Firefly Algorithm for Finding Optimal Shapes of Electromagnetic Devices

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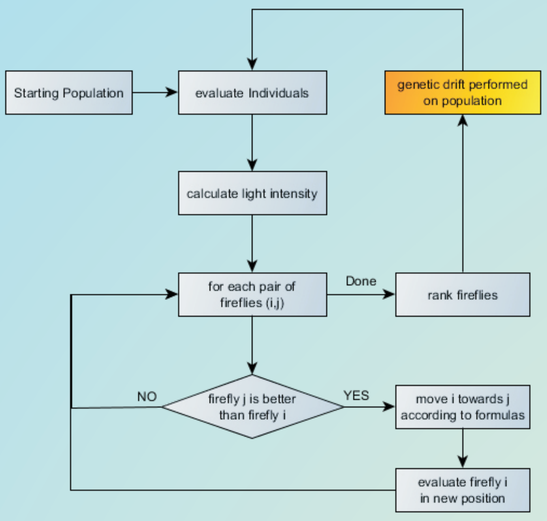
Abstract

Many real world optimization problems have to be treated as multi-objective optimization problems. Relying on scalar optimization methods, a suitable objective function taking all objectives into account has to be defined. A scalar optimization strategy should be able to end up in the best of all possible solutions (in the given search space) and additionally detect as many local solutions as possible. The Firefly Algorithm, one of many metaheuristic optimizatzion methods, mimics the natural behaviour of fireflies, which use a kind of flashing light to communicate with other members of their species. The information conveyed can be either the message about the quality of food supply, but it can also be a notice about possible threats. A Cascaded Firefly Algorithm is applied to detect as many local solutions as possible on its way to the best solution in the given search space and its performance is compared to a Niching Higher Order Evolution Strategy.

Firefly Algorithm



Cascaded Firefly Algorithm

Repeat n Times

k Firefly Iterations of given population size

„Genetic Drift" of Final Population

Detect Isolated Clusters of Fireflies

Evaluate Distances

$$r_{ij} = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2}$$

Evaluate Attractiveness

$$\beta(r) = \beta_0 e^{-\gamma r^2}$$

Update the Population

$$x_i^{t+1} = x_i^t + \beta_0 e^{-\gamma r_{ij}^2}(x_j^t - x_i^t) + \alpha \epsilon_i^t$$

Rastrigin Function

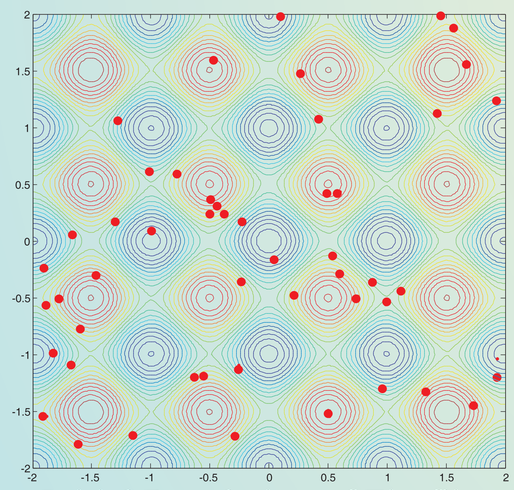
$$f(\mathbf{x}) = 20 + \sum_{i=1}^{2} [x_i^2 - 10\cos(2\pi x_i)]$$

Cascaded Firefly Algorithm

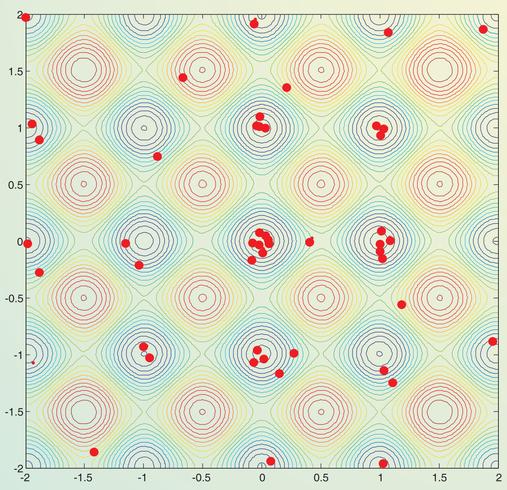
Repeat 10 Times

10 Firefly Iterations

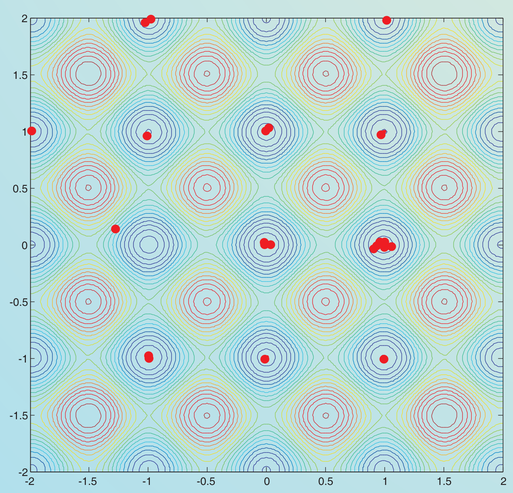
40 Fireflies per Iteration



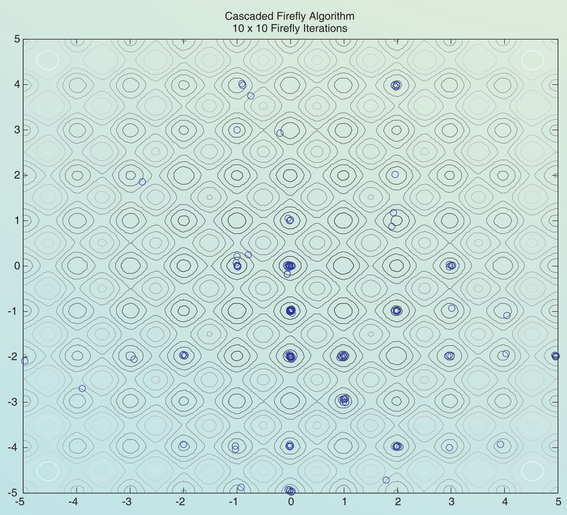
Initial Population of Fireflies



Intermediate Population of Fireflies

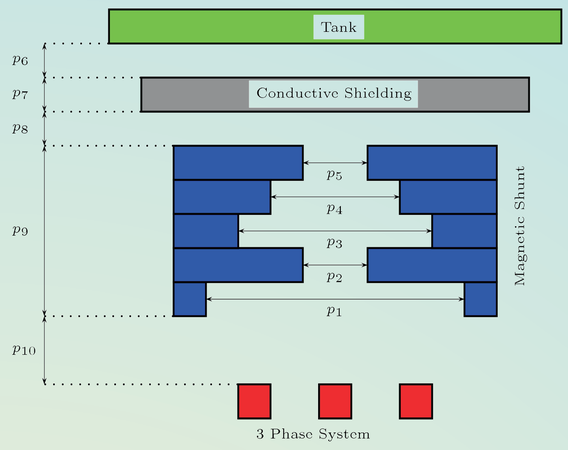


Final Population of Fireflies



All Isolated Solutions

Shielding/Shunt Optimization Problem



2D Eddy Current Problem

Conductive/Magnetig Shunt

(+ Conductive Shielding)

Adjust p_1 to p_{10} to meet 2 (3) Objectives:

Minimize Losses in the Tank (P_T)

Minimize Volume of Magnetic Shunt (V_{Sh})

(Minimize Volume of Copper Shielding V_{Cu})

Objective Functions q

$q = w_1 * P_T + w_2 * V_{Sh}$

$q = w_1 * P_T + w_2 * V_{Sh} * w_3 * V_{Cu}$

w_1, w_2, w_3 ... Suitable Weights

Results

2 Objectives: Minimize Losses, Minimize Volume of Magnetic Shunt

Cascaded Firefly Algorithm

Repeat 10 Times

10 Firefly Iterations

15 Fireflies per iteration

Approx. 10000 function calls set of weights

Niching Evolution Strategy

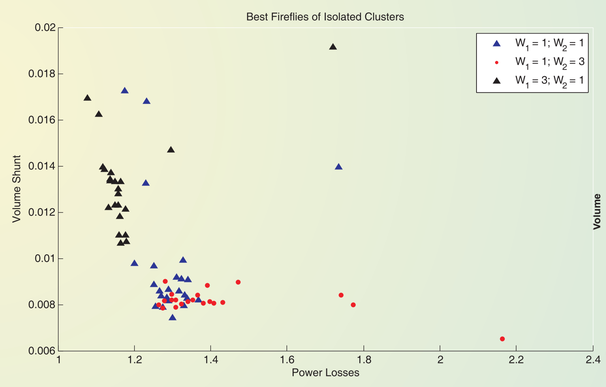
[10(8/2, 20)] ES

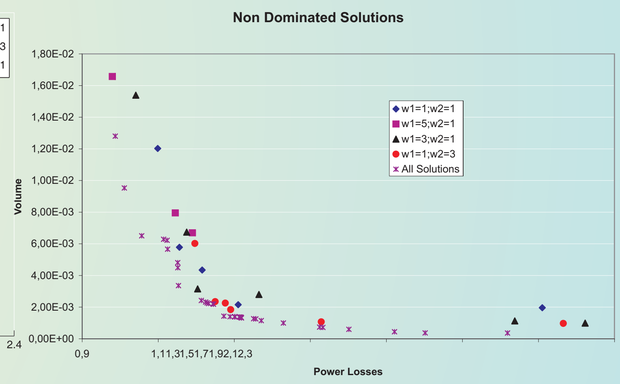
10 Cluster

8 Parents (2 Recombining)

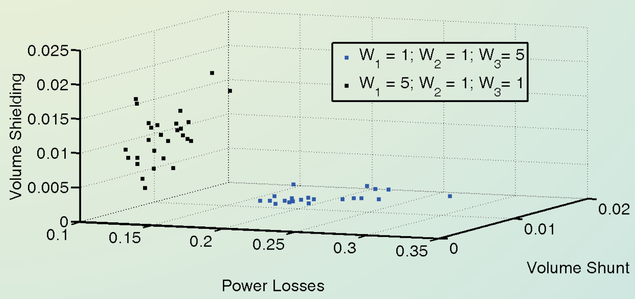
20 Children

Approx. 15000 function calls set of weights





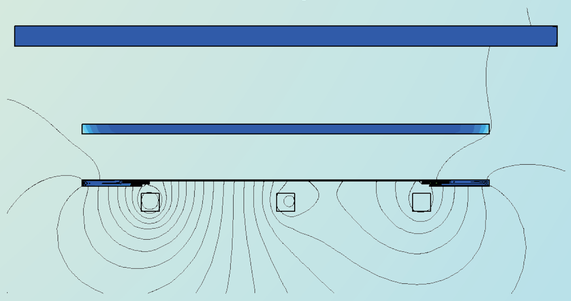
3 Objectives: Minimize Losses, Minimize Volume of Magnetic Shunt, Minimize Volume of Copper Shield



Solutions of Isolated Clusters

Optimized Solution

Current Density Distribution



Conclusion

The Firefly Algorithm can very efficiently be used to solve multi-objective optimization problems. Due to its implicit capability to cluster the population of fireflies, this algorithm is able to find a high number of local solutions, which can be expected very close (or even on) the Pareto optimal front. Therefore, this algorithm is able to find a good approximation of the Pareto optimal front in the neighbourhood of the (global) solution of a given scalar optimization problem. This is very advantageous in case of a rather high number of objectives.