# Evolutionary computation for optimization

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Optimization is use of specific methods/tools to evaluate the most efficient and cost effective feasible solution to a problem. The need for finding such optimal solutions in a problem comes mostly from the extreme purpose of either designing a solution for minimum possible cost of fabrication, or for maximum possible profit and/or reliability, or minimum waste generation, or maximum yield/selectivity, or others. Because of such extreme properties of the desired objectives, the optimization methods are of great importance in practice, particularly in the engineering design, the scientific experiments and the business decision-making. Most of the traditional optimization algorithms based on the gradient methods (e.g. Newton's method, Steepest Descent, Quasi – Newton method etc.) (Edgar et al., 2001), have the possibility of getting trapped at local optimum depending upon the degree of non-linearity and the value of initial guess. Unfortunately, none of the gradient based algorithms are guaranteed to find the global optimal solution (Biegler and Grossmann, 2004). However, the deterministic terrain methodology (Lucia and Yang, 2002, 2003), has a potential of handling single objective nonlinear engineering problems at relatively small amount of computer time. Population based search algorithms (which are stochastic in nature, with probabilistic transition rule) are found to have a better global perspective resulting in more number of near global solutions (for non-linear and complex real life problems) than the gradient based traditional methods (Onwubolu and Babu, 2004). The user will have a choice of selecting one of the near global solutions depending upon the requirement unlike the traditional methods which results in a single optimal solution.

In the recent years, non-traditional search and optimization methods based on the natural phenomena, such as Simulated Annealing (SA), Genetic Algorithms (GA), Differential Evolution (DE), Self Organizing Migrating Algorithms (SOMA), Particle Swarm Optimization (PSO), Tabu Search (TS), Scatter Search (SS), and Ant Colony Optimization (ACO) have been developed to overcome the problems associated with the traditional optimization methods ( Price et al., 2006; Onwubolu and Babu, 2004; Babu, 2004; Corne et al., 1999). Most of these algorithms originate from the evolutionary approach, which have been used successfully for both the single- and multi-objective optimization problems. The specialty with Multi-objective Evolutionary Algorithms (MOEAs) is that they can find multiple optimal solutions in one single simulation run due to their population based search approach. These evolutionary algorithms (EAs) are ideally suited for Multi-Objective Optimization Problems (MOOPs).

The expected outcome of MOEAs is that it should result in a set of solutions which are non-dominated with respect to each other. A solution $x_1$ is said to dominate the other solution $x_2$ if both the following conditions 1 and 2 are correct (Deb, 2001).

1. The solution $x_1$ is no worse than $x_2$ in all objectives
2. The solution $x_1$ is strictly better than $x_2$ in at least one objective.

Such a set of solutions is called the global Pareto front, if the obtained front approaches the true Pareto front. But it is possible that many MOEAs may get converged to a local Pareto front. Therefore, there is a need for a robust MOEA that evaluates the solutions on entire search space and approaches the global Pareto front. A robust algorithm is the one which does not change its performance by a small change in values of its control parameters.

Some of the popular MOEAs are Non-dominated Sorting Genetic Algorithms (NSGA) (Deb, 2001), NSGA-II with jumping gene adaptations and its improved variants (Ramteke and Gupta, 2009; Agrawal et al., 2006;Chakraborti et al., 2008), Strength Pareto Evolutionary Algorithm (SPEA) (Zitzler, 2000), Multi-objective Simulated Annealing (MOSA) (Dongkyung and Park, 2000), Multi-objective Differential Evolution (MODE) and its strategies (Babu et al., 2005, 2007a, 2007b), elitist multi-objective differential evolution (E-MODE) (Babu and Gujarathi, 2007c; Gujarathi and Babu, 2009a), hybrid multi-objective differential evolution (Gujarathi and Babu, 2009b). Recently, metallurgical engineering based applications were successfully solved under multi-objective optimization scenario using multi-objective genetic algorithms (Biswas et al., 2009a, 2009b).

Differential Evolution (DE), which was originally developed by developed by Price and Storn (1997) and then was modified by many researchers, is an improved version of GA (Goldberg, 1989) for faster optimization. DE has been successfully applied in various fields. Some of the successful applications of DE include: digital filter design (Storn, 1995), Batch fermentation process (Wang and Chen, 1999), estimation of heat transfer parameters in trickle bed reactor (Babu and Sastry, 1999), dynamic Optimization of a continuous reactor using a modified differential evolution (Lee et al., 1999), optimal design of heat exchangers (Babu and Munawar, 2007), optimization of low pressure chemical vapor deposition reactors using hybrid differential evolution (Lu and Wang, 2001), nonisothermal pyrolysis of biomass (Sheth and Babu, 2009), etc. Successful application of modified differential evolution (MDE) is also reported in the literature (Angira and Babu, 2006a, 2006b, 2006c; Babu and Angira, 2006). Several researchers have extended DE to handle MOOPs (Abbas et al., 2001; Babu et al., 2005). Multi-objective Differential Evolution (MODE) was applied successfully by Babu et al. (2005) on multi-objective optimization of adiabatic styrene reactor. MODE was tested for its robustness by applying it on several benchmark test problems (Babu and Gujarathi, 2007a). Recently multi-objective optimization of supply chain planning and management was carried out using MODE, where MODE has given a better Pareto front than NSGA-II (Babu and Gujarathi, 2007b). Improved strategy of MODE (Elitist-MODE) was applied to solve multi-objective optimization of purified terephthalic acid (PTA) oxidation process (Gujarathi and Babu, 2009a).

MODE was found to give a better Pareto front (Babu et al., 2005) when compared to the one obtained when NSGA was used (Yee et al., 2003). In addition to satisfying the definition (that at least one member of current set of solutions has the best value in at least one objective than all solutions of the other set, and none of the members of a current Pareto front is worse than the other set of solutions), a better Pareto front would satisfy the following characteristics:

1. Capturing a better set of non-dominated of solutions (local Pareto front vs. near global or the global Pareto front) with better spread
2. Improved diverse set of non-dominated solutions with appropriate Euclidean distance and covering a wider range
3. More number of non-dominated solutions on the Pareto front

## Further reading

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Onwubolu G. C., Babu, B. V. 2004. New optimization techniques in engineering, Springer-Verlag, Heidelberg, Germany. (Link »)

Deb, K., 2001. Multi-Objective Optimization using Evolutionary Algorithms, John Wiley & Sons Limited, New York. (Link »)

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Differential Evolution

Genetic Algorithms and New Optimization Methods in MATLAB

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## Related peer-reviewed articles

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**1.** Improved multiobjective differential evolution (MODE) approach for purified terephthalic acid (PTA) oxidation process
(2009) Gujarathi, A.M. | Babu, B.V.
Materials and Manufacturing Processes pp.303-319 **Cited** 3 times.

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## Web search results

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**1.** Swarm Intelligence And Evolutionary Computation For Single And Multiobjective Optimization In Water Resource Systems
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[http://hdl.handle.net/2005/370]

**2.** Inference of biochemical network models in S-system using multiobjective optimization approach -- Liu and Wang 24 (8): 1085 -- ...
Mar 2009
Motivation: The inference of biochemical networks, such as gene regulatory networks, protein–protein interaction networks, and metabolic pathway networks, from time-course data is one of the main challenges in systems biology.
[http://bioinformatics.oxfordjournals.org/cgi/conte...]

**3.** Evolutionary Algorithms in Computer-Aided Molecular Design
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Banzhaf, W., Nordin, P., Keller, R.E. and Francone, F.D. Genetic Programming: An Introduction on the Automatic Evolution of Computer Programs and its Applications, Morgan Kaufmann, San Francisco, 1997. Baeck, T., Fogel, D.B. and Michalewicz, Z. (Eds).
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**4.** Microsoft Word - Babu_AMJ_MODE_JET.doc
Oct 2007
This algorithm is equipped with non-dominated population selection combined with basic DE algorithm. In this study, the MODE algorithm is further applied on six different Test problems with/ without constraints and extensive simulation runs are carried out . ..
[http://discovery.bits-pilani.ac.in/~bvbabu/Babu_AM...]

**5.** K.E. PARSOPOULOS :: Citations
Jun 2008
1. US Patent No. 7225107, "Methods and Apparatus for Data Analysis" (issued May 29, 2007) Inventors: Ali M. S. Zalzala, Emilio Miguelanez Martin, Eric Paul Tabor, Paul M. Buxton Assignee: Test Advantage, Inc. Application: No. 10730388 filed on 2003-12-07 ...
[http://www.math.upatras.gr/~kostasp/cita.html]

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[http://www.brics.dk/DS/03/6/BRICS-DS-03-6.pdf]

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Oct 2008
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