Group 6 Assignment Report

An Evolutionary Algorithm for solving Sudokus

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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* [**?**] 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.

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- This paper tries to find an Evolutionary Algorithm approach to solve scalable (bigger than standard 9x9) Sudokus. (is this just a Genetic Algorithm?)

- It discusses why naive methods fail (hopefully) as the size of the puzzle increases and why an evolutionary algorithm approach is more scalable in the context of solving Sudokus

- The objective is to minimize the time the evolutionary algorithm takes to solve the Sudokus of increasing sizes.

- The baseline to compare the performance of the evolutionary algorithm to will be Depth-First Search(DFS). (Maybe add more naive methods or the very basic evolutionary algorithm without any modifications)

- The document is structured as follows: Section 1: Introduction and goal of the paper. Section 2: Describes the problem the paper solves in detail + motivation of the evolutionary approach used. Section 3: Describes the algorithm in detail. Section 4: Describes the experiments run with the algorithm. Section 5: Presents and analyses the results. Section 6: Conclusion.

2 Problem this is the problem

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 [**?**].

- 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.

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- This section presents the problem this paper solves with the use of evolutionary algorithm approach.

- Math in solving Sudokus? Maybe rather introducing quickly a sudoku, how to solve it and describing the steep increase of difficulty with increasing sizes of sudoku puzzles

- Cite 3 published papers. Cite where our idea is from[2]. Another Paper[1].

- Motivation behind evolutionary approach. Should link back to previous paragraphs. Literature gap (increasing sizes of the sudoku) and potential of evolutionary algorithm in this context

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 [**?**].

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

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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

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

the fitness function used in an evolutionary algorithm. An example, following the principles of [**?**], 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 [**?**]:

- Provide the details of the hardware and software that you used.

- Describe the steps you carried out during your experiments.

- Detail the data you used for the evaluation of your algorithm.

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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 [**?**] 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 [**?**] to see a few examples of proper tables.

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

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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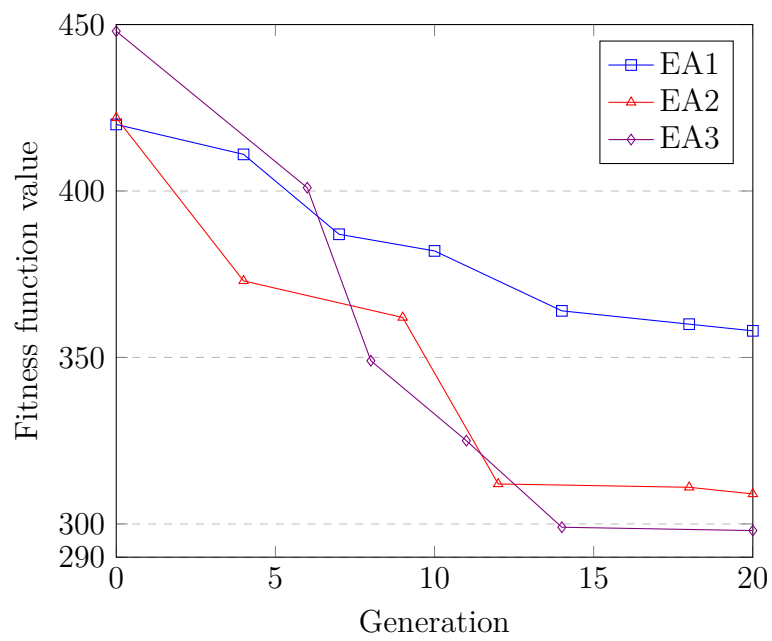
Figure 1: Example of convergence analysis.

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] P. R. Amil and T. Mantere, "Solving sudoku's by evolutionary algorithms with pre-processing," *Advances in Intelligent Systems and Computing*, vol. 837, pp. 3–15, 2019.

[2] T. Mantere and J. Koljonen, "Solving, rating and generating sudoku puzzles with ga," *2007 IEEE Congress on Evolutionary Computation, CEC 2007*, pp. 1382–1389, 2007.