Group 24 Assignment Report

An Evolutionary Algorithm for an elevator to deliver as many people as possible to their desired floor

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September 30, 2024

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1 Introduction

The recommended software for typesetting assignment reports is LaTeX. It will allow you to prepare high-quality documents, especially in the area of Computer Science. This document can serve as a template for reports. Each section begins with brief instructions in red text. All the instructions in red, as well as the dummy text, should be removed in the final version to submit. The LaTeX source of this file includes examples of using the most needed commands and environments. You can find plenty of other examples with explanations in many web forums and discussion groups on the Internet. The easiest way to edit your report is to use `https://www.overleaf.com/`. Overleaf does not require any setup on your computer, and it is free to create an account.

The book *Writing for Computer Science* [1] is a useful assistance on how to write properly and present your work when it comes to Computer Science topics. It is a strong recommendation to follow its guidelines and limit the usage of AI tools to generate text. Keep in mind that the examiner is an expert in Evolutionary Computation and therefore, any false information generated by an AI tool is easily notable. Such case may lead to failing the assignment.

The introduction should briefly introduce the assignment and its purpose.

This report addresses an investigation for optimizing an elevators route to improve the efficiency of picking up and delivering passengers to their desired floors in the least amount average waiting time. In large buildings with a lot of floors, efficient elevators are crucial for managing traffic and must serve every one in a reasonable time. Poorly designed elevator systems will lead to long waiting time, unnecessary stops and unsatisfied users. Elevator technology have made progress during the years, but many elevators still struggle with finding an efficient way to serve passengers.

The hypotheses that evolutionary algorithms will be able to find near-optimal or optimal routes for elevators aiming to maximize the number of passengers served while minimizing travel distance and/or travel time is the core focus in the report. Different strategies and hyperparameter are experimented with to enable demonstration of how evolutionary algorithms can be used in such a problem.

This paper will focus on a statically defined problem, i.e., there will not be more passengers coming to the elevator as time goes on, unlike a normal elevator.

2 Optimize elevator routing

The second section should present the problem you tackle using your evolutionary approach. Overall, this section should include:

- The mathematical formulation considered in your study. Some problems have a clear mathematical model (e.g., Travelling Salesman Problem), while others do not (e.g., n-Queens). Based on the problem you chose, search the literature and find a proper way to present the problem.
- One paragraph that briefly presents at least 3 published academic works where any evolutionary approach is used to solve the problem. It would be wise to cite here works that influenced your algorithm. This practice saves you time from looking for additional academic resources. You can find more information about reading and searching in the literature in [2].
- The motivation behind the evolutionary approach you decided to develop. A good practice would be to align the motivation with some literature gap found in the academic works you presented above. However, this is not mandatory. You can motivate your selection on the characteristics of the algorithm making it proper for the problem.

Note: Change the section's title to match the name of the problem you chose for your assignment.

2.1 Mathematical formulation

2.2 Similar published academic work

[3], "Each vertex of a graph initially may contain an object of a known type. A final state, specifying the type of object desired at each vertex, is also given. A single vehicle of unit capacity is available for shipping objects among the vertices. The swapping problem is to compute a shortest route such that a vehicle can accomplish the rearrangement of the objects while following this route."

Mapping the elevator problem to the swapping problem.

- Vertices are represented as floors in the elevator.

- The object is defined as a person.
- Initial state consists of N persons waiting at the floors.
- The final state is reached when all persons are at their destination floor.
- The elevator is a vehicle with a max capacity that moves the persons between floors, i.e. a single vehicle shipping objects among the vertices.
- The elevator problem is aiming to reduce the waiting time of the persons in the elevator and thereby reduce the distance traveled.

According to [3], "Even the simple swapping problem is NP-hard."

2.1 Why this evolutionary approach

3 Algorithm

The third section should present the evolutionary approach you developed. You can divide this section into subsection. In any case, you should mention the following details:

Evolutionary approach. Clearly describe the algorithm you developed. You should clearly explain the evolutionary operators you used and what modifications you did to match the problem. It is extremely important to present also a pseudocode of your algorithm. An example is given in 1, below. For more insight into presentation of algorithms, you can advise [4].

To typeset pseudocode in LaTeX you can use one of the following options:

- Choose ONE of the (`algpseudocode` OR `algcompatible` OR `algorithmic`) packages to typeset algorithm bodies, and the algorithm package for captioning the algorithm.
- The `algorithm2e` package.

You can find more information here: `https://www.overleaf.com/learn/latex/Algorithms`

Solution representation. Clearly describe the solution representation you used. You can use figures to improve the comprehensibility of this part.

Fitness function. It is also very important to mention the fitness function you used. In many cases, the objective function of the problem is not the same as

Algorithm 1 Example of an algorithm's pseudocode

Require: $n \geq 0$
Ensure: $y = x^n$
  $y \leftarrow 1$
  $X \leftarrow x$
  $N \leftarrow n$
  while $N \neq 0$ **do**
    if N is even **then**
      $X \leftarrow X \times X$
      $N \leftarrow \frac{N}{2}$ ▷ This is a comment
    else if N is odd **then**
      $y \leftarrow y \times X$
      $N \leftarrow N - 1$
    end if
  end while

the fitness function used in an evolutionary algorithm. An example, following the principles of [5], is given below.

$$F = \sum_{i=1}^{d} x_i^2 \tag{1}$$

where x_i is the i-th gene (i.e., decision variable) in the solution and d corresponds to the number of decision variables in the problem.

Note: Change the section's title to match the name of the algorithm you developed for your assignment.

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4 Experimental part

This section describes the setup of experiments:

Each experiment consists of two JSON files: one representing the building which specifies where all people are located, and another containing the population with a set of initial genomes. These experiments are saved to files rather than being generated randomly each time to ensure the ability to run the same experiment multiple times for consistency.

One specific building which already had result data available was used to compare our algorithm's results against previously known results.

To thoroughly evaluate the algorithm we decided to test it on buildings of different sizes (small, medium, large) and with corresponding population sizes. Given the number of experiments required to be run we selected buildings with 10, 50, and 100 floors containing populations of 10, 50, and 100 people respectively. Additionally the specific building mentioned earlier which has 21 floors and 10 people was included.

Buildings were generated with constraints ensuring that each floor could hold between 0 and half of the maximum population. While it was theoretically possible for all people to be on just two floors in practice the distribution was more balanced. For example in the small 10-floor building with 10 people the distribution looked as follows:

From		**To**
0	→	6
0	→	8
3	→	5
4	→	7
5	→	7
6	→	2
7	→	0
8	→	4
9	→	0
9	→	2

After generating and validating all buildings and populations we proceeded to run the experiments. Each experiment was conducted on a computer with an AMD Ryzen 7 7800X3D and took roughly ten seconds to a minute. In totally 150 experiments were run.

Due to time constraints the only parameter that was adjusted during the experiments was the mutation rate to limit the number of results to analyze. To ensure the reliability of results each combination of building and population was tested five times allowing us to identify potential anomalies. Experiments were conducted with two mutation rates, 10% and 60%, to observe differences in algorithm performance. The thought process behind the very high mutation rate was to semi-simulate the effects of a longer generation limit without significantly increasing runtime.

The experimental procedure is outlined as follows:

- Generate the building and population, or load a pre-existing experiment.
- Run the experiment generating a CSV file with results and a PNG with a graph.
- Re-run the same experiment with different parameters.
- Analyze the results to evaluate the algorithm's performance.

5 Results and Analysis

This section should present the obtained results and provide an insightful analysis of them. You can present the results using graphs, tables, or any other visualization method suits your purpose. Do not forget to include proper captions [6] in any of these illustration methods you use. You do not need to provide any execution details as they are already presented in Sec. 4.

A good practise would be to compare your algorithm with a simpler approach, such as (a) a naive method, (b) a Hill Climbing approach, or (c) a simple evolutionary algorithm. In the third case, you can use the simpler version of the algorithm you developed, i.e., the original algorithm without your modifications. In that case, you should briefly describe the comparing method(s) in Sec. 4. Alternatively, you can use some reference results derived from the repositories you found some benchmark instances.

To display tables, the `booktabs` package might be useful. For example, Table 1 shows how you should increase the size of n, when running your code. You can advice [6] to see a few examples of proper tables.

You can use different illustration methods to present different aspects of your analysis. Figure 1 gives an example using the `pgfplots` package.

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Table 1: Example of comparison the developed algorithm's results with the best ones from a repository.

Instance	**Optimum (Repository xyz)**	**EA**	**time (s)**
st70	678.597	677.109	0.67
ei176	545.387	544.369	1.16
kroA100	21285.443	21285.443	1.69
rd100	7910.396	7910.396	2.14
Pr136	96772	96770.924	7.11
Pr144	58537	58535.221	7.97
a280	2856.769	2856.769	33.47

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6 Conclusions

In this section you should provide a concise summary of what has been done, the obtained results and some recommendations on how this study could be extended.

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References

[1] J. Zobel, *Writing for computer science*. Springer, 2014.

[2] J. Zobel, "Reading and reviewing," in *Writing for Computer Science*, pp. 19–33, Springer, 2014. https://doi.org/10.1007/978-1-4471-6639-9_3.

[3] S. Anily and R. Hassin, "The swapping problem," *Networks*, vol. 22, no. 4, pp. 419–433, 1992.

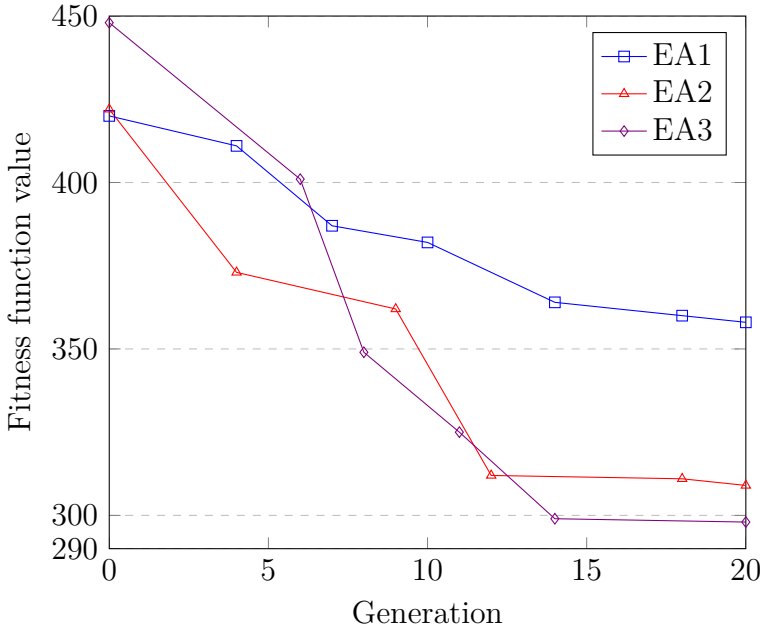

Figure 1: Example of convergence analysis.

[4] J. Zobel, "Algorithms," in *Writing for Computer Science*, pp. 115–128, Springer, 2014. https://doi.org/10.1007/978-1-4471-6639-9_10.

[5] J. Zobel, "Mathematics," in *Writing for Computer Science*, pp. 131–143, Springer, 2014. https://doi.org/10.1007/978-1-4471-6639-9_9.

[6] J. Zobel, "Graphs, figures, and tables," in *Writing for Computer Science*, pp. 83–113, Springer, 2014. https://doi.org/10.1007/978-1-4471-6639-9_11.