1 Experiment methods

1.1 Experiment 1 1

There are two distinct algorithms being used in this project, the Hybrid Repair and the Multi-objective algorithm. These two algorithms both have there strengths and weaknesses and whilst not the ideal choice for solving sudoku, one of these methods might be better than the other. So the question becomes:

- How does a hybrid repair EA algorithm compare to a Multi-objective EA?
- Is one method more efficient than the other?
- Is one method more consistent than the other?
- Is there a large difference in runtime?

The first question can be answered by looking at the next three questions. For finding out the efficiency or effectiveness of the algorithms, looking at and comparing the number of generations it takes to get to the solution. For finding out the consistency of the algorithms, looking at the number of times each algorithm fails to solve the puzzle it is presented and also looking at the standard deviation from the average number of generations and runtime.

The final question has the least impact on the overall investigation, as it can be affected the most by outside factors, however looking at the average runtimes and standard deviations from the average can clearly show how fast each algorithm generally, however it also worth noting, that this could be due to inefficient programming rather than the algorithms design itself. Due to the randomness of both of the algorithms, both sets of results will have to process and compared using a statistical test which can data that is not normally distributed such as a Wilcoxon test.

1.2 Experiment 2

The second and arguably more interesting question being looked at in this project, concerns difficulty in Sudoku puzzles. With Sudoku puzzles, there are two main ways to increase the difficulty of the puzzles, the first is by increasing the size of the puzzle, as with larger puzzles, there are more numbers involved and more potential solutions. Meaning that inherently a 4x4 puzzle is easier than a 9x9 puzzle. The other way in which difficulty can be measured for people, is by changing the number of initial squares that are filled. Concerning the minimum number of spaces required for a unique solution to be found by a human, research has been done and it has been found that a minimum of 17 filled in spaces are needed for a Sudoku to be solvable.

For the purposes of this question broader catagories for difficulty, will be more appropriate, this will be done by using sudoku generated by Sudoku.com[] and using their difficulty system of Easy, Medium, Hard and Extreme puzzles. The interesting part comes from looking for a link between the difficulty that humans find solving these puzzles and the algorithms that are designed to do so. By looking at both algorithms and using them on different difficulty sets, some questions are created:

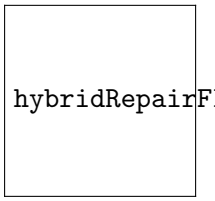
- Is there a correlation between human difficulty and algorithm performance?
- Does either algorithm perform particularly well with a certain difficulty or size puzzle? Why?
- Is the relationship between initial puzzle size and generations?

For the first question, looking at a mapped graph displaying difficulty against runtime and generations. For the second question, looking at the results for the datasets on both sides for each difficulty and finding any noticable difference in the averages outside of the conclusions from experiment 1. The final question further builds on question 1, by seeing if the correlation is simply due to the size of the puzzle given.

1.3 Approach for Hybrid Repair method

The idea for the hybrid method is, firstly much like a normal EA the population of the puzzle is created , this will be generated from several intial variations on the initial sudoku puzzle given. The next step is sorting and selection, this will take the population, sort them based on their fitness values and then removes half the puzzles from the population. The remaining members of the population would then mutate, creating a mutated child, pushing the population back to the intended size and mutating itself. After this the repair algorithm, looks at every member of the population that is currently breaking one of the games rules and brings it back into the range of a feasible solution. The final step is updating the fitness values of the population and if there are no violations and no empty spaces in any puzzle population, or alternatively the algorithm has reached the maximum number of generations, it returns the solution and ends, otherwise it will loop back to sorting and selecting step.

Figure 1: Flow diagram for Hybrid repair method



1.4 Approach for Multi-objective method

generate population is puzzle complete and not over generation limit mutate population split each mutated against its parent using specific comparison function fitness based on both number of squares and number of violations

flow diagram for approach here

1.5 Alternatives

Originally both programs were to use methods close to the current algorithm used for the hybrid algorithms approach,

1.6 Experiment design

The experiment program for method type load each puzzle test it 30 times collect times and generations for each time calculate averages and failures for each puzzle write results to files

The data set is then processed in R, using

1.7 Tools

The programs used in this project are coded in Java 18, and are written in the IntelliJ IDEA IDE development environment. This is due to familiarity with the language and development environment. Within the development the use 3rd party library through Maven, JUnit was

needed, to test individual features and functions of certain key methods, including ones listed in the requirements(see Chapter 3.1). GitHub was used as a version control tool and also used for project management , this was necessary as it allowed for a backup file system, which can be added to from different places, as well as providing a feature which can be used as a kanban board(mentioned in 1.4). The statistical analysis needed for the experiments use the programming language R to perform the tests and produce graphs based on the data produced. texStudio and LaTeX were used in the creation of documentation providing a way to structure and document the final report for the project. The diagrams used in the documentation, were created using the tool draw.io, created diagrams visually explaining concepts, flowcharts used to show the basic outline of the program and class diagrams detailing each part of the project.