

Table A1. Benchmark functions

Function Name	Function	Range	f^*
Unimodal functions			
F01 Rosenbrock	$f(\mathbf{x}) = \sum_{i=1}^{d-1} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$	$[-30, 30]$	0
F02 RotatedHyperEllipsoid	$f(\mathbf{x}) = \sum_{i=1}^d \sum_{j=1}^i x_j^2$	$[-65.536, 65.536]$	0
F03 Schwefel 2.20	$f(\mathbf{x}) = \sum_{i=1}^d x_i $	$[-100, 100]$	0
F04 Schwefel 2.21	$f(\mathbf{x}) = \max_{i \in [1, d]} x_i $	$[-100, 100]$	0
F05 Schwefel 2.22	$f(\mathbf{x}) = \sum_{i=1}^d x_i + \prod_{i=1}^d x_i $	$[-100, 100]$	0
F06 Schwefel 2.23	$f(\mathbf{x}) = \sum_{i=1}^d x_i^{10}$	$[-10, 10]$	0
F07 Sphere	$f(\mathbf{x}) = \sum_{i=1}^d x_i^2$	$[-100, 100]$	0
F08 Step	$f(\mathbf{x}) = \sum_{i=1}^d (x_i^2 + 0.5)$	$[-100, 100]$	7.5
F09 SumSquares	$f(\mathbf{x}) = \sum_{i=1}^d i x_i^2$	$[-10, 10]$	0
Multimodal functions			
F10 Ackley	$f(\mathbf{x}) = -20 \cdot \exp(-0.2 \sqrt{\frac{1}{d} \sum_{i=1}^d x_i^2}) - \exp(\frac{1}{d} \sum_{i=1}^d \cos(2\pi x_i)) + 20 + \exp(1)$	$[-32.768, 32.768]$	0
F11 Penalized 1	$f(\mathbf{x}) = \frac{\pi}{d} \{10 \sin(\pi w_1) + \sum_{i=1}^{d-1} (w_i - 1)^2 [1 + 10 \sin^2(\pi w_{i+1})] + (w_d - 1)^2\}$ $+ \sum_{i=1}^d u(x_i, 10, 100, 4) w_i = 1 + \frac{x_i + 1}{4} : \forall i = 1, \dots, d$ $u(\mathbf{x}_i, \mathbf{a}, \mathbf{k}, \mathbf{m}) = \begin{cases} k(x_i - a)^m & x_i > a, \\ 0 & -a < x_i < a, \\ k(-x_i - a)^m & x_i < -a. \end{cases}$	$[-50, 50]$	0
F12 Penalized 2	$f(\mathbf{x}) = 0.1 * [\sin^2(3\pi x_1) + \sum_{i=1}^d (x_i - 1)^2 [1 + \sin^2(3\pi x_i + 1)]]$ $+ (x_d - 1)^2 [1 + \sin^2(2\pi x_d)] + \sum_{i=1}^d u(x_i, 5, 100, 4)$	$[-50, 50]$	0
F13 Griewank	$f(\mathbf{x}) = \frac{1}{4000} \sum_{i=1}^d x_i^2 - \prod_{i=1}^d \cos(\frac{x_i}{\sqrt{i}}) + 1$	$[-600, 600]$	0
F14 Levy	$f(\mathbf{x}) = \sin^2(\pi w_1) + \sum_{i=1}^{d-1} (w_i - 1)^2 [1 + 10 \sin^2(\pi w_i + 1)]$ $+ (w_d - 1)^2 [1 + \sin^2(2\pi w_d)] w_i = 1 + \frac{x_i - 1}{4} : \forall i = 1, \dots, d$	$[-10, 10]$	0
F15 Quartic	$f(\mathbf{x}) = \sum_{i=1}^n i x_i^4 + \text{random}[0, 1)$	$[-1.28, 1.28]$	-0.175408
F16 Rastrigin	$f(\mathbf{x}) = \sum_{i=1}^d (x_i^2 - 10 \cos(2\pi x_i) + 10)$	$[-5.12, 5.12]$	0
F17 Schwefel	$f(\mathbf{x}) = 418.9829d - \sum_{i=1}^d x_i \sin(\sqrt{ x_i })$	$[-500, 500]$	0
F18 Schwefel 2.26	$f(\mathbf{x}) = -\sum_{i=1}^d x_i \sin(\sqrt{ x_i })$	$[-500, 500]$	-418.9829d
f^* , the optimal function value			