

the average error rates obtained in the 23 benchmark functions. The ranking of
all the algorithms based on their MAE calculations is illustrated in table 7.

Table 2: Unimodal testbench functions [41]

Function	Dim	Interval	f_{min}
$F_1(x) = \sum_{i=1}^n x_i^2$	30	$[-100, 100]$	0
$F_2(x) = \sum_{i=1}^n x_i + \prod_{i=1}^n x_i $	30	$[-10, 10]$	0
$F_3(x) = \sum_{i=1}^n (\sum_{j=1}^i x_j)^2$	30	$[-100, 100]$	0
$F_4(x) = \max_i \{ x_i , 1 \leq i \leq n\}$	30	$[-100, 100]$	0
$F_5(x) = \sum_{i=1}^{n-1} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$	30	$[-30, 30]$	0
$F_6(x) = \sum_{i=1}^n ([x_i + 0.5])^2$	30	$[-100, 100]$	0
$F_7(x) = \sum_{i=1}^n ix_i^4 + \text{random}[0, 1)$	30	$[-1.28, 1.28]$	0

Table 3: Multimodal testbench functions [41]

Function	Dim	Interval	f_{min}
$F_8(x) = \sum_{i=1}^n -x_i \sin(\sqrt{ x_i })$	30	$[-500, 500]$	-2094.9145
$F_9(x) = \sum_{i=1}^n [x_i^2 - 10 \cos(2\pi x_i + 10)]$	30	$[-5.12, 5.12]$	0
$F_{10}(x) = -20 \exp \left(-0.2 \sqrt{\frac{1}{n} \sum_{i=1}^n x_i^2} \right) - \exp \left(\frac{1}{n} \sum_{i=1}^n \cos(2\pi x_i) \right) + 20 + e$	30	$[-32, 32]$	0
$F_{11}(x) = \frac{1}{4000} \sum_{i=1}^n x_i^2 - \prod_{i=1}^n \cos \left(\frac{x_i}{\sqrt{i}} \right) + 1$	30	$[-600, 600]$	0
$F_{12}(x) = \frac{\pi}{n} \left\{ 10 \sin(\pi y_1) + \sum_{i=1}^{n-1} (y_i - 1)^2 [1 + 10 \sin^2(\pi y_{i+1})] + (y_n - 1)^2 \right\} + \sum_{i=1}^n u(x_i, 10, 100, 4)$	30	$[-50, 50]$	0
$y_i = 1 + \frac{x_i + 1}{4} u(x_i, a, k, m) = \begin{cases} k(x_i - a)^m & x_i > a \\ 0 - a < x_i < a \\ k(-x_i - a)^m & x_i < -a \end{cases}$			
$F_{13}(x) = 0.1 \{ \sin^2(3\pi x_1) + \sum_{i=1}^n (x_i - 1)^2 [1 + \sin^2(3\pi x_i + 1)] + (x_n - 1)^2 [1 + \sin^2(2\pi x_n)] \} + \sum_{i=1}^n u(x_i, 5, 100, 4)$			

Table 4: Fixed-dimension Multimodal testbench functions [41]

Function	Dim	Interval	f_{min}
$F_{14}(x) = \left(\frac{1}{500} + \sum_{j=1}^{25} \frac{1}{j + \sum_{i=1}^{12} (x_i - a_{ij})^6} \right)^{-1}$	2	$[-65, 65]$	1
$F_{15}(x) = \sum_{i=1}^{11} [ai - \frac{\pi 11(6i^2 + 6ix2)}{6i^2 + 6ix2 + 4}]^2$	4	$[-5, 5]$	0.00030
$F_{16}(x) = 4x_1^2 - 2.1x_1^4 + \frac{5}{3}x_1^6 + x_1x_2^2 - 4x_2^2 + 42^4$	2	$[-5, 5]$	-1.0316
$F_{17}(x) = (x_2 - \frac{5.1}{\sqrt{17}}x_1^2 + \frac{5}{8}x_1 - 6)^2 + 10(1 - \frac{x_1}{\sqrt{8}}) \cos x_1 + 10$	2	$[-5, 5]$	0.398
$F_{18}(x) = [1 + (x_1 + x_2 + 1)^2 (19 - 14x_1 + 3x_1^2 - 14x_2 + 6x_1x_2 + 3x_2^2)] \times [30 + (2x_1 - 3x_2)^2 \times (18 - 32x_1 + 12x_1^2 + 48x_2 - 36x_1x_2 + 27x_2^2)]$	2	$[-2, 2]$	3
$F_{19}(x) = -\sum_{i=1}^4 c_i \exp \left(-\sum_{j=1}^3 a_{ij} (x_j - p_{ij})^2 \right)$	3	$[1, 3]$	-3.86
$F_{20}(x) = -\sum_{i=1}^4 c_i \exp \left(-\sum_{j=1}^6 a_{ij} (x_j - p_{ij})^2 \right)$	6	$[0, 1]$	-3.32
$F_{21}(x) = -\sum_{i=1}^5 [(X - a_i)(X - a_i)^T + c_i]^{-1}$	4	$[0, 10]$	-10.1532
$F_{22}(x) = -\sum_{i=1}^7 [(X - a_i)(X - a_i)^T + c_i]^{-1}$	4	$[0, 10]$	-10.4028
$F_{23}(x) = -\sum_{i=1}^{10} [(X - a_i)(X - a_i)^T + c_i]^{-1}$	4	$[0, 10]$	-10.5363