is carried out using AWS EC2 t2.micro virtual machines.
- We observed a **linear** relation between the running time and the number of fire points.



Effect of Initial Population:

We observed that:

- All crossover methods performed worse when initial population is set **randomly.**
- **Uniform crossover** is more affected than the other methods.



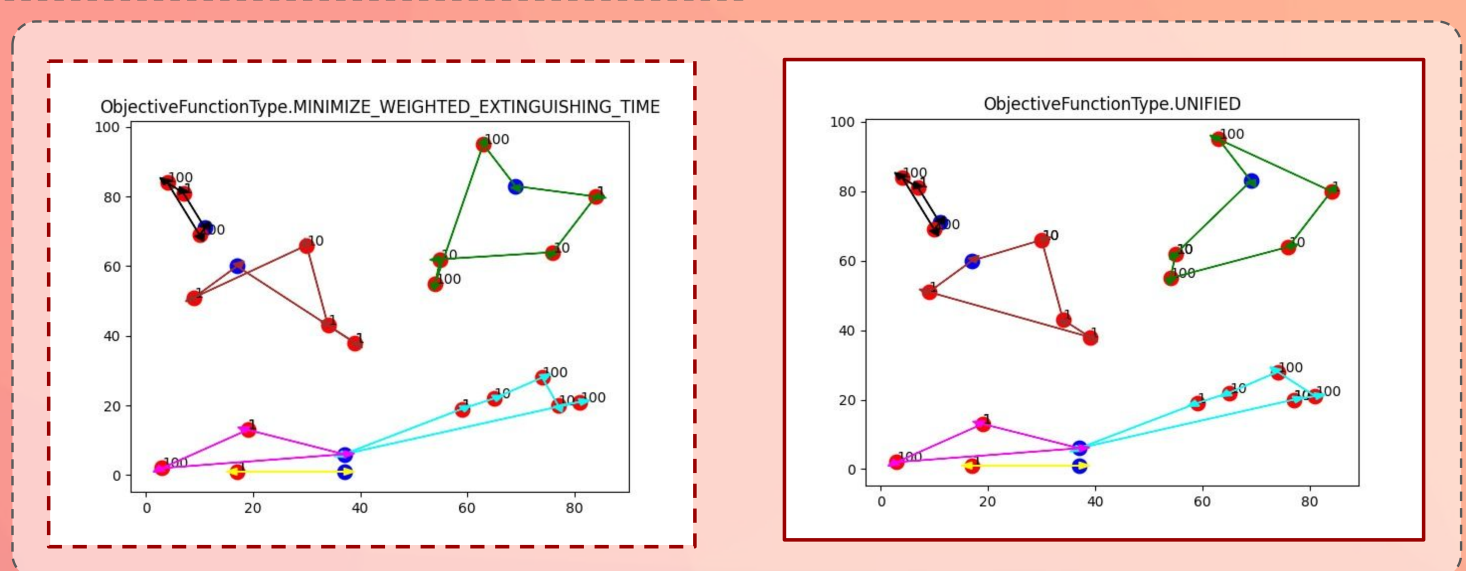
Example Solution:

We created a test case:

- **5** fire stations with **20** vehicles each
- **20** fire points

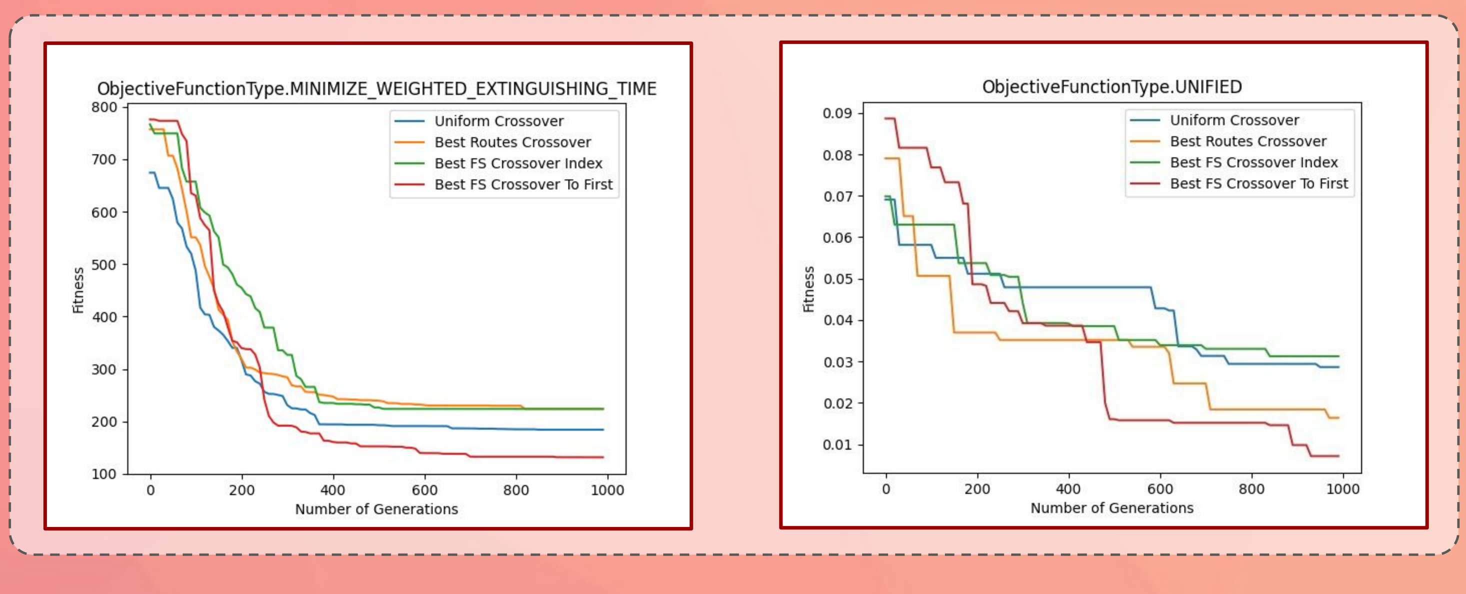
Conducted the tests with different objective functions. The results showed that changing the objective affected:

- The scheduling inside routes
- The number of routes for a fire station
- The number of vehicles in routes



Comparing Crossover Results:

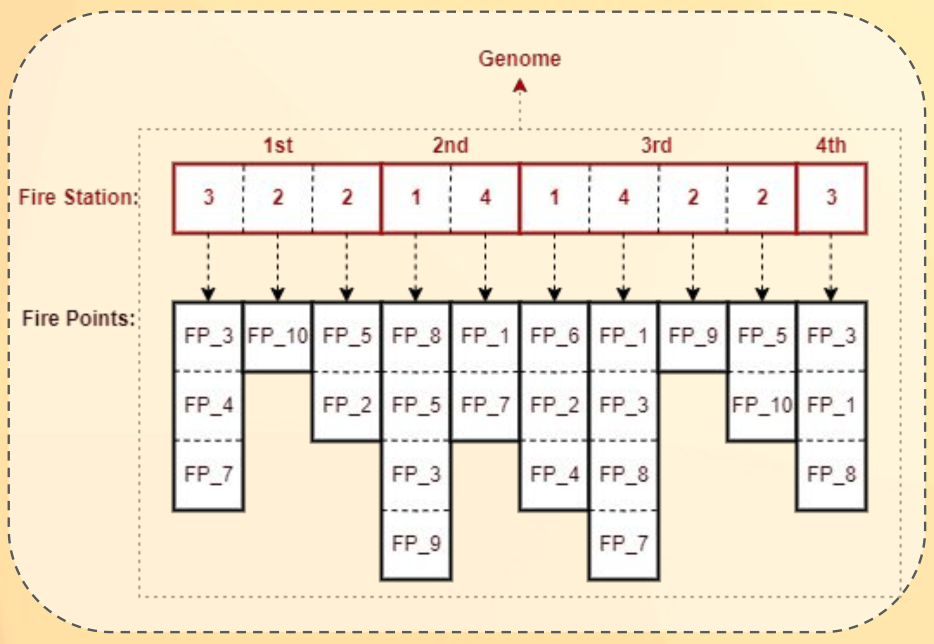
- We observed that in average, **Best FS To First** method outperforms other methods.
- We saw that **Uniform Crossover** and **Best FS at Index** method do not perform well for the unified objective. However **Uniform Crossover** method can be used if the time is limited, as it runs **fast**.



OUR GA APPROACH

Description: We propose a **unique** way of encoding the solutions to accomplish **multi-depot** behavior.

The encoding scheme holds a list of fire stations which in itself holds the routes. A route comprises of the the number of vehicles along with the list of fire points that should be visited.



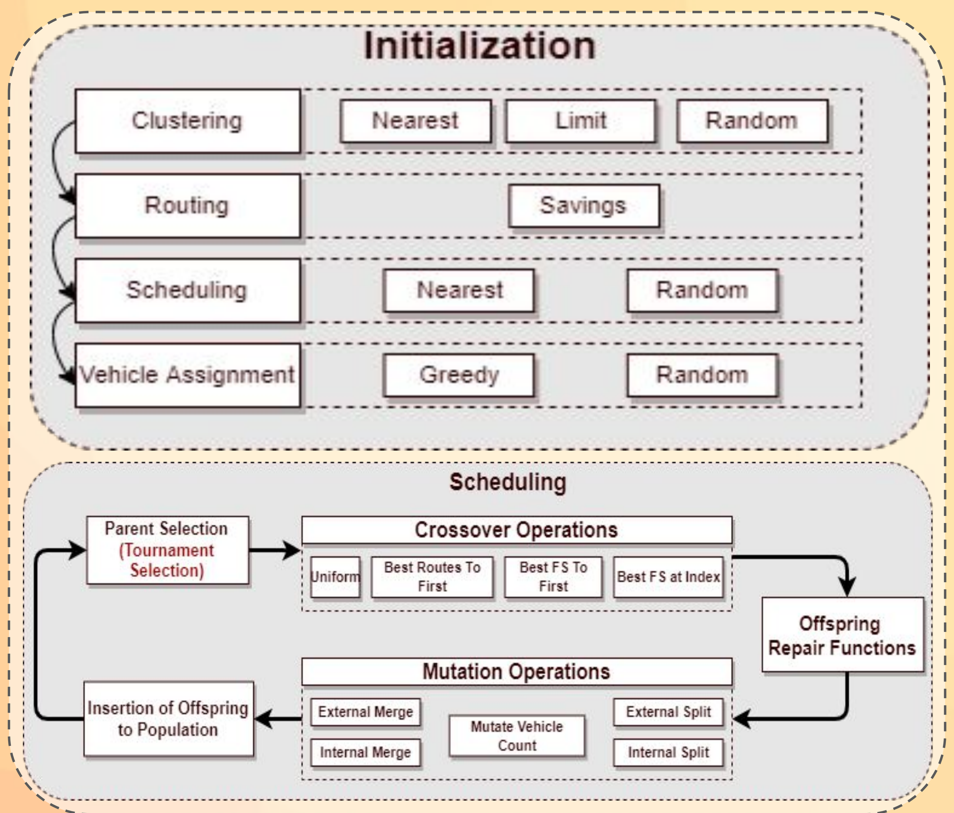
Initialization

Clustering: Assigning fire points to fire stations.

Routing: Assigning fire points to several routes within a fire station.

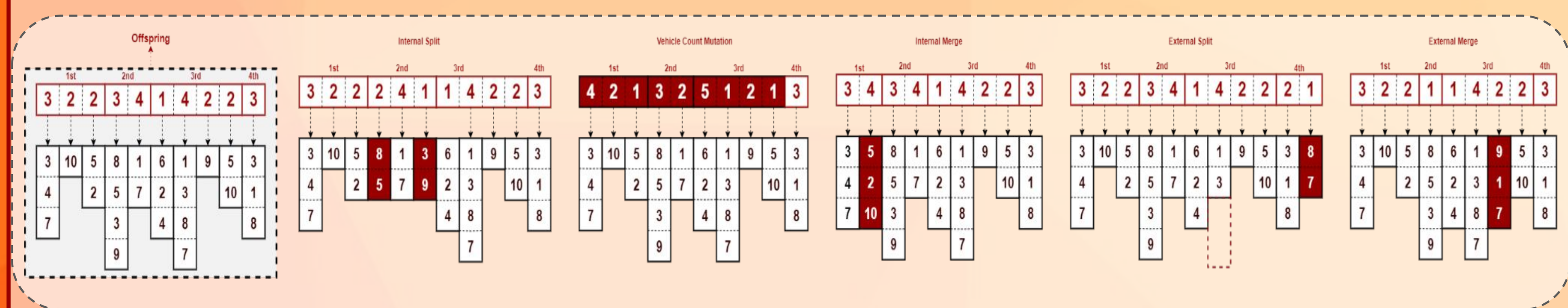
Scheduling: Determining the order of fire points within a route.

Vehicle Assignment: Assigning the number of vehicles to a route.



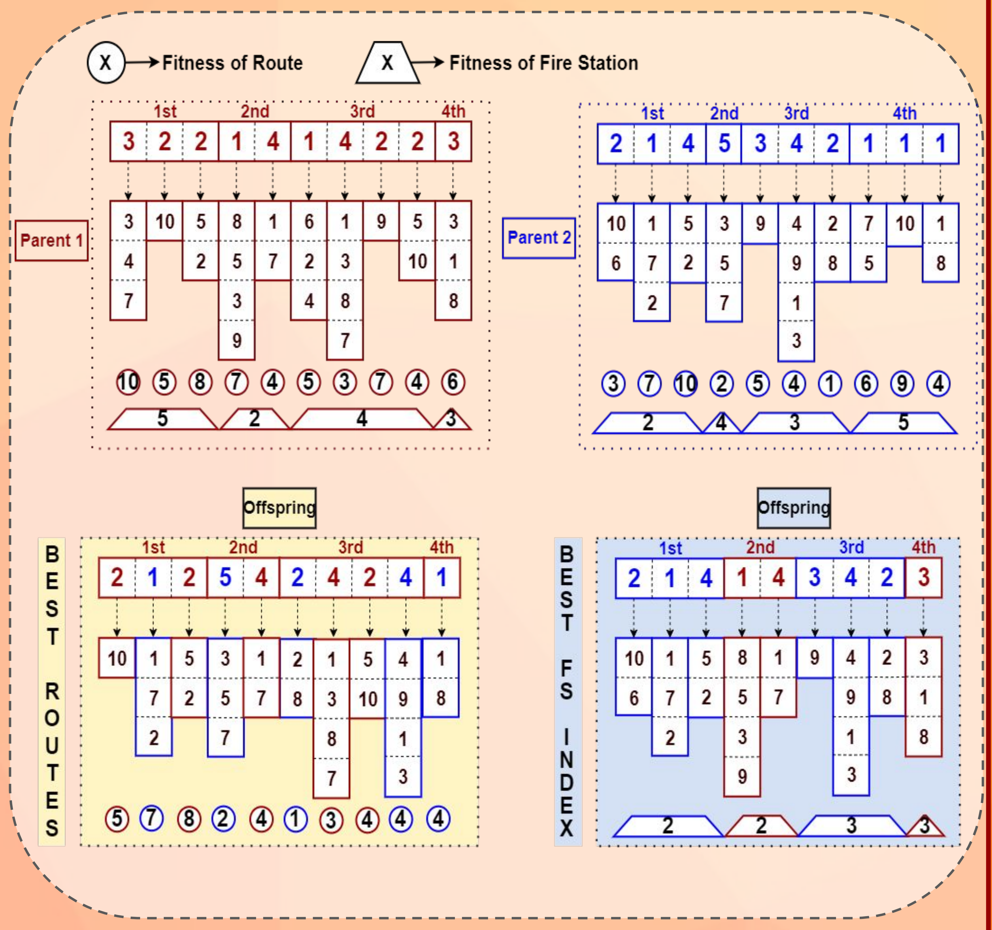
Mutation Operators:

Internal Split: A new route will be created with a subpath from another route in the same fire station.
Internal Merge: Two routes are merged into one route within the same fire station.
External Split: Selected subpath from a route is added into a route in another fire station.
External Merge: As in internal merge but path merged with the route in another FS.
Vehicle Count Mutation: # of vehicles in routes will be redistributed randomly.



Crossover Operators:

Uniform: Randomly selects the fire stations from the parents and inserts it to the offspring.
Best Routes to First: Finds best routes in parents and inserts them to the offspring, preserving the index of the fire station.
Best FS to First: Finds best fire stations in parents and inserts them to the offspring in order.
Best FS at Index: Finds the best fire station at the given index and insert it to the offspring.



CONCLUSION

In this work, we utilized a GA based solution with problem specific initialization and recombination procedures. We compared different scenarios of placements of fire station and points, evaluated the best operators to get the best results.

A possible direction for the future research would be the incorporation of multi-objective algorithms like **NSGA**.

SELECTED REFERENCES

[1]Peng Wu, Feng Chu, Ada Che, Mengchu Zhou. Bi-Objective Scheduling of Fire Engines for Fighting Forest Fires: New Optimization Approaches. IEEE Transactions on Intelligent Transportation Systems, IEEE, 2018, 19 (4), pp.1140--1151.
[2] Lubing Wang, Peng Wu 0004, Feng Chu. A Multi-objective Emergency Scheduling Model for Forest Fires with Priority Areas. In IEEE International Conference on Industrial Engineering and Engineering Management, IEEM 2020, Singapore, December 14-17, 2020. pages 610-614, IEEE, 2020
[3] Ren, Yaping & Tian, Guangdong. (2016). Emergency scheduling for forest fires subject to limited rescue team resources and priority disaster areas. IEEJ Transactions on Electrical and Electronic Engineering.