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# THE BEE OPTIMIZATION METAHEURISTIC METHOD BASED ON ORDERED FUZZY NUMBERS

## The summary of the doctoral dissertation

The main underlying idea of the doctoral dissertation was to combine arithmetic of ordered fuzzy numbers with a bee swarm algorithm to obtain a new optimization method. The solutions that optimize e.g. production or labor and resources management costs are currently being sought. That is why development of an efficient and easy-to-implement optimization method is an important element that can contribute to more rational use of resources. Bee swarm optimization algorithms are based on the herd behavior of bees, which can perfectly search large areas for food or water. Individual specimens pass information on the direction, the amount of and the distance to the source of food. Current algorithms use a simplified model of herd behavior of bees. Thanks to properties of ordered fuzzy numbers, it is possible to better represent information management by bees and, consequently, increase the efficiency of the new method. At the same time, this increases the possibilities of searching the space of solutions. As a result of the performed research, it turned out that the new hybrid method ensures better or similar results to that of known bee swarm optimization algorithms while using fewer specimens to search the solution space.

In order to test and compare the method with other algorithms, a set of mathematical functions used for testing the efficiency of new methods was selected. The entire study was divided into four stages.

The following functions were used in the first part:  Sphere, Rosenbrock, Rastrigin, Griewank, Schwefel, Ackley. to test, which configuration of the new hybrid OFNBee method is the best one. As regards its design, the method uses fuzzification and defuzzification functions. As there are no fuzzification methods available in the literature, several such methods were proposed for the research purposes. While for defuzzification functions, the methods described in the references were used. During the first stage of the study, a new algorithm was executed for each mathematical function of the first set separately for all combinations of fuzzification and defuzzification functions. As a result, the optimal combination of these methods was selected. Another parameter of the new method is the size of the population, i.e. the number of specimens. The algorithm uses conventional operation and the division of bees into three groups: onlooker bees, worker bees and scouts. The population size means the total number of bees. The effectiveness of OFNBee was tested with the population size of 10, 50, 100, 300, 500, 800 and 1000. The algorithm achieved the best results for the population size of 50 specimens in the case of selected mathematical functions and using the indicated fuzzification and defuzzification methods.

In the second stage of the research, the same test set was used to compare OFNBee with broadly known algorithms such as ABC, MBO, IMBO, TLBO, HBMO and BBMO. The best results were obtained for the new method, while the second best algorithms turned out to be ABC and MBO. However, due to the fact that the ABC method has implementations in the R language, it allows to generate results for other test sets.

In the third stage of the research, the set of testing functions included: Bukin N.6, Cross-in-tray, Drop Wave, Eggholder, Levy, Holder Table. The new algorithm was executed for all mathematical functions and a combination of fuzzification and defuzzification methods. The results for individual combinations were compared with the results of the ABC algorithm. The new method achieved better results, i.e. when both functions did not reach the global minimum, OFNBee was closer to that result.

The last stage of the research is a test on selected construction problems. OFNBee was compared there with ABC and literature results for such problems. It is believed that the result generated by the algorithm should have the same value as the result from the literature. While, if the algorithm does not generate such value, the method that was closer to the expected result is considered better.

In the case of mathematical functions, 75% of the results of the new optimization method exactly reached the global extreme. If the exact local extreme was not found, the new method, in all cases, was closer to that point as compared to the ABC results.

The OFNBee algorithm itself as well as mathematical functions and OFN arithmetic were implemented in the R language thus creating an environment for testing and comparison with other algorithms.

As illustrated here, the combination of ordered fuzzy numbers with a bee swarm algorithm gives better or comparable results to the results of other broadly known algorithms. At the same time, it can be observed that the selection of fuzzification and defuzzification functionals largely affects the effectiveness of the new method. It seems that the development of dedicated fuzzification and defuzzification functionals can reduce the size of the population, which in turn will reduce the demand for the algorithm's resources. Also, a proper selection of those methods for a given problem can have a positive impact on the results achieved.