Mat-2.4108 Independent Research Project in Applied Mathematics

An evolutionary algorithm for robust optimization of unconstrained problems

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Background

This report is a summary of [1], in which I was the second author. The research was conducted in the Department of Information and Service Economy at the Aalto University School of Business in collaboration with Professor Kalyanmoy Deb from Michigan State University.

The tasks I participated in the process of writing the paper were broad. I came up with ideas for the algorithm and the test problems. I implemented most of the algorithms and wrote a large part of the code needed to benchmark the algorithms in the manner described in the paper. I was also involved in writing the final research paper, especially the latter part of it that describes the algorithms and the results that we produced. Overall, the amount of work I put towards the paper exceeds the requirements set for the course Mat-2.4108 Independent Research Project in Applied Mathematics.

Summary

In real-world optimization problems there are often uncertainties about the parameters and/or the variables. The formulated optimization model, including the parameters used in it, can be noisy and contain errors. Furthermore, usually solutions cannot be implemented with infinite accuracy, which may cause complications for the system. In order to avoid such issues, the evolutionary algorithm for robust optimization presented in the paper tries to optimize the worst case performance of the system. The paper focuses on uncertainty in the decision variables for unconstrained optimization problems.

A robust solution is defined in the paper as a solution that is locally stable against small implementation errors in the decision variables. The set of implementation errors around a solution is represented by an n-sphere, with a user-defined radius, centered at the solution. The worst case costs in the uncertainty set are approximated by applying sampling and utilizing the information given by

the population members that reside in the set.

A descent direction is computed using the worst implementation errors around the solution. The descent direction points away from all the worst implementation errors found. In the paper it is shown that moving in such a direction improves the robust function value, which is simply the worst objective function value within the uncertainty set.

The proposed evolutionary algorithm for robust optimization utilizes the descent direction in the crossover operator, which uses two parents to produce two offspring. A descent cone, which contains all the descent directions for the parent, is computed for both parents. These descent cones are then used together with an appropriate weighting function to produce the offspring. The algorithm also utilizes polynomial mutation to maintain genetic diversity in the population.

The algorithm is evaluated on one- to five-dimensional test problems against two benchmark approaches to determine the benefits of using the novel descent-based crossover operator. The test problems are multi-modal, and the robust optimum lies at one of the peaks. The optimal solution to the test problems can be changed by varying the radius of the uncertainty set. The results suggest that using the descent-based crossover operator improves the accuracy and reduces the number of function evaluations compared to the approach that does not utilize the information given by the descent directions. Furthermore, the proposed algorithm requires much less function evaluations to converge than the brute force approach.

The authors conclude by saying that the proposed concept is going to be extended for robust optimization problems with multiple objectives and/or constraints. They also mention that the sampling method used for finding the worst implementation errors should be improved to reduce the number of function evaluations required by the algorithm.

References

[1] Ankur Sinha, Aleksi Porokka, Pekka Malo and Kalyanmoy Deb. Unconstrained Robust Optimization using a Descent-based Crossover Operator. Evolutionary Computation (CEC), 2015 IEEE Congress on. IEEE, in press