A Comparative Study of Particle Swarm Optimization and Genetic Algorithms for Post-Earthquake Relief Distribution.

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***Abstract*—Effective post-earthquake relief distribution is critical in alleviating the impact of such disasters. However, the complexity and unpredictability of these situations demand sophisticated planning and optimization strategies. This report presents a comparative study of two popular evolutionary algorithms - Particle Swarm Optimization (PSO) and Genetic Algorithms (GA) - in addressing this challenge. Our study involves developing a data-driven model that captures the essential aspects of post-earthquake relief distribution, including the various needs and resources of affected regions, and the logistical constraints on delivery. Through a series of computational experiments, we evaluate the performance of PSO and GA in solving this complex optimization problem. Our results reveal that while both methods are effective in simpler scenarios, GA outperforms PSO in more complex situations due to its faster convergence rate. This study underlines the importance of problem-specific adaptations and thorough algorithmic fine-tuning in deploying these methods for real-world disaster relief scenarios.**

***Index Terms*—Genetic Algorithms, Particle Swarm Optimization, Post-Earthquake Relief Distribution, Distribution with optimization algorithms.**

I. Introduction

The devastation caused by earthquakes often requires immediate relief and assistance for the affected communities. It's during these times of crisis that effective resource distribution strategies play a significant role in alleviating suffering and rebuilding the affected areas. A critical challenge in these situations is the complexity and unpredictability of the problem space: the extent of damage, the varying needs of different regions, and the logistical constraints on resources and transport.

Given the complexity and high-stakes nature of this task, the application of advanced optimization techniques like Particle Swarm Optimization (PSO) and Genetic Algorithms (GA) has been proposed. These techniques can help navigate the complicated problem space by identifying optimal distribution strategies that maximize relief impact. However, these algorithms' effectiveness can vary based on the complexity of the problem. In this report, I focus on a comparative study of PSO and GA in solving the post-earthquake relief distribution problem.

II. Problem Formulation

The objective of this study is to formulate the post-earthquake relief distribution as an optimization problem. The task is to distribute different types of resources (water, food, petrol, medicine) from different distribution centers (Istanbul, Ankara, Antalya) to the affected provinces optimally. The optimization objective is to minimize the cost and time of delivery, while ensuring that each province receives the necessary resources.

The problem can be mathematically represented as follows:

Let C represent the set of distribution centers, and P represent the set of provinces in need.

For each distribution center $c \in C$, we have an available amount of each type of resource, denoted by A_c.

For each province $p \in P$, we have a required amount of each type of resource, denoted by R_p.

For each pair of distribution center and province, we have a cost and time associated with each transportation mode (i.e., truck, cargo plane), denoted by $COST_{c,p}$ and $TIME_{c,p}$ respectively.

The task is to find a distribution strategy $D_{c,p}$ for each pair of distribution center and province such that:

1. For each province, the sum of all incoming resources meets or exceeds the required amount: $\sum_{c \in C} D_{c,p} \geq R_p$, for all $p \in P$.

2. For each distribution center, the sum of all outgoing resources does not exceed the available amount: $\sum_{p \in P} D_{c,p} \leq A_c$, for all $c \in C$.

3. The total cost and time are minimized: minimize $\sum_{c \in C} \sum_{p \in P} (D_{c,p} \times COST_{c,p} + D_{c,p} \times TIME_{c,p})$.

III. Data

Our dataset represents multiple parameters of post-earthquake scenarios, including the different regions affected, the type and quantity of resources required, and the mode of transportation for delivery. The data was generated and gathered from different sources. Sources are foundable in the ipynb file as comments whenever they are used. Since the data was not directly usable, We made some assumptions such as:

A. Earthquake Zone Assumptions:

- Water, food, oil and medicine needs increase in direct proportion to the population of the provinces.
- The effect of the earthquake is not the same in all provinces in the earthquake zone. According to the data obtained from the Ministry of Strategy and Budget, I determined the need in some provinces as 'extreme' and multiplied the needs in this region with a coefficient(it is adjustable).
- In extreme regions, the need for oil is higher than normal. Because more than half of the city has been damaged and almost all of the population lives in cars, if any. (There is a need for more oil than the coefficient mentioned in the previous item.)

B. Distribution Center Assumptions

- The total material in 3 provinces(Istanbul, Ankara, Antalya) is sufficient for needs such as water,food,petrol and medicine in the earthquake zone.
- The supply of water in a province is directly proportional to the total cubic meter of water in the dams of that province.
- The food supply in all provinces is the same.(Couldn't find relative data)
- The oil supply in a province is directly proportional to the distribution of the Oil Terminals.(Let's underline that we are talking about oil terminals, not gas stations.)
- The supply of medicine in a province is directly proportional to the number of repository in that province.
- The flight cost of a cargo plane is 60.000 USD and the flight time is equal to the flight time of the passenger plane.
- 1 dollar is 20 TL
- A truck burns an average of 32 liters of diesel per 100 km.

C. Population of the Provinces(as units)

- Adana: 220
- Adiyaman: 70
- Diyarbakir: 180
- Gaziantep: 210
- Hatay: 160
- Maras: 170
- Kilis: 10
- Osmaniye: 56
- Malatya: 80
- Sanliurfa: 210
- Elazig: 59

D. Water Availabilities

- ISTANBUL WATER AVAILABILITY https://www.aski.gov.tr/tr/baraj.aspx
- ANKARA WATER AVAILABILITY https://www.iski.istanbul/web/tr-TR/baraj-doluluk
- ANTALYA WATER AVAILABILITY http://web.archive.org/web/20230000000000*/https://seffaflik.epias.com.tr/transparency/barajlar/aktif-doluluk.xhtml

IV. Real World Application

The results of this study are not suitable for direct use in case of a possible earthquake. Real-world problems involve much more complex parameters to solve. This study is a simulation of it and can only give 'insights' about the situation. Better orientations can be obtained as a result of using these algorithms in a possible earthquake scenario. It can provide better directions to the authority/team directing the earthquake. It can make solving the problem very short by delivering the 'insights' to the necessary people in a very short time.

V. Methods

This study employed two advanced optimization techniques, Particle Swarm Optimization (PSO) and Genetic Algorithms (GA), to solve the post-earthquake relief distribution problem.

A. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a nature-inspired optimization algorithm based on the movement and intelligence of swarms. The algorithm is initialized with a group of random solutions and searches for optimal solutions by updating generations. In each generation, each particle is updated by two essential components - velocity and position. Velocity controls the direction of the particle's movement, while the position represents the potential solutions. In this study, we used a variant of PSO where the update of a particle's position not only depends on its personal best position but also on the best position among its neighbors. The weights of the cognitive and social components (c1 and c2) are important parameters, determining the relative importance of personal experiences versus the swarm's collective knowledge. Additionally, a time coefficient was introduced to address the critical aspect of relief distribution problems - the timeliness of deliveries.

B. Genetic Algorithms

Genetic Algorithms (GA) is another widely used evolutionary algorithm that utilizes concepts of genetics and natural evolution, such as selection, crossover (recombination), and mutation. For the selection operation, we used tournament selection, which involves running several "tournaments" among a few individuals (or "chromosomes") chosen at random from the population. The winner of each tournament (the one with the best fitness) is selected for crossover. Crossover is the equivalent of reproduction and biology. During crossover, genes from parents generate children for the next generation. The mutation operation helps maintain genetic diversity from one generation of a population to the next. It alters one or more gene values in a chromosome from its initial state. In this study, mutation rate and crossover rate were carefully chosen to maintain a balance between exploration (searching new areas) and exploitation (refining around a specific area), both critical in searching an optimal solution.

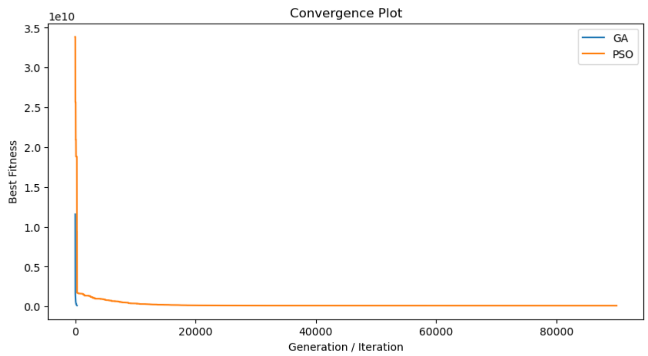

Fig. 1. Convergences of PSO and GA for the Relief distrubition

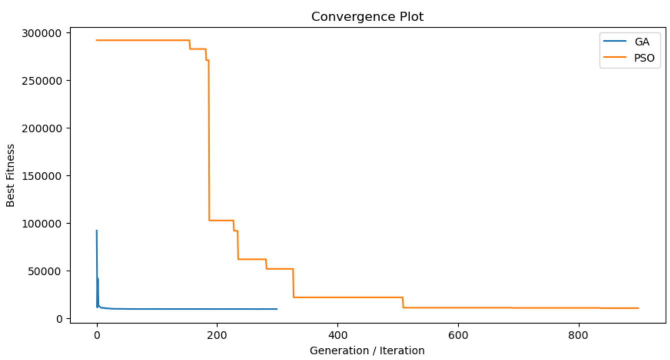

Fig. 2. Convergences of PSO and GA for a simpler problem

VI. Experimental Evaluation

In our experimental evaluations, both PSO and GA were effective in solving simpler instances of the problem. However, as the problem complexity increased, GA showed superior performance compared to PSO. Specifically, GA converged more rapidly to the solution, which is a crucial factor in time-sensitive scenarios like post-earthquake relief distribution. This faster convergence rate can be attributed to GA's property of maintaining a diverse population, which enables more robust exploration of the solution space.

On the other hand, the PSO algorithm, despite its potential in certain scenarios, demonstrated slower convergence. This could be potentially due to the choice of parameters, requiring further fine-tuning to adapt to the complexity of the problem. PSO was tried with different coefficients, naturally better results were obtained with some coefficients. In the result, none of them passed GA.

Both of the GA and PSO reflects to the time effect. From here we can deduce that there is no problem in their implementation.

VII. Conclusion

Through the comparative study of PSO and GA in solving the post-earthquake relief distribution problem, this report demonstrated the effectiveness and limitations of these two popular evolutionary algorithms. Despite their potential, the performance of these algorithms heavily depends on problem-specific adaptations and fine-tuning. Particularly in complex, high-stakes scenarios like post-earthquake relief distribution, these algorithms should be appropriately customized and thoroughly evaluated to ensure their effectiveness and reliability. But unexpectedly, GA showed better results than PSO.

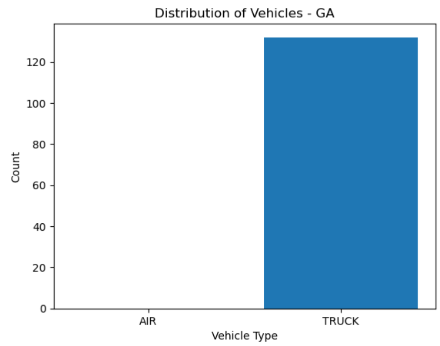

Fig. 3. Nearly none time effect

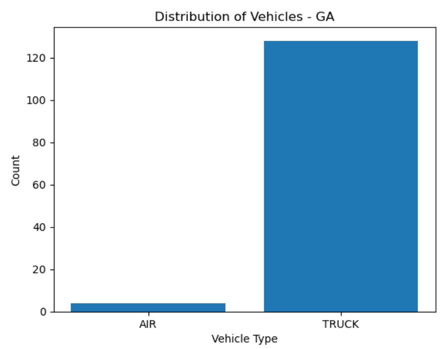

Fig. 4. Increased time effect

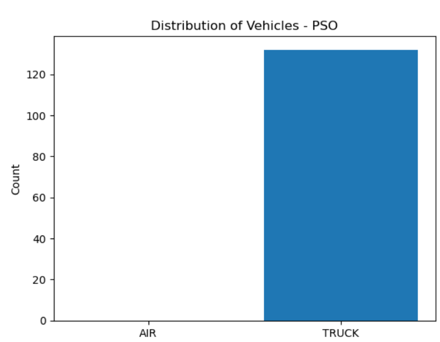

Fig. 5. Nearly none time effect

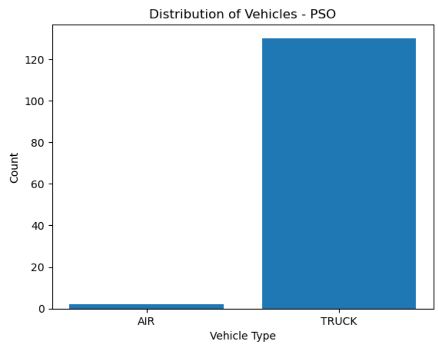

Fig. 6. Increased time effect

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Transport 298L of water from istanbul to hatay using route TRUCK(BURSA-ESKISEHIR-) (Cost: 2052624, Time: 17)
Transport 10L of food from istanbul to hatay using route TRUCK(BURSA-ESKISEHIR-) (Cost: 68880, Time: 17)
Transport 1L of petrol from istanbul to hatay using route TRUCK(BOLU-ANKARA-ADANA) (Cost: 6654, Time: 15)
Transport 359L of medicine from istanbul to hatay using route TRUCK(BURSA-ESKISEHIR-) (Cost: 2472792, Time: 17)
Transport 485L of water from istanbul to gaziantep using route TRUCK(BOLU-ANKARA-ADANA) (Cost: 3320310, Time: 15)
Transport 27L of food from istanbul to gaziantep using route TRUCK(BOLU-ANKARA-ADANA) (Cost: 184842, Time: 15)
Transport 63L of petrol from istanbul to gaziantep using route TRUCK(BOLU-ANKARA-ADANA) (Cost: 431298, Time: 15)
Transport 223L of medicine from istanbul to gaziantep using route TRUCK(BOLU-ANKARA-ADANA) (Cost: 1526658, Time: 15)
Transport 266L of water from istanbul to sanliurfa using route TRUCK(BOLU-ANKARA-ADANA) (Cost: 2047668, Time: 18)
Transport 2L of food from istanbul to sanliurfa using route TRUCK(BOLU-ANKARA-ADANA) (Cost: 15396, Time: 18)
Transport 174L of petrol from istanbul to sanliurfa using route TRUCK(BOLU-ANKARA-ADANA) (Cost: 1339452, Time: 18)
Transport 313L of medicine from istanbul to sanliurfa using route TRUCK(BOLU-ANKARA-ADANA) (Cost: 2409474, Time: 18)
Transport 23L of water from istanbul to maras using route TRUCK(BOLU-ANKARA-KAYSERI) (Cost: 142140, Time: 15)
Transport 258L of food from istanbul to maras using route TRUCK(BOLU-ANKARA-KAYSERI) (Cost: 1594440, Time: 15)
Transport 96L of petrol from istanbul to maras using route TRUCK(BOLU-ANKARA-KAYSERI) (Cost: 593280, Time: 15)
Transport 149L of medicine from istanbul to maras using route TRUCK(BOLU-ANKARA-KAYSERI) (Cost: 920820, Time: 15)
Transport 95L of water from istanbul to adana using route TRUCK(BURSA-ANKARA-NIGDE) (Cost: 551190, Time: 14)
Transport 194L of food from istanbul to adana using route TRUCK(BURSA-ANKARA-NIGDE) (Cost: 1125588, Time: 14)
Transport 1L of petrol from istanbul to adana using route TRUCK(BURSA-ANKARA-NIGDE) (Cost: 5802, Time: 14)
Transport 133L of medicine from istanbul to adana using route TRUCK(BURSA-ANKARA-NIGDE) (Cost: 771666, Time: 14)
Transport 41L of water from istanbul to adiyaman using route TRUCK(BOLU-ANKARA-KAYSERI) (Cost: 284130, Time: 17)
Transport 98L of food from istanbul to adiyaman using route TRUCK(BOLU-ANKARA-KAYSERI) (Cost: 679140, Time: 17)
Transport 162L of petrol from istanbul to adiyaman using route TRUCK(BOLU-ANKARA-KAYSERI) (Cost: 1122660, Time: 17)
Transport 54L of medicine from istanbul to adiyaman using route TRUCK(BOLU-ANKARA-KAYSERI) (Cost: 374220, Time: 17)
Transport 211L of water from istanbul to diyarbakir using route TRUCK(BOLU-ANKARA-KAYSERI) (Cost: 1691376, Time: 18.5)
...
Transport 79L of food from antalya to elazig using route TRUCK(MALATYA) (Cost: 480636, Time: 18)
Transport 26L of petrol from antalya to elazig using route TRUCK(SIVAS) (Cost: 160368, Time: 15)
Transport 68L of medicine from antalya to elazig using route TRUCK(SIVAS) (Cost: 419424, Time: 15)
Total cost: 99861672, Total time: 1741.3999999999996
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Fig. 7. Example Output of the algorithms