GeDEA-II: A Simplex-Crossover Based Multi Objective Evolutionary Algorithm Including The Genetic Diversity As Objective

Claudio Comis Da Ronco*
HIT09 S.r.l
Galleria Storione 8, 35131
Padova, ITALY
c.comis@hit09.com

Ernesto Benini†
Department of Industrial Engineering
University of Padova
Via Venezia 1, 35131
Padova, ITALY
ernesto.benini@unipd.it

ABSTRACT

The key issue for an efficient and reliable multi-objective evolutionary algorithm is the ability to converge to the True Pareto Front with the least number of objective function evaluations, while covering it as much as possible. To this purpose, in a previous paper [3] performance comparisons showed that the Genetic Diversity Evolutionary Algorithm (GeDEA) was at the same level of the best state-of-the-art MOEAs due to it intrinsic ability to properly conjugate exploitation of current non-dominated solutions and the exploration of the search space. In this paper, an improved version, namely the GeDEA-II, is proposed which features a novel crossover operator, the Simplex-Crossover, and a novel mutation operator, the Shrink-Mutation. GeDEM operator was left unchanged and completed using the non-dominated-sorting based on crowding distance. In order to judge the performance of the GeDEA-II, a comparison with other different state-of-the-art multi-objective EAs was performed. SPEA-2 [6], NSGA-II [1] and IBEA [5] were chosen as competitors, and their performance against GeDEA-II was measured on the ZDT_3 test function. The test function, the methodology and the metric of performance used in the comparison are deeply described in [3]. Here we propose the test problem with 100 decision variables, and the initial population constituted by 100 individuals is evolved for only 30 generations. For measuring the quality of the results, we employed the Hypervolume approach, due to its construction simplicity and reliability when it comes to judge the performance of a MOEA. The comparison among GeDEA-II and GeDEA, as well as with three other modern elitist methods, clearly indicates that the performance of GeDEA-II is, at least in this case, superior. In addition, authors aimed at putting in evidence the excellent performance of GeDEA-II even on extremely multidimensional landscapes. To do this, one test problem is considered only, due to limitations on the number of pages, and the GeDEA-II performance tested by changing every time the number of decision variables. Test function chosen for this test is the $DTLZ_3$ that is, one of the most difficult to solve problems among those presented in [2]. In particular, the decision variables were increased up to 100 times the original proposed number, and only 150 generations (with a population size of 100 individuals) were sufficient to reach and properly cover the Final Approximation Set. To the best of the authors' knowledge, this is the first time a MOEA is tested on such test problem, featuring this number of decision variables. Results obtained demonstrate the GeDEA-II breakthrough performance.

*PhD. Research Engineer
†Associate Professor. Corresponding author

GECCO'12 Companion, July 7–11, 2012, Philadelphia, PA, USA.
ACM 978-1-4503-1178-6/12/07.

Categories and Subject Descriptors

G.1.6 [**Optimization**]: Global optimization; G.1.0 [**General**]: Numerical algorithms; G.4 [**Mathematical Software**]: Algorithm design and analysis

General Terms

Algorithms

Keywords

Evolutionary algorithms, Simplex Crossover, Multi Objective Optimization, Empirical - Comparison.

1. GENETIC DIVERSITY EVOLUTIONARY ALGORITHM-II (GEDEA-II)

The Genetic Diversity Evolutionary Algorithm II (GeDEA-II), is a framework that is strictly designed around GeDEM to exalt its characteristics. GeDEM is a diversity preservation mechanism which computes the actual ranks of the solutions maximizing (i) the ranks scored with respect to the objectives of the original MOOP, the non-dominated solutions having the highest rank, and (ii) the values assigned to each individual as a measure of its genetic diversity, calculated according to the chosen distance metric, i.e. the (normalized) Euclidean distance in the objective functions space. In order to enhance GeDEA algorithm performance further, several main features were added to the previous GeDEA version, yet retaining its constitutive framework. The main innovation is the novel crossover operator, namely the Simplex-crossover, which takes the place of the previous Uniform crossover. The remaining steps characterizing GeDEA algorithm, in particular the GeDEM, were left unchanged. The latter was integrated with the Non-Dominating sorting procedure based on the crowding distance.

1.1 The SIMPLEX crossover

In [4], a simplex crossover (SPX) is proposed, a new multi-parent recombination operator for real-coded GAs. However, the authors did not consider the application of the SPX to multiobjective problems. Moreover, they did not consider the possibility to take into account the fitness of the objective function/s as the driving force of the simplex. Therefore, we decided to integrate in the GeDEA-II the simplex crossover with these and further new distinctive features. Unlike the Simplex-crossover presented in [4], in GeDEA-II only two parents are required to form a new child. These two parents are selected according to the selection procedure from the previous population, and combined following the guidelines of the simplex algorithm. *Refl* coefficient is set equal to a random number ($refl \in [0, 1]$), unlike the elemental Simplex theory, which assumes a value equal to 1 for the *Refl* coefficient. This choice allows to create a child every time distant in a random manner from the parents, hence to explore more deeply the design space. This new crossover operator was expected to combine both exploration and exploitation characteristics. In fact, the new formed child explores a design space region opposite to that covered by the worst parent, that means it explores a region potentially not covered so far. In the early stages of the evolution, this means that child moves away from regions covered from bad parents, while exploring new promising ones. In addition, the characteristics of the good parents are deeply exploited to accelerate the evolution process. During evolution, GeDEA-II makes use exclusively of the Simplex Crossover until three-quarters of the generations has been reached. After that, Simplex Crossover is used alternatively with the Simulated Binary Crossover [1].

2. RESULTS AND CONCLUSION

In Figure 1, an excerpt of the non-dominated fronts obtained by the MOEAs on ZDT_3 test function and the Pareto-optimal fronts (continuous curves) is presented on the left, along with the boxplots (on the right). Figure 2 shows in

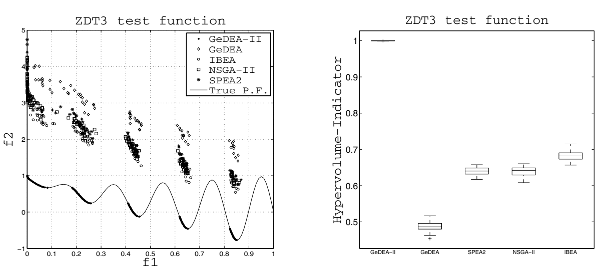

Figure 1: Final Approximation Set reached by the GeDEA-II on test function ZDT_3 (ON THE LEFT), and box plots based on the *Hypervolume* metric (ON THE RIGHT), referring to the five algorithms.

the objective space, the distribution of all the non dominated points found on $DTLZ_3$ test function, in the run with the lowest Hypervolume-value by the GeDEA-II, for the maximum number of decision variables. The boxplots showing GeDEA-II performance are also presented, as the decision variables are increased from the minimum value (equal to the orignal proposed of 12) up to the maximum one (1200). In this paper, we have presented GeDEA-II, an improved

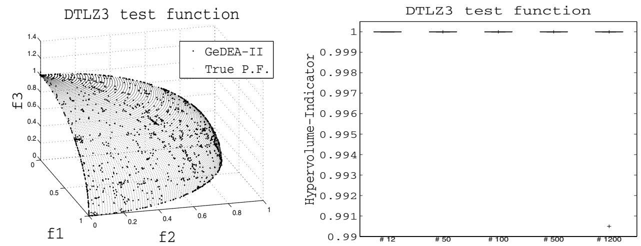

Figure 2: Non dominated solutions computed by the GeDEA-II on test function $DTLZ_3$ featuring 1200 decision variables (ON THE LEFT), and box plots based on the *Hypervolume* metric (ON THE RIGHT), referring to the five number of decision variables.

multi-objective evolutionary algorithm that employs novel genetic operators compared to its predecessor GeDEA. Extensive numerical comparisons of GeDEA-II with GeDEA and with NSGAII, SPEA-2 and IBEA, three state-of-the-art recently proposed algorithms, have been carried out on two test problems. The key results of the comparison show the outstanding performance of the GeDEA-II, when compared to the competitors algorithm, in terms of both exploration and exploitation capabilities. Boxplots shows that the reproducibility of results of GeDEA-II is high-level, when compared to that of the NSGAII, SPEA-2 and IBEA. In extremely high dimensional spaces, GeDEA-II clearly shows excellent performance. In addition to these characteristics, GeDEA-II performs these tasks with a reduced number of objective functions evaluations, which is not negligible when considering its application to real-world engineering problems.

3. REFERENCES

[1] K. Deb, A. Pratap, S. Agarwal, and T. Meyarivan. A fast and elitist multiobjective genetic algorithm: NSGA-II. *IEEE Transactions on Evolutionary Computation*, 6(2):182–197, 2002.

[2] K. Deb, L. Thiele, M. Laumanns, and E. Zitzler. Scalable test problems for evolutionary multi-objective optimization. *Computer Engineering and Networks Laboratory (TIK), TIK-Technical Report No. 112, Swiss Federal Institute of Technology*, 2001.

[3] A. Toffolo and E. Benini. Genetic diversity as an objective in multi-objective evolutionary algorithms. *Evolutionary Computation*, 11(2):151–157, 2002.

[4] S. Tsutsui, M. Yamamura, and T. Higuchi. Multi-parent recombination with simplex crossover in real coded genetic algorithms. *Proceedings of the GECCO-99*, pages 657–644, 1999.

[5] E. Zitzler and S. Künzli. *Indicator-Based Selection in Multiobjective Search.* In *Parallel Problem Solving from Nature (PPSN VIII)*, X. Yao et al., Eds. Berlin, Germany: Springer-Verlag, 2004, pp. 832-842., 2004.

[6] E. Zitzler, M. Laumanns, and L. Thiele. *SPEA2: Improving the Strength Pareto Evolutionary Algorithm.* Technical Report 103, Computer Engineering and Networks Laboratory (TIK), Swiss Federal Institute of Technology (ETH) Zurich, Gloriastrasse 35, CH-8092 Zurich, Switzerland,May 2001., 2001.