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**Software development for performance validation of heuristic
algorithms**

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Abstract:

The development of today's technology and science led to the increased complexity of products and processes. This enormous complexity has a great impact on suitable design methods. New mathematical models have made it possible to make more complex and detailed description of the reality. The third industrial revolution and the development of computer sciences opened a new window to accelerate the efficiency of optimization methods. The optimization of complex problems in all fields of science requires more and more computing power, which can be reduced by sophisticated algorithms. The fourth industrial revolution means the transformation of conventional production and services into cyber-physical systems, where smart technologies and processes have emerged. The artificial intelligence inside these smart things is mainly created by learning algorithms generally based on heuristics. Within the frame of this paper the development and use of an algorithm tester application

Keywords: *heuristics, optimization, complexity, computational performance, operational research*

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1. Introduction

Several new heuristic algorithms appear every year, most of which could easily be applied to NP-hard logistical problems, but due to their little acquaintance, besides popular algorithms such as evolutionary algorithms, these new algorithms never spread. The aim of our current research is to create a modular algorithm testing application that can compare the performance of certain algorithms in practice, solving individual logistic problems. Problems and models have also been incorporated into the testing process that can handle complete supply chains, route planning tasks, vehicle-fleet composition or internal logistics processes and can generate an appropriate solution within testing. In this paper, we present the operation of the application on a much simpler logistic task, the travel agent problem. In the following, we will present the process of preparing this test application, the outline of its operation, its modules and the logistical tasks it wants to solve.

2. Developing the algorithm tester application

It is often seen in the literature that the performance of different algorithms is examined and compared in different tasks. Tasks are classified into three categories based on their manageability and complexity. There may be simple predefined and accurate test functions [1], that can be formulated in a few lines in programming languages. The second category is the basic tasks that can be simply described, but counts as an NP-hard, such as clustering or the travel agent problem, which we will present in this study. The third category three where complex tasks imitating or simulating reality, which are produced by long surveys, parameter determination, modelling, simulation and testing [2] to write down a given process as accurately as possible. An example of this can be the optimization of logistic tasks related to the production depth [3] or the design of large scale maintenance networks [4]. Other important application fields of heuristics and metaheuristic are the followings: selecting transport connections [5], optimization of the multi-objective green cyclical inventory routing problem [6], logistics and supply chain

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management [7-8], competitive multi-facility location-routing problem [9], tactical decision-making based on a decision-analytic model for balancing timber stock [10], integrated planning of spare parts and service engineers with partial backlogging [11], joint optimization of preventive maintenance, spare parts inventory and transportation options [12] or operating expense optimization in multiple depots and charge stations environment [13].

However, there are more problems with these comparative studies. The programming language, quality and programming skills are very important.

The language only counted when translated, while the programming quality and the programmer's skill are reflected in running stability and functionality. Each element has a great influence on running time and computing power. Because all people are different, even considering the development of a person through time. The programming ability also changes with the time, so not only comparing the data in the various studies but also in the comparisons that can be made in a study could have mistakes. We made efforts to reduce these errors when we created our algorithm testing application, which provides a framework for our current and future research.

Our application can be a good example of making the testing process more consistent. We have created an application that consists of programmable modules and stores tasks and algorithms based on a pre-prepared template. Each module is located in subfolders within the application folder and has the extension “.m”. An outline of the application is shown in Figure 1, which will be explained in the next chapter.

3. Structure and operation of the testing application

The algorithm testing application was created in MATLAB programming language for several reasons. Since this is not a commercial application, it was considered unnecessary to write in a programming language used by current programmers such as C #, Java, or Python. Also, these languages and their compiler have the special feature that it is much more difficult to change the source code after each version or run. In an application that

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has modules and can be expanded with newer ones, continuous overwriting is essential. Also, we did not need any special plug-ins or object-oriented programming to create the application, not to mention that MATLAB can use these elements. The only thing the chosen language requires is that the applications made in MATLAB can only run optimally in their programming environment, which requires the MATLAB program.

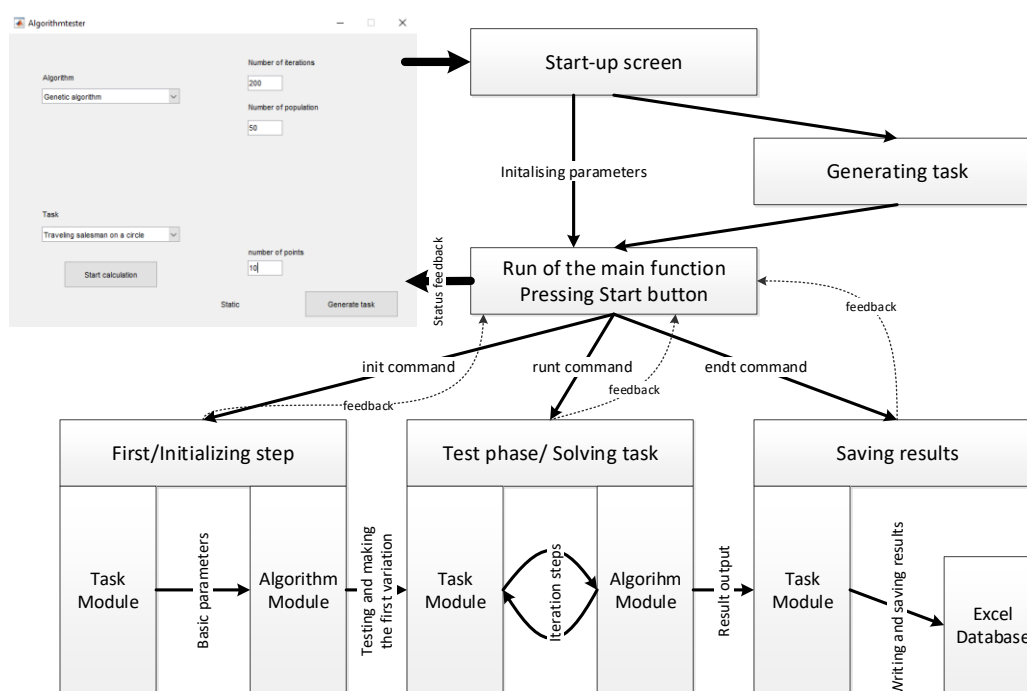


Figure 1.: The structure of the testing application

Source: created by the authors

Launching the application immediately loads the graphical start-up screen, which is shown in the upper left corner of Figure 1. From the top left-hand drop-down menu, you can select the algorithm you want to test, and from the next drop-down menu, you can select the task. On the right side of the start screen, you can specify the criteria for stopping the algorithm, in this case, an iteration number, and below that, you can give the population size. You can also see a Generate task button on the start-up screen and a value above it. An example is the version of the travelling agent task, where the points are

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generated on a circle, and the algorithm has to define the shortest route that contains all the points. It is clear that the shortest path is along the perimeter of the circle, but the algorithms do not recognize this, and the computational power demand increases exponentially as the number of points is increased.

By pressing the „Start calculation” button, the application's main program starts running. The main program itself has only three tasks: to retrieve the data from the start-up screen, to create and combine the communication between the modules, and then to guide the testing process. At the beginning of the test, you use the 'init' command to find the module for the selected task that you open and query the type of variables in the task and the number of variables. Also, it can acquire the min-max values of the variables or other limiter parameters. The type of task variables is a very important parameter that the main program will compare to the algorithm's solver type. The algorithms can work with three types of variables, but they can only use one in each calculation. The three types of variables can be real number variables (decimal), integer variables (contains both natural and binary variables), or number sequences (permutation or sequential). From these types, the task module must specify the type of variables it needs, and only algorithms created for that variable type can handle it. This also means that when we make the algorithm module, we need to make three versions of the algorithm to handle all the types in the best cause.

In the next step, the main program passes the parameters to the algorithm module, which generates the ‘V’ matrix containing the first variables. This matrix contains as many variations as the population number. Then the process of solving the problem begins, and the main program issues the ‘runt’ command. Then, the algorithm module passes the ‘V’ matrix to the task module, which replaces the variables in the appropriate location and determines the result for each variation and saves it into an 'S' matrix that has been transferred to the algorithm module to improve its variables. The 'S' matrix is usually received by the main program for analysis and provides the user with continuous feedback on the state of testing. The algorithm module then generates new variables for ‘V’ matrix

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and continues this cycle until the main program reaches the stop criterion and executes the 'end' command.

By issuing the final command, the last process begins, which examines which is the best result and saves the values of the task parameters. A save file is created in a pre-defined Excel workbook, where you can see the data of the original task, the optimization process as statistics and the best values of the variables.

4. Comparison of Genetic and Blackhole algorithm

In this chapter, we can see the test results created by application with the comparison of Genetic- and Blackhole algorithms. The Genetic algorithm is one of the most famous and reliable population-based metaheuristic algorithm, loved by many programmers. For us, it's basically a standard, and we do almost all comparisons with it. The Blackhole algorithm, on the other hand, is a very new, easy to use the program, but not known population-based heuristics, which in our opinion can compete with the Genetic algorithm.

As the table shows, we create seven scenarios for the two algorithms, four test functions and 3 Centrum search logistical problems. We defined a maximum of 1000 iteration steps to generate their best solution. The test functions are basic test functions, with two parameters except for the 10-parameter parabolic function. There are three Centrum search tasks, where we have to give the exact location of our collecting warehouse where we can collect goods from other cities. For the last task, the multicentre warehouse, we looked for three locations simultaneously, which is a much harder and intensive task.

In the table, we can see the two algorithms, GA as a Genetic Algorithm and BH as Blackhole Algorithm. There are two different number of populations in each case, a lower 30 population and a higher 300 population. In most cases, there is no significant difference between the different population runs.

The two main parameters that we are looking for is accuracy and runtime. Accuracy means, how far is the created best solution from the real solution in a ten based

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logarithmic scale (the bigger the negative number, the better the result). Runtime was given in seconds.

Table 1.: Accuracy and runtime comparison of Genetic and Blackhole algorithms

| Algorithms | Population 30 | | | | Population 300 | | | |
|------------------------------|------------------|------|----------|---------|------------------|------|----------|---------|
| | Accuracy (log10) | | Time (s) | | Accuracy (log10) | | Time (s) | |
| | GA | BH | GA | BH | GA | BH | GA | BH |
| 2 variable parabolic | -114 | -312 | 3,5791 | 3,7831 | -143 | -312 | 4,5683 | 4,7932 |
| 10 variable parabolic | -85 | -312 | 4,2597 | 4,8622 | -104 | -312 | 5,3259 | 5,8736 |
| Goldstein price | -103 | -197 | 2,9737 | 3,4253 | -96 | -223 | 3,7634 | 4,7352 |
| Himmelblau | -92 | -162 | 3,1085 | 3,2743 | -113 | -207 | 4,7895 | 4,5782 |
| Centrum search 10 city | -49 | -68 | 5,7113 | 7,8761 | -65 | -82 | 7,2458 | 8,2511 |
| Centrum search 100 city | -35 | -27 | 6,8633 | 9,1282 | -43 | -56 | 9,6514 | 10,3568 |
| 3 Multicentre search 30 city | -26 | -21 | 15,4872 | 19,3554 | -25 | -37 | 18,4768 | 20,7895 |

Source: created by the authors

As we can see from the table, the Black Hole algorithm is almost every time reach a much higher accuracy, but it's a little slower than the Genetical algorithm in these cases. We can say both algorithms performed very good, but the Blackhole algorithm had nearly twice more accuracy than GA in test functions, with approximately 20% more runtime. In the centrum search task section, they performed almost equally.

5. Conclusion

Nowadays, besides the many options, the techniques that make it easier to choose between several things are necessary. In this case, we have presented an application that is able to show which algorithms are able to solve certain problems and how to solve them. We have made this all the way to unify the testing of current and future algorithms that we

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have achieved with the use of template-like modules, both in terms of algorithms and the tasks to be solved.

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