DOCTORAL THESIS

Many objective optimization: objective reduction and weight design

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Abstract

Many-objective optimization problems (MaOPs), in which the number of objectives is greater than three, are common in various applications, and have drawn many scholars' attention. Evolutionary multiobjective optimization (EMO) algorithms have been successfully applied to solve bi- and tri-objective optimization problems. However, MaOPs are more challenging compared with the bi- and tri-objective optimization problems. The performances of most existing classical EMO algorithms generally deteriorate over the number of objectives. Thus, this thesis presents a weight design method to modify classical decomposition-based EMO algorithms for solving MaOPs, and a novel objective extraction method to transform the MaOP into a problem with few objectives.

The decomposition-based EMO algorithms, e.g. MOEA/D, M2M, have demonstrated the effectiveness in dealing with MaOPs. Nevertheless, these algorithms need to design the weight vectors, which has significant effects on the algorithms' performance. Especially, when the Pareto front of the problem is incomplete, these algorithms cannot obtain a set of uniform solutions by using the conventional weight design methods. Not only can self-organizing map (SOM) preserve the topological properties of the input data by using the neighborhood function, but also its display is more uniform than the probability density of the input data. This phenomenon is advantageous to generate a set of uniform weight vectors based on the distribution of the individuals. Therefore, we propose a novel weight design method based on SOM, which can be integrated with most of the decomposition-based EMO algorithms. In this thesis, we choose the existing M2M algorithm as an example for such integration. This integrated algorithm is then compared with the original M2M and two state-of-the-art algorithms, i.e. MOEA/D and NSGA-II on eleven redundancy problems and eight non-redundancy problems. The experimental results show the

effectiveness of the proposed approach.

As some MaOPs may have redundant or correlated objectives, it is desirable to reduce the number of the objectives in such circumstances. However, the Pareto solution of the reduced problem obtained by most existing objective reduction methods may not be the Pareto solution of the original MaOP. Thus, this thesis proposes an objective extraction method for MaOPs. It formulates the reduced objective as a linear combination of the original objectives to maximize the conflict between the reduced objectives. Subsequently, the Pareto solution of the reduced problem obtained by the proposed algorithm is that of the original MaOP, and the proposed algorithm can preserve the non-dominant relation as much as possible. We compare the proposed objective extraction method with three objective reduction methods, i.e., REDGA, L-PCA and NL-MVU-PCA. The numerical studies show the effectiveness and robustness of the proposed approach.

Additionally, performance metrics play an important role in understanding the strengths and weaknesses of an algorithm. To the best of our knowledge, there is no direct performance metric for the objective reduction algorithms. Their performance can only be indirectly evaluated by the metrics, such as IGD-metric and H-metric, of the solutions obtained by an EMO algorithm equipped with the objective reduction method. This thesis presents a direct performance metric featuring the simplicity and usability of the objective reduction algorithms. Meanwhile, we propose a novel framework for many-objective test problems, which features both simple and complicated Pareto set shape, and is scalable in terms of the numbers of the objectives and the essential objectives. Also, we can control the importance of essential objectives.

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