Center for the Advancement of Natural Discoveries using Light Emission

SYNCHROTRON RESEARCH INSTITUTE

The Optimization Algorithms of Dynamic Aperture

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The Task

- Study Multi-Objective Genetic and Particle Swarm Optimization Algorithms.

Contents

- Genetic Algorithm (GA)
- Multi- Objective Genetic Algorithm (MOGA)
- Particle Swarm Optimization (PSO)
- Comparing MOGA to PSO
- Example of Dynamic Aperture Optimization using MOGA
- Future plans

Genetic Algorithm

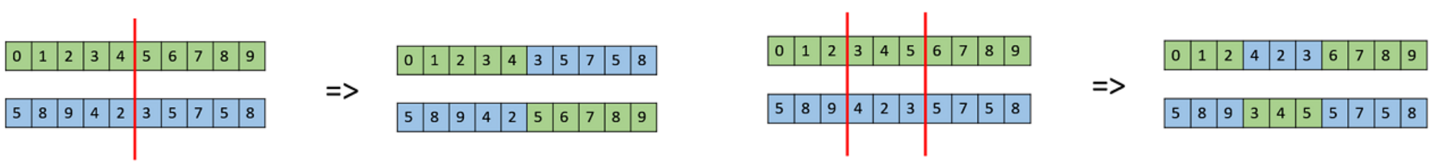
The genetic algorithm is frequently used to solve optimization problems.

How the genetic algorithm works?

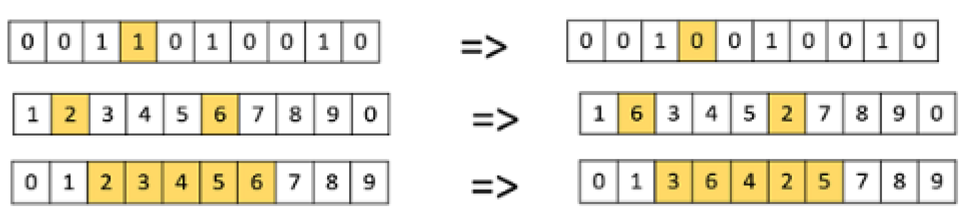
- The algorithm begins by creating a random initial population.
- The algorithm then creates a sequence of new populations. At each step, the algorithm uses the individuals in the current generation to create the next population.
- The algorithm stops when one of the stopping criteria is met.

The genetic algorithm creates three types of children for the next generation from the current population:

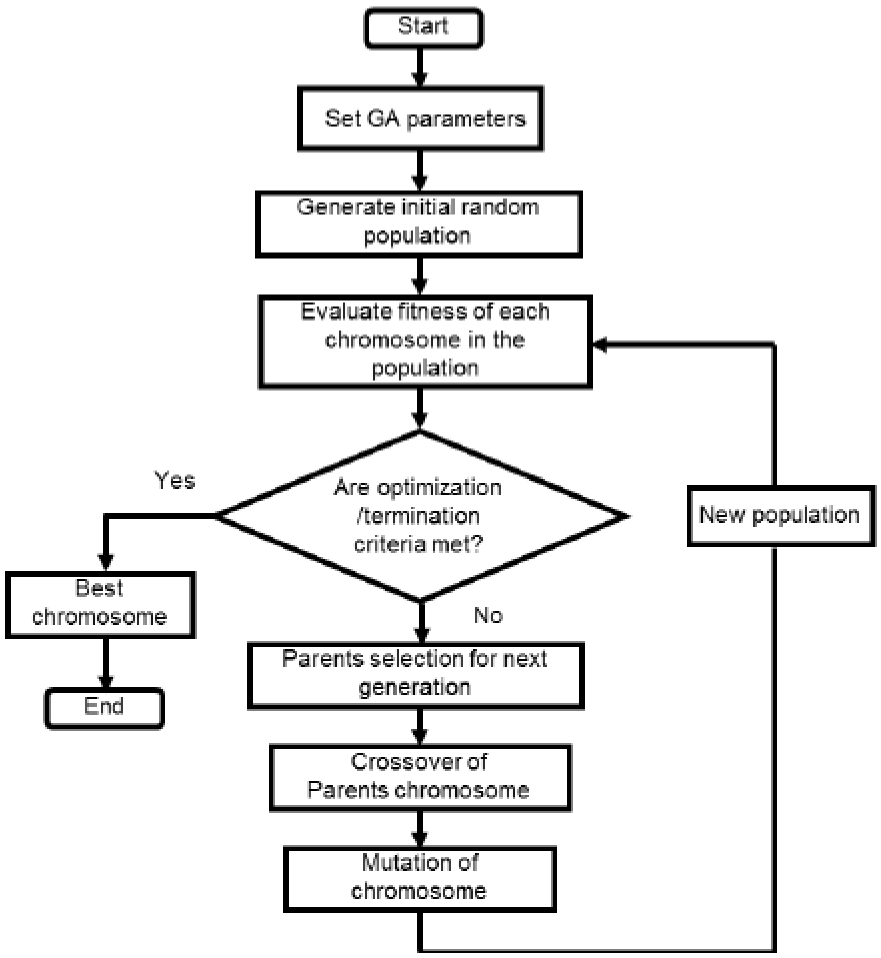
1. Elite children - Best value
2. Crossover children



3. Mutation children



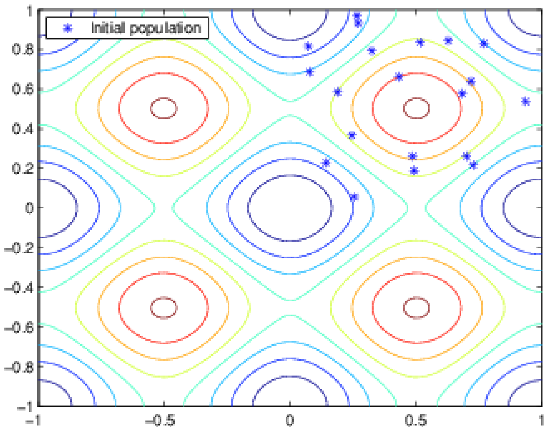
The Diagram illustrating the GA



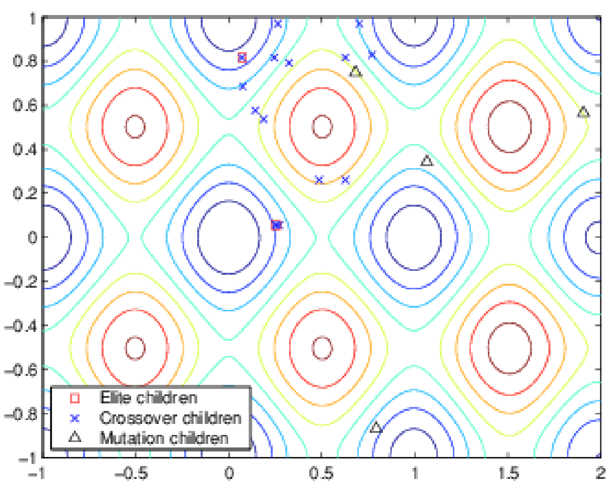
Note: The fitness/ objective function is the function, which we want to optimize

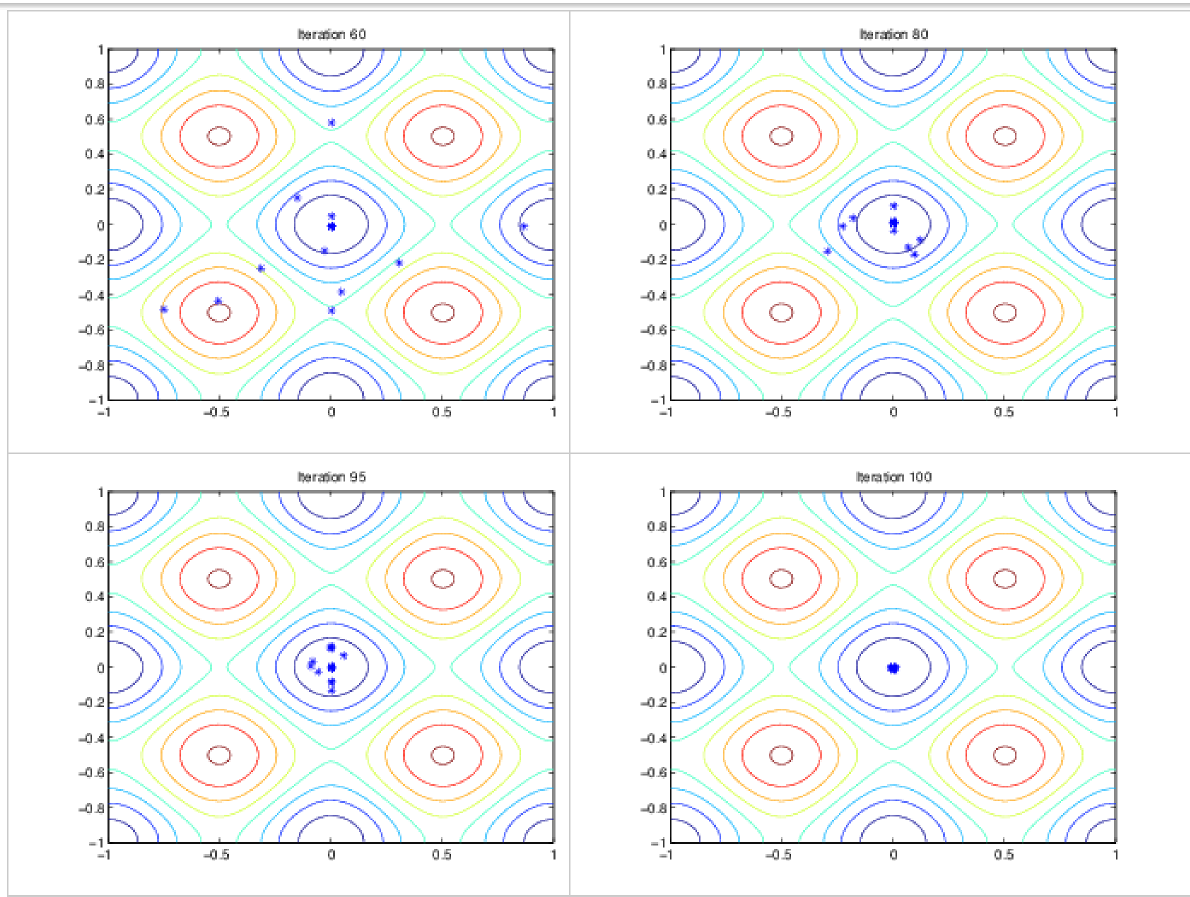
Example

Initial population, which contains 20 individuals



The children of the initial populatio





The figure shows the populations at iterations 60, 80, 95, and 100.

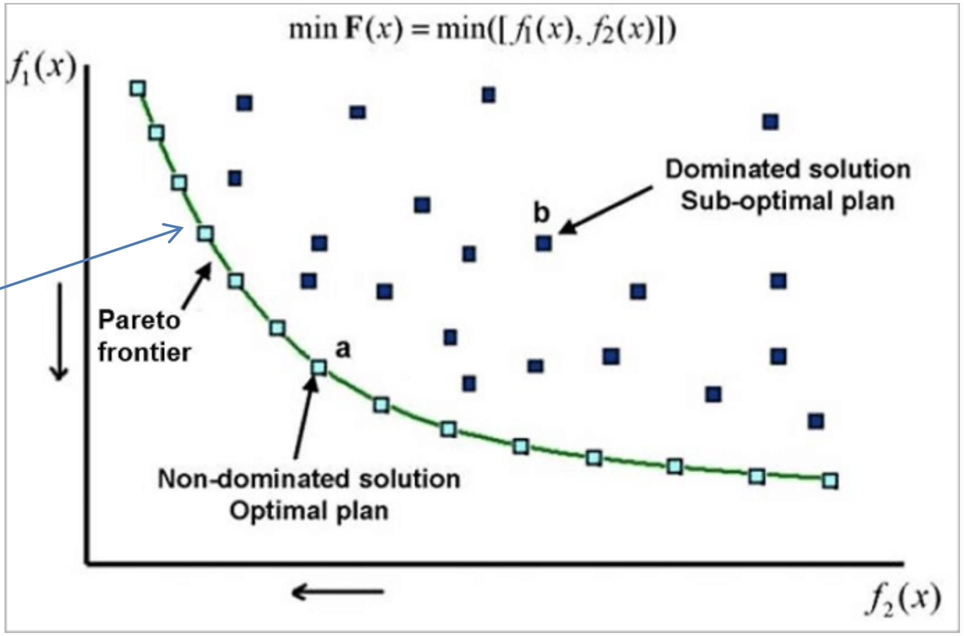
Multi-Objective Genetic Algorithms

The multi-objective optimization problem is formulated as:

$$\left.\begin{array}{lll} Minimize & f_m(x), & m = 1,2,\ldots,M; \\ subject\ to & g_j(x) \geq 0, & j = 1,2,\ldots,J; \\ & h_k(x) = 0, & k = 1,2,\ldots,K; \\ & x_i^{(L)} \leq x_i \leq x_i^{(U)} & i = 1,2,\ldots,n. \end{array}\right\}$$

$\mathbf{x} = (x_1, x_2, \ldots, x_n)^T$ → Individual

A multi-objective optimizer returns a population of x's. This returned population is an optimal surface in the objective space called a **Pareto front** .The user of a multi-objective optimizer typically applies additional criteria when selecting a particular solution from the Pareto front.



Particle Swarm Optimization

The algorithm looks like birds flocking around food sources

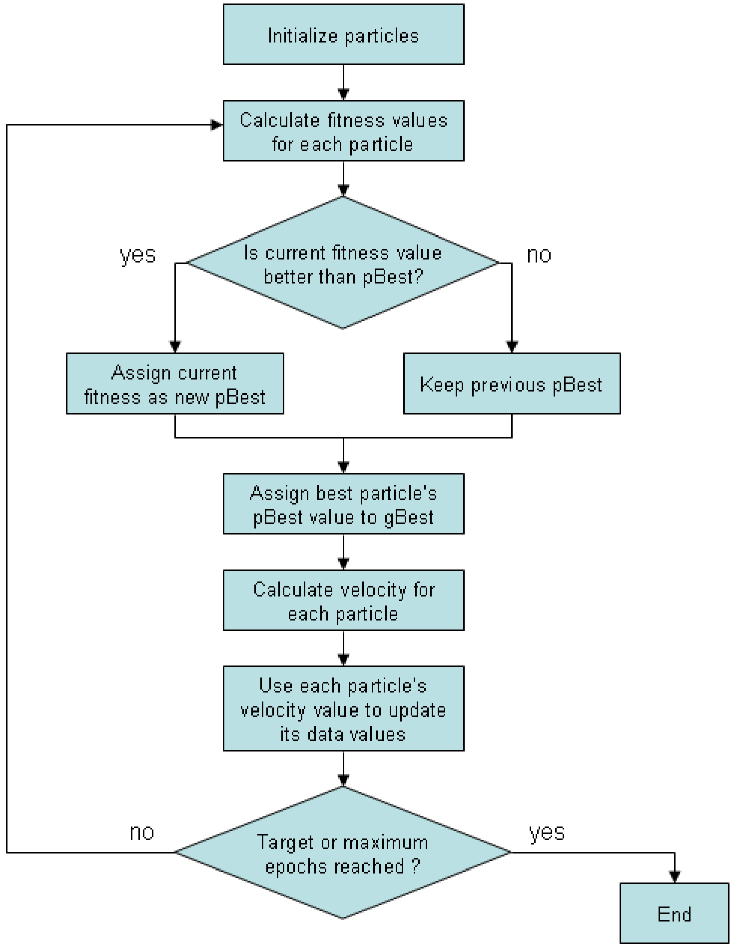
The algorithm keeps track of three global variables:

- Target value or condition
- **Global best** (gBest) value indicating which particle's data is currently closest to the Target
- Stopping value indicating when the algorithm should stop if the Target isn't found

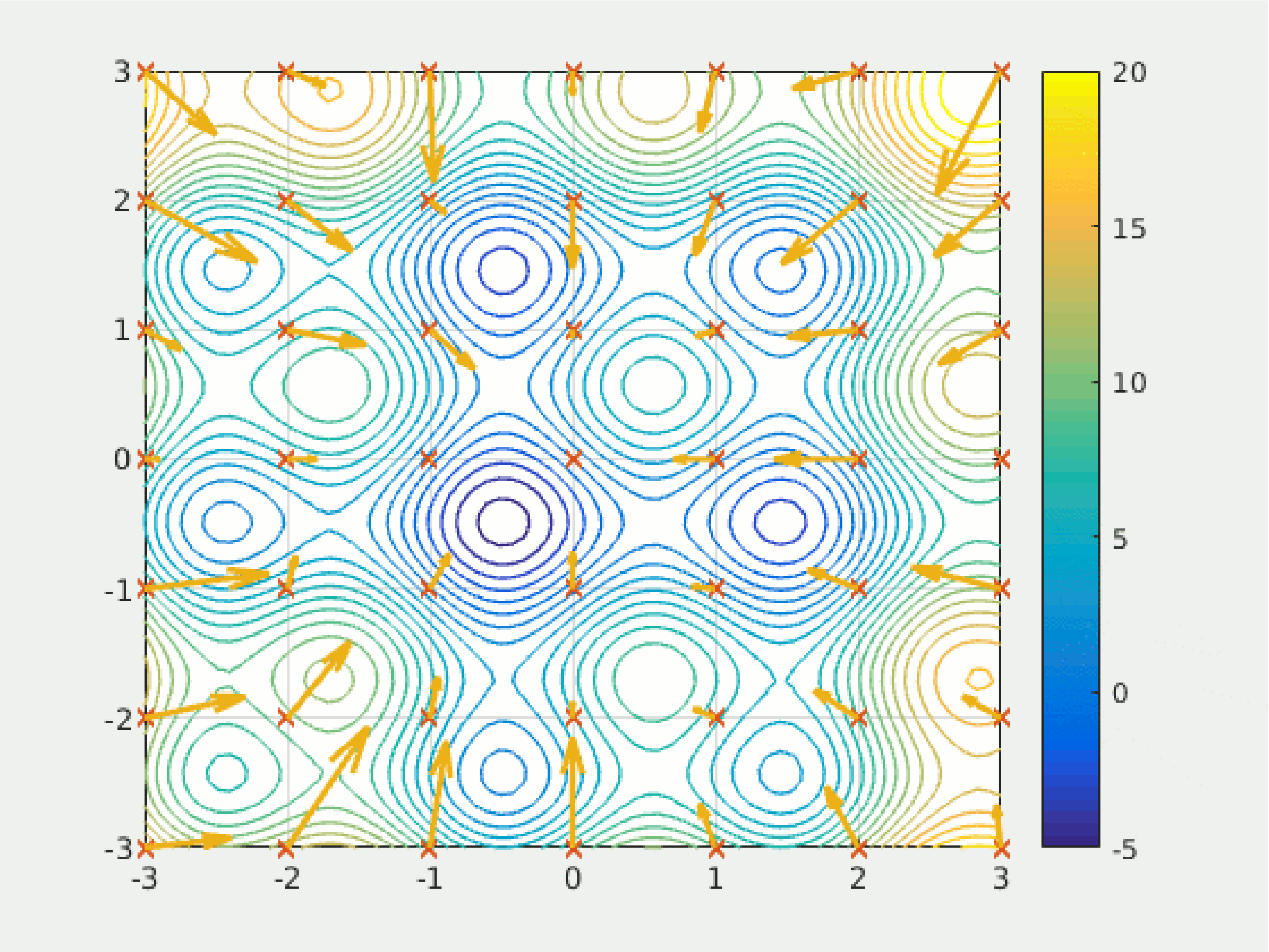
Each particle consists of:

- Data representing a possible solution
- A Velocity value indicating how much the Data can be changed
- A **personal best** (pBest) value indicating the closest the particle's Data has ever come to the Target

The Diagram illustrating the particle swarm optimization algorithm.



Example

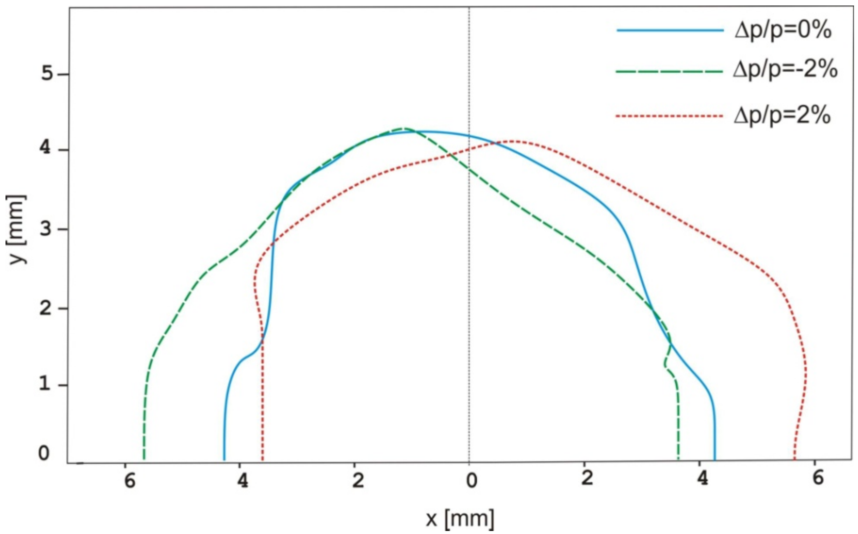


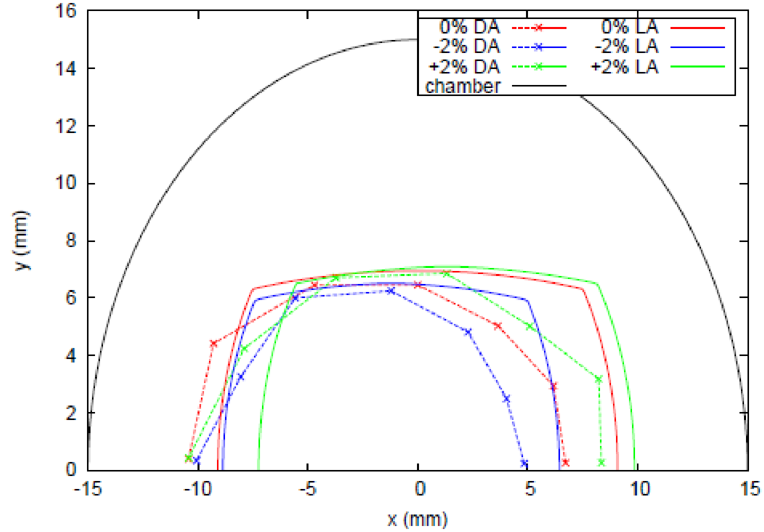
A particle swarm searching for the global minimum of a function

The Global Difference Between MOGA and PSO

MOGA	PSO
Advantages	
Solutions it finds are globally optimal.	1. It converges to the best solution quickly, 2. It is a relatively new method.
Disadvantages	
It takes a lot of time	Solutions it finds can be local optimal

Example of dynamic aperture optimization using MOGA for





Dynamic aperture (DA) and linear aperture (LA) for CANDLE at 0%, −2%, and 2% energy offset before and after optimization.

Objective functions - the on-energy dynamic aperture and the dynamic aperture at−2% and +2%.
Constraints - Boundary on sextuple strength, Global bound on nonlinear dispersion at −2%, and 2% energy offset , Confine chromatic tune footprint

Future plans

- Choose the optimization algorithm MOGA or PSO
- Then to code optimization algorithms by MATLAB,
- Then to do simulations and optimizations of dynamic aperture by ELEGANT for current CANDLE storage ring using developed MATLAB code.

THANK YOU FOR ATTENTION