Results of the 2017 IEEE CEC Competition on Evolutionary Many-Objective Optimization

R. Cheng, M. Li, Y. Tian, X. Zhang, S. Yang, Y. Jin, and X. Yao

2017 IEEE Congress on Evolutionary Computation,
San Sebastián, Spain, June 5-8, 2017

Outline

I. Introduction

II. Entries

III. Results

IV. Summary

Motivation

- Optimization problems with more than three objectives (i.e. many-objective) prose great challenge to existing evolutionary algorithms for traditional multi-objective optimization

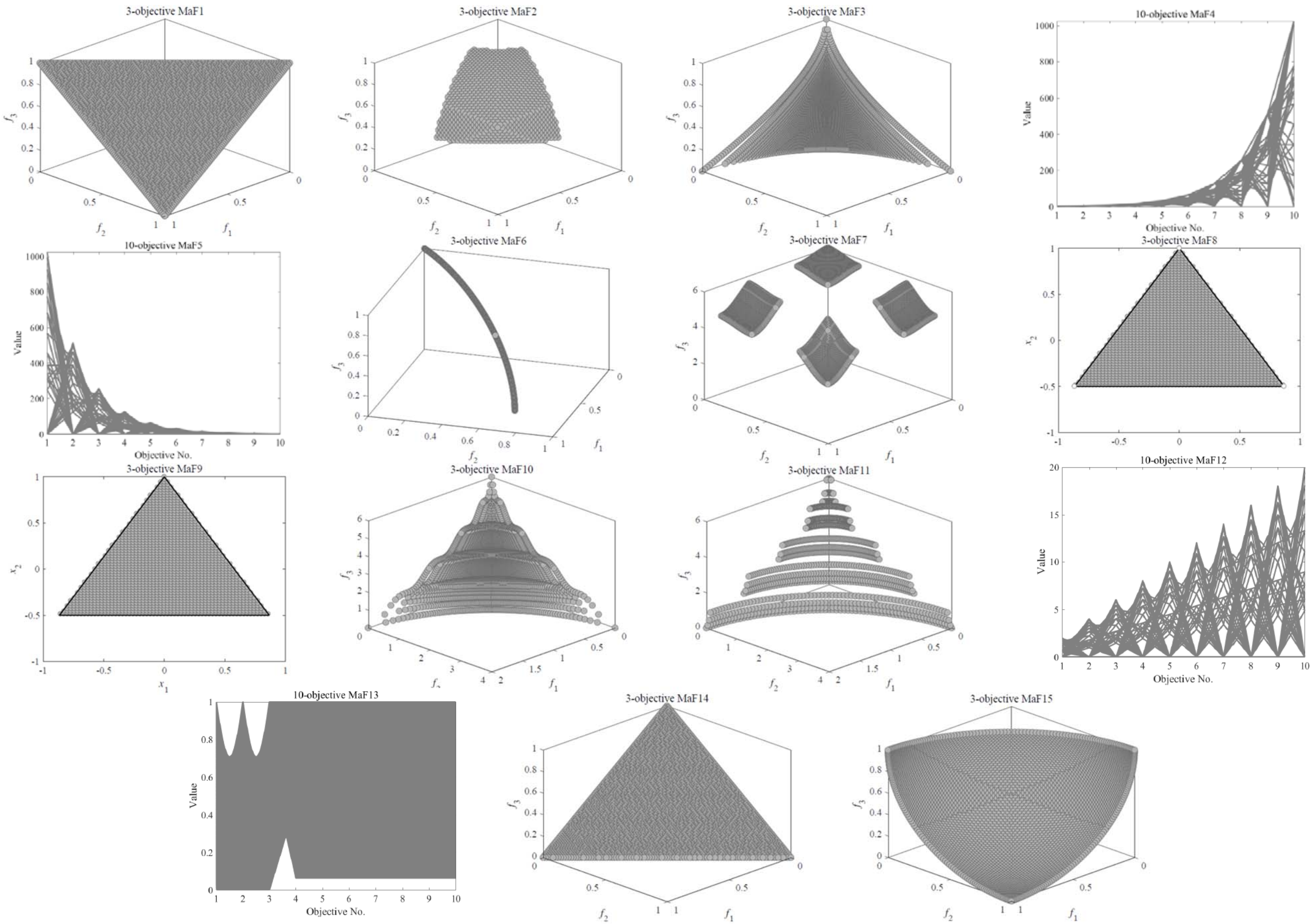
- There is still NO tailored test suite for many-objective optimization

- This competition aims at proposing 15 many-objective test problems with diverse properties, and investigating the performance of evolutionary algorithms on these problems [1]

Test problems

Test problem	Modified from	Difficulty
MaF1	DTLZ1 [2]	Inverted PF
MaF2	DTLZ2BZ [3]	Concurrent convergence
MaF3	DTLZ3 [2]	Convex PF, multimodal
MaF4	DTLZ3 [2]	Inverted and scaled PF, multimodal
MaF5	DTLZ4 [2]	Scaled PF, highly biased distribution
MaF6	DTLZ5(I,M) [4]	Degenerate PF
MaF7	DTLZ7 [2]	Disconnected PF
MaF8	MP-DMP [5]	Large search space
MaF9	ML-DMP [6]	Large search space
MaF10	WFG1 [7]	Complicated mixed PF
MaF11	WFG2 [7]	Scaled disconnected PF
MaF12	WFG9 [7]	Complicated fitness landscape
MaF13	PF7 [8]	Degenerate PF, complicated variable linkage
MaF14	LSMOP3 [9]	Complicated fitness landscape, large-scale
MaF15	LSMOP8 [9]	Inverted PF, complicated fitness landscape, large-scale

Pareto front of the test problems



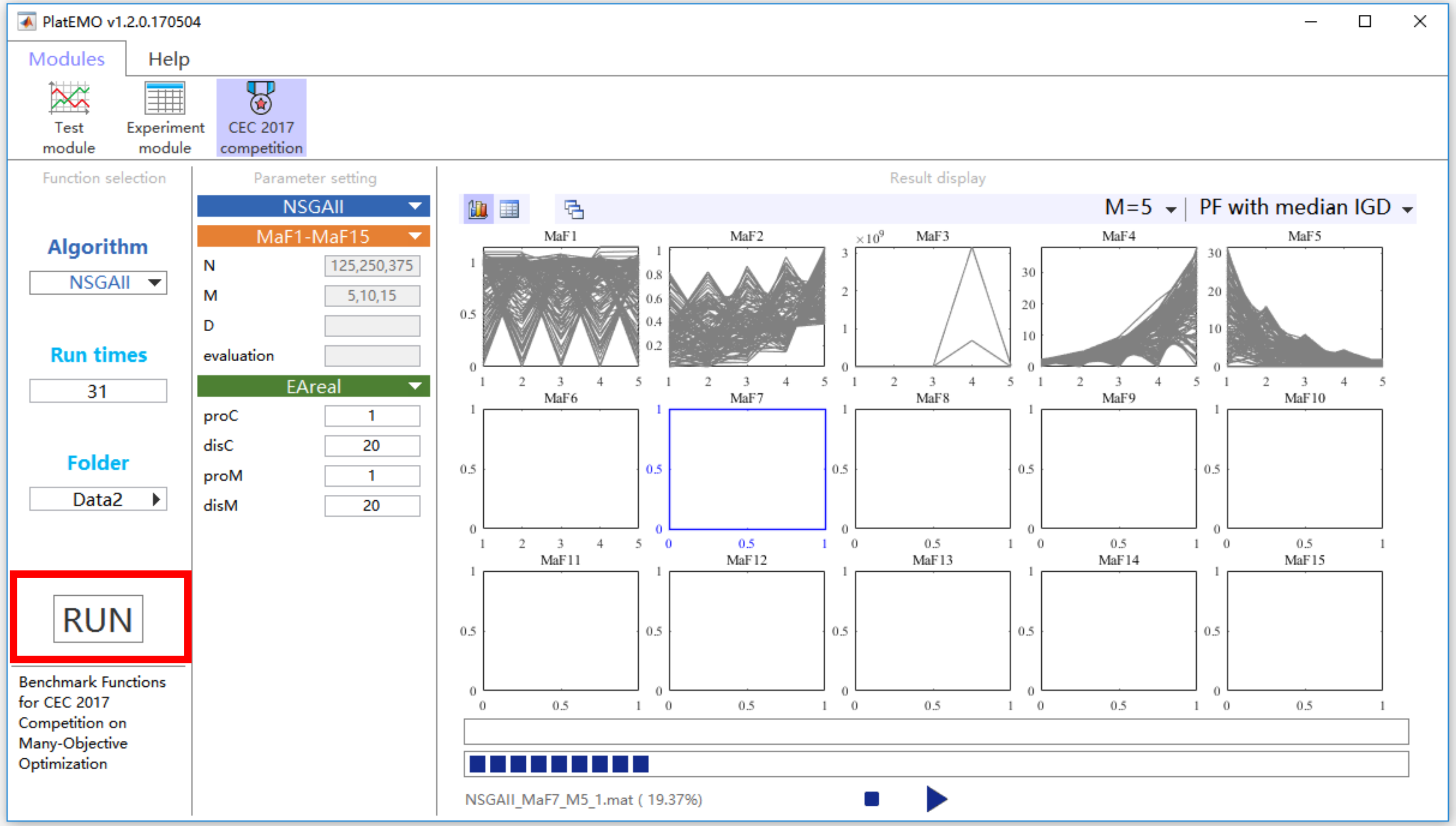
Experimental platform

- This competition is conducted on PlatEMO, which is a MATLAB based platform for evolutionary multi-objective optimization [10]
- PlatEMO includes more than 60 algorithms and 110 multi-objective test problems, which are all open-source and fully commented
- PlatEMO provides friendly GUI for users to perform experiments and obtain experimental results in the format of $\LaTeX$, without writing any code

Download: http://bimk.ahu.edu.cn/index.php?s=/Index/Software/index.html

Experimental platform

- Specially tailored GUI for this competition – One click to obtain all the results.



Competition entries

- Seven entries from three different countries
- Four new algorithms
- Three existing algorithms

Algorithm	Author	Description
AGE-II [11]	Markus Wagner	Approximation-guided evolution II
BCE [12]	Miqing Li	Bi-criterion evolution
GSRA	Ye Chen	Gradient stochastic ranking algorithm
KnEA [13]	Xingyi Zhang	Knee point driven evolutionary algorithm
MaOEA-CS	Haoran Sun	Many-objective evolutionary algorithm based on corner solution search
RSEA	Cheng He	Radial space division based evolutionary algorithm
RVEA [14]	Ran Cheng	Reference vector guided evolutionary algorithm

Performance indicators

- Inverted generational distance (IGD) [15]

  10,000 uniformly distributed reference points sampled on the Pareto front

$$IGD(P, P^*) = \frac{\sum_{x \in P^*} \min_{y \in P} dis(x, y)}{|P^*|}$$

- Hypervolume (HV) [16]

  Normalize the population by the nadir point of the Pareto front

  Monte Carlo estimation method with 1,000,000 points is adopted

$$HV(P, R) = \lambda(H(P, R))$$

$$H(P, R) = \{z \in Z | \exists x \in P, \exists r \in R : f(x) \leq z \leq r\}$$

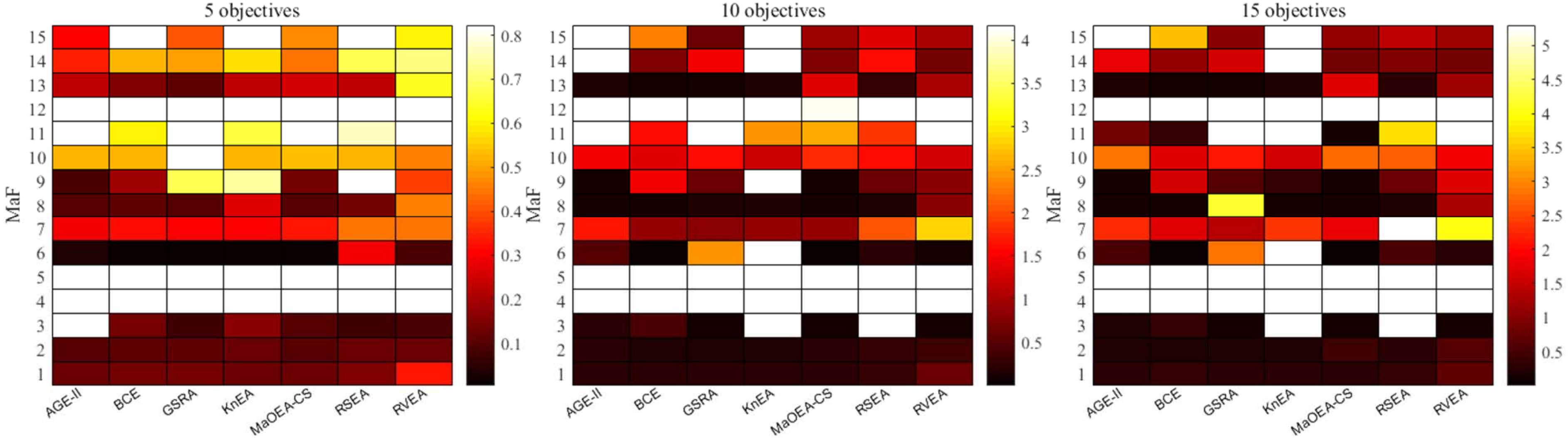
$$\lambda(H(P, R)) = \int_{\mathbb{R}^n} 1_{H(P,R)}(z) dz$$

Ranking strategy

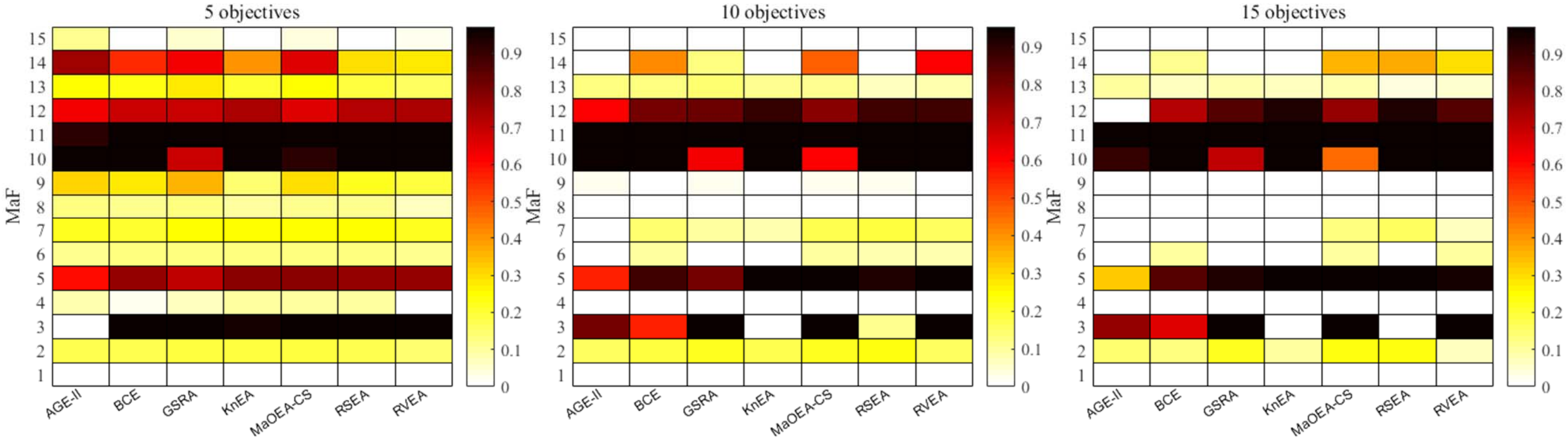
- Each algorithm executes on each problem with 5, 10 and 15 objectives for 31 runs, respectively (i.e. 1395 results)
- Sort the means of each indicator values on each problem with each number of objectives (i.e. 90 ranks)
- The SCORE of achieved by each algorithm is the sum of the reciprocal values of the ranks.

Overview of the Results

- IGD values of the results (5-, 10- 15-ojective)



- HV values of the results (5-, 10- 15-ojective)



Overview of the Ranks

- Ranks according to IGD values

	AGE-II	BCE	GSRA	KnEA	MaOEA-CS	RSEA	RVEA
MaF1	1	5	4	3	2	6	7
MaF2	1	3	4	7	2	5	6
MaF3	7	5	2	6	4	1	3
MaF4	7	5	3	2	1	4	6
MaF5	2	3	4	6	1	7	5
MaF6	5	2	4	3	1	7	6
MaF7	1	4	3	2	5	7	6
MaF8	2	4	1	6	3	5	7
MaF9	1	3	5	6	2	7	4
MaF10	4	2	7	3	6	5	1
MaF11	7	1	6	2	4	3	5
MaF12	3	5	6	4	1	7	2
MaF13	4	2	1	3	6	5	7
MaF14	1	4	3	5	2	6	7
MaF15	1	6	2	7	3	5	4
Total	2	3	4	5	1	7	6

	AGE-II	BCE	GSRA	KnEA	MaOEA-CS	RSEA	RVEA
MaF1	1	5	4	3	2	6	7
MaF2	4	3	2	1	5	6	7
MaF3	4	5	1	7	2	6	3
MaF4	6	2	5	3	1	4	7
MaF5	2	6	3	5	1	4	7
MaF6	5	1	6	7	2	4	3
MaF7	5	3	1	2	4	6	7
MaF8	1	2	5	4	3	6	7
MaF9	1	6	3	7	2	4	5
MaF10	4	3	6	1	7	5	2
MaF11	7	1	6	3	4	2	5
MaF12	2	4	3	6	1	7	5
MaF13	3	2	1	4	7	5	6
MaF14	7	3	4	6	2	5	1
MaF15	7	5	1	6	2	4	3
Total	4	2	3	5	1	6	7

	AGE-II	BCE	GSRA	KnEA	MaOEA-CS	RSEA	RVEA
MaF1	1	6	4	3	2	5	7
MaF2	4	3	2	1	6	5	7
MaF3	4	5	1	7	3	6	2
MaF4	7	4	5	2	1	3	6
MaF5	3	6	2	5	1	4	7
MaF6	4	2	6	7	1	5	3
MaF7	4	2	1	5	3	7	6
MaF8	1	3	7	4	2	5	6
MaF9	1	6	4	3	2	5	7
MaF10	7	2	4	1	6	5	3
MaF11	3	2	6	5	1	4	7
MaF12	7	3	5	2	1	6	4
MaF13	4	2	1	3	7	5	6
MaF14	6	4	5	7	2	3	1
MaF15	7	5	1	6	2	4	3
Total	5	3	2	4	1	6	7

- Ranks according to HV values

	AGE-II	BCE	GSRA	KnEA	MaOEA-CS	RSEA	RVEA
MaF1	2	5	6	3	1	4	7
MaF2	6	5	1	2	3	4	7
MaF3	7	5	4	6	1	2	3
MaF4	4	6	5	2	1	3	7
MaF5	7	3	6	2	1	5	4
MaF6	6	2	4	3	1	5	7
MaF7	6	7	4	1	3	2	5
MaF8	1	5	2	6	3	4	7
MaF9	2	4	1	7	3	5	6
MaF10	5	1	7	4	6	3	2
MaF11	7	2	6	4	3	1	5
MaF12	7	4	5	1	6	3	2
MaF13	3	4	1	5	2	6	7
MaF14	1	4	3	5	2	6	7
MaF15	1	6	2	7	3	5	4
Total	6	5	2	3	1	4	7

	AGE-II	BCE	GSRA	KnEA	MaOEA-CS	RSEA	RVEA
MaF1	2	4	6	5	3	1	7
MaF2	7	4	2	5	3	1	6
MaF3	4	5	2	7	1	6	3
MaF4	4	5	6	2	3	1	7
MaF5	7	5	6	1	2	4	3
MaF6	5	2	6	7	1	4	3
MaF7	7	4	5	6	2	1	3
MaF8	3	5	4	6	2	1	7
MaF9	3	6	1	7	4	2	5
MaF10	5	1	6	3	7	2	4
MaF11	7	2	6	3	4	1	5
MaF12	7	5	4	1	6	3	2
MaF13	2	3	1	5	4	7	6
MaF14	6	3	4	7	2	5	1
MaF15	5	6	1	7	2	4	3
Total	7	3	4	6	2	1	5

	AGE-II	BCE	GSRA	KnEA	MaOEA-CS	RSEA	RVEA
MaF1	1	3	5	6	7	2	4
MaF2	4	5	3	6	2	1	7
MaF3	4	5	2	6	1	7	3
MaF4	6	2	4	3	7	1	5
MaF5	7	6	5	1	2	3	4
MaF6	5	1	6	7	2	4	3
MaF7	7	4	5	6	2	1	3
MaF8	3	5	6	4	2	1	7
MaF9	2	7	1	5	3	4	6
MaF10	5	1	6	4	7	2	3
MaF11	6	2	5	3	4	1	7
MaF12	7	6	4	1	5	2	3
MaF13	1	4	2	5	3	7	6
MaF14	6	4	5	7	2	1	3
MaF15	5	6	3	7	1	4	2
Total	6	3	4	7	2	1	5

Winner Algorithms

MaOEA-CS

Many-objective evolutionary algorithm based on corner solution search
Haoran Sun, Chunyang Zhu and Xinye Cai
Nanjing University of Aeronautics and Astronautics, China

GSRA

Gradient stochastic ranking algorithm
Ye Chen, Xiaoping Yuan, Hui Sun and Peng Jin
China University of Mining and Technology, China

AGE-II

Approximation-guided evolution II
Markus Wagner
University of Adelaide, Australia

Conclusion

- 15 many-objective test problems were proposed for this competition
- 7 many-objective evolutionary algorithms joined the competition
- According to the final ranking based on IGD and HV metrics, the winner is **MaOEA-CS** (Many-objective evolutionary algorithm based on corner solution search)

Future work

- Re-organize this competition with further enhancements (Java code, better computational efficiency, etc.)
- Attract more effective algorithms to join the competition
- Introduce other performance indicators

Q & A

R. Cheng (ranchengcn@gmail.com)
M. Li (limitsing@gmail.com)
Y. Tian (field910921@gmail.com)
X. Zhang (xyzhanghust@gmail.com)
S. Yang (syang@dmu.ac.uk)
Y. Jin (yaochu.jin@surrey.ac.uk)
X. Yao (x.yao@cs.bham.ac.uk)

Competition Homepage: http://www.cercia.ac.uk/news/cec2017maooc/

References

[1] Cheng R, Li M, Tian Y, et al. A Benchmark Test Suite for Evolutionary Many-objective Optimization. Complex & Intelligent Systems, 3(1): 67-81, 2017.

[2] Deb K, Thiele L, Laumanns M, et al. Scalable test problems for evolutionary multiobjective optimization[M]. Springer London, 2005.

[3] Brockhoff D, Zitzler E. Objective reduction in evolutionary multiobjective optimization: Theory and applications[J]. Evolutionary Computation, 2009, 17(2): 135-166.

[4] Deb K, Saxena D. Searching for Pareto-optimal solutions through dimensionality reduction for certain large-dimensional multi-objective optimization problems[C]//Proceedings of the World Congress on Computational Intelligence (WCCI-2006). 2006: 3352-3360.

[5] Köppen M, Yoshida K. Substitute distance assignments in NSGA-II for handling many-objective optimization problems[C]//Evolutionary multi-criterion optimization. Springer Berlin/Heidelberg, 2007: 727-741.

[6] Li M, Grosan C, Yang S, et al. Multi-line distance minimization: A visualized many-objective test problem suite[J]. IEEE Transactions on Evolutionary Computation, 2017.

[7] Huband S, Hingston P, Barone L, et al. A review of multiobjective test problems and a scalable test problem toolkit[J]. IEEE Transactions on Evolutionary Computation, 2006, 10(5): 477-506.

[8] Saxena D K, Zhang Q, Duro J A, et al. Framework for many-objective test problems with both simple and complicated Pareto-set shapes[C]//International Conference on Evolutionary Multi-Criterion Optimization. Springer Berlin Heidelberg, 2011: 197-211.

[9] Cheng R, Jin Y, Olhofer M, et al. Test problems for large-scale multiobjective and many-objective optimization[J]. IEEE Transactions on Cybernetics, 2016.

[10] Tian Y, Cheng R, Zhang X, et al. PlatEMO: A MATLAB Platform for Evolutionary Multi-Objective Optimization[J]. arXiv preprint arXiv:1701.00879, 2017.

[11] Wagner M, Neumann F. A fast approximation-guided evolutionary multi-objective algorithm[C]//Proceedings of the 15th annual conference on Genetic and evolutionary computation. ACM, 2013: 687-694.

[12] Li M, Yang S, Liu X. Pareto or Non-Pareto: Bi-Criterion Evolution in Multiobjective Optimization[J]. IEEE Transactions on Evolutionary Computation, 2016, 20(5): 645-665.

[13] Zhang X, Tian Y, Jin Y. A knee point-driven evolutionary algorithm for many-objective optimization[J]. IEEE Transactions on Evolutionary Computation, 2015, 19(6): 761-776.

[14] Cheng R, Jin Y, Olhofer M, et al. A reference vector guided evolutionary algorithm for many-objective optimization[J]. IEEE Transactions on Evolutionary Computation, 2016, 20(5): 773-791.

[15] Zhou A, Jin Y, Zhang Q, et al. Combining model-based and genetics-based offspring generation for multi-objective optimization using a convergence criterion[C]//Evolutionary Computation, 2006. CEC 2006. IEEE Congress on. IEEE, 2006: 892-899.

[16] While L, Hingston P, Barone L, et al. A faster algorithm for calculating hypervolume[J]. IEEE transactions on evolutionary computation, 2006, 10(1): 29-38.