



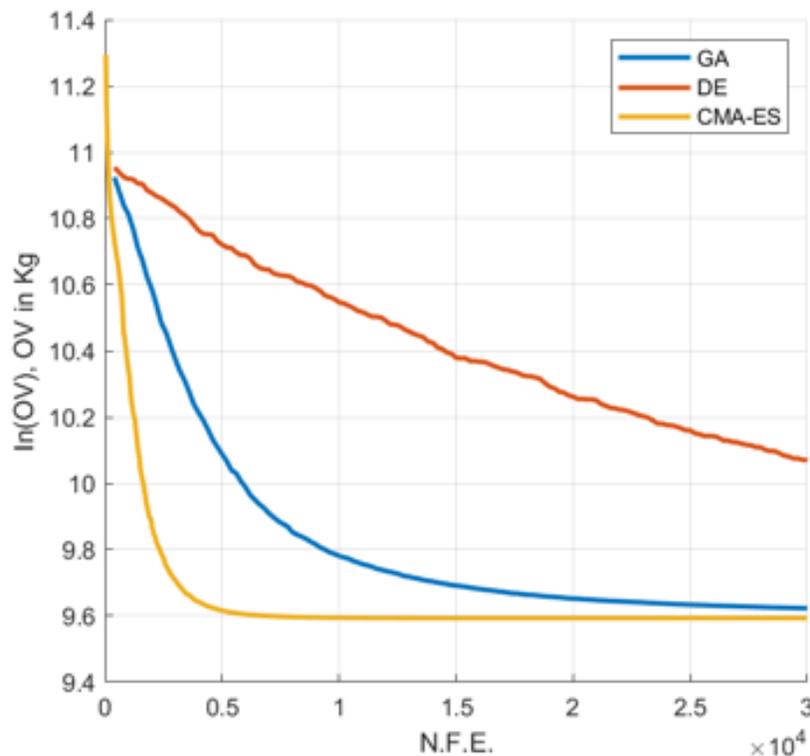
# CMA-ES SPECIFICATION

**Covariance Matrix Adaptation evolution strategy (CMA-ES)  
optimization algorithm**

## Covariance matrix adaptation evolution - strategy (CMA-ES) optimization algorithm

Design optimization and artificial intelligence in general require the application of optimization algorithms to find extrapolated responses of a function or pattern. Among the most popular methods are genetic algorithm (GA) [1] and differential evolution (DE) [2]. A more recent algorithm created by Hansen in 2005 called covariance matrix adaptation - evolution strategy (CMA-ES) [3] has demonstrated superior performance in many optimization tasks in the field of structural analysis.

In an illustrative example, these three algorithms were applied 20 times in the design optimization of 96 design variable truss. Figure 1 illustrates the 20 average convergence curve of GA, DE and CMA-ES.



**Fig. 1** - 20 average convergence curve of GA, DE and CMA-ES, versus number of fitness evaluations (NFE)

## Fast Kriging (FKR), also called Tessellated Partitions Surface with Kriging (TPS-KR)

Table 1 displays the convergence values of Figure 1, where is possible to see that beside the CMA-ES algorithm achieving the best overall value, it has a faster convergence curve, and also a very low variance of the achieved response.

algorithm	average	variance
GA	1.480e+04	2.246e+03
DE	1.681e+04	3.267e+04
CMA-ES	1.466e+04	6.966e-25

**Tab. 1** - 20 average convergence values of GA, DE and CMA-ES

VMC Consulting offers this algorithm as a Matlab app. In order to acquire the Matlab app, contact [info@vmc-consulting.net](mailto:info@vmc-consulting.net), or call (413) 684-8373.

### References

[1] D. Whitley, "A genetic algorithm tutorial," *Statistics and Computing* 1994 4:2, vol. 4, no. 2, pp. 65–85, Jun. 1994, doi: 10.1007/BF00175354.

[2] R. Storn and K. Price, "Differential Evolution – A Simple and Efficient Heuristic for global Optimization over Continuous Spaces," *Journal of Global Optimization*, vol. 11, no. 4, pp. 341–359, 1997, doi: 10.1023/A:1008202821328.

[3] N. Hansen, "The CMA Evolution Strategy: A Comparing Review," in *Towards a New Evolutionary Computation: Advances in the Estimation of Distribution Algorithms*, J. A. Lozano, P. Larrañaga, I. Inza, and E. Bengoetxea, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2006, pp. 75–102. doi: 10.1007/3-540-32494-1\_4.