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Funciones seleccionadas para la práctica 2:

F2, F3, F6, F12, F13, F14

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- Algorithms involved in the comparison:
  - **BLX-GL50 (Garcia-Martinez & Lozano, 2005):** Hybrid Real-Coded Genetic Algorithms with Female and Male Differentiation
  - **BLX-MA (Molina *et al.*, 2005):** Adaptive Local Search Parameters for Real-Coded Memetic Algorithms
  - **CoEVO (Posik, 2005):** Mutation Step Co-evolution
  - **DE (Ronkkonen *et al.*,2005):**Differential Evolution
  - **DMS-L-PSO:** Dynamic Multi-Swarm Particle Swarm Optimizer with Local Search
  - **EDA (Yuan & Gallagher, 2005):** Estimation of Distribution Algorithm
  - **G-CMA-ES (Auger & Hansen, 2005):** A restart Covariance Matrix Adaptation Evolution Strategy with increasing population size
  - **K-PCX (Sinha *et al.*, 2005):** A Population-based, Steady-State real-parameter optimization algorithm with parent-centric recombination operator, a polynomial mutation operator and a niched -selection operation.
  - **L-CMA-ES (Auger & Hansen, 2005):** A restart local search Covariance Matrix Adaptation Evolution Strategy
  - **L-SaDE (Qin & Suganthan, 2005):** Self-adaptive Differential Evolution algorithm with Local Search
  - **SPC-PNX (Ballester *et al.*,2005):** A steady-state real-parameter GA with PNX crossover operator

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- task: black-box optimization of 25 benchmark functions
- 25 runs on each benchmark function for each dimension $n = 10, 30$
- a run is successful if the global optimum is reached with the given precision, before the
- maximum number of function evaluations

$$\mathrm{FE}_{\max} = \begin{cases} 10^5 & \text{for } n = 10 \\ 3 \times 10^5 & \text{for } n = 30 \end{cases}$$ is reached

Remark

the setting of $\mathrm{FE}_{\max}$ has a remarkable influence on the results, if the target function value can be reached only for a (slightly) larger number of function evaluations with a high probability. Where $\mathrm{FE}s \geq \mathrm{FE}_{\max}$ the result must be taken with great care.

Reference

Suganthan, Hansen, Liang, Deb, Chen, Auger, and Tiwari (2005). *Problem Definitions and Evaluation Criteria for the CEC 2005 Special Session on Real-Parameter Optimization*, Technical report, Nanyang Technological University, Singapore, May 2005, http://www.ntu.edu.sg/home/EPNSugan

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Function Sets

We split the function suit into three subsets

- unimodal functions
- solved multimodal functions

  at least one algorithm conducted at least one successful run
- unsolved multimodal functions

  no single run was successful for any algorithm

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Unimodal Functions

Success Performance Indices

$n = 10$, $\mathrm{FE}_{\max} = 100000$

1 Sphere
2 Schwefel 1.2
3 Ellipsoid Condition 10^6
4 Schwefel 1.2 with Noise
5 Schwefel 2.6 on Bounds
6 Rosenbrock

	solved functions	success rate	1000	2400	6500	2900	5900	7100
G-CMA-ES	6	100%	1.6(25)	1.0(25)	1.0(25)	1.0(25)	1.0(25)	1.5(25)
EDA	6	97%	10.0(25)	4.6(25)	2.5(23)	4.1(25)	4.2(25)	9.6(22)
DE	6	96%	29.0(25)	19.2(25)	18.5(20)	17.9(25)	6.9(25)	6.6(24)
L-CMA-ES	6	88%	1.7(25)	1.1(25)	1.0(25)	65.5(7)	1.0(25)	1.3(25)
BLX-GL50	5	83%	19.0(25)	17.1(25)	[9]	14.5(25)	4.7(25)	7.3(25)
DMS-L-PSO	5	80%	12.0(25)	5.0(25)	1.8(25)	[11]	18.6(20)	7.7(25)
L-SaDE	5	77%	10.0(25)	4.2(25)	8.0(16)	15.9(24)	[9]	6.9(25)
SPC-PNX	4	67%	6.7(25)	12.9(25)	[11]	10.7(25)	6.8(25)	[10]
CoEVO	4	67%	23.0(25)	11.3(25)	6.8(25)	16.2(25)	[10]	[11]
K-PCX	4	62%	1.0(25)	1.0(25)	[8]	19.7(21)	[11]	1.0(22)
BLX-MA	3	49%	12.0(25)	15.4(25)	[10]	25.9(24)	[8]	[9]

- **First row**: Success Performance $\mathrm{SP} = \mathrm{mean}(\#\mathit{fevals}) \times \frac{\#\text{all runs (25)}}{\#\text{successful runs}}$ of the best algorithm, where $\#\mathit{fevals}$ includes only successful runs
- **Table entries**: Success Performance SP divided by SP of the best algorithm (first row), (number of successful runs in round brackets), [rank in square brackets]

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Unimodal Functions

Success Performance Indices

$n = 30$, $\mathrm{FE}_{\max} = 300000$

1 Sphere
2 Schwefel 1.2
3 Ellipsoid Condition 10^6
4 Schwefel 1.2 with Noise
5 Schwefel 2.6 on Bounds
6 Rosenbrock

	solved functions	success rate	2700	12000	43000	59000	66000	60000
G-CMA-ES	6	90%	1.7(25)	1.1(25)	1.0(25)	1.0(10)	1.0(25)	1.0(25)
L-CMA-ES	5	83%	1.8(25)	1.2(25)	1.0(25)	[11]	1.1(25)	1.1(25)
EDA	4	67%	55.6(25)	13.3(25)	5.1(25)	3.4(25)	[3]	[10]
DMS-L-PSO	4	63%	1.9(25)	10.8(25)	7.9(21)	[9]	[9]	5.5(24)
BLX-GL50	3	50%	21.5(25)	13.3(25)	[7]	[6]	[6]	3.7(25)
SPC-PNX	4	45%	11.1(25)	26.7(22)	[11]	6.1(19)	[10]	86.7(1)
K-PCX	3	43%	1.0(25)	1.0(25)	[6]	[8]	[7]	1.1(14)
L-SaDE	3	41%	7.4(25)	12.5(24)	[8]	9.2(13)	[4]	[8]
BLX-MA	1	17%	11.9(25)	[10]	[10]	[7]	[7]	[8]
DE	1	17%	51.9(25)	[11]	[9]	[5]	[5]	[7]
CoEVO	2	7%	519 (3)	70.0(8)	[5]	[10]	[11]	[11]

- **First row**: Success Performance $\mathtt{SP} = \mathtt{mean}(\#\mathit{fevals}) \times \frac{\#\text{all runs (25)}}{\#\text{successful runs}}$ of the best algorithm, where $\#\mathit{fevals}$ includes only successful runs
- **Table entries**: Success Performance $\mathtt{SP}$ divided by $\mathtt{SP}$ of the best algorithm (first row), (number of successful runs in round brackets), [rank in square brackets]

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Multimodal Functions

Solved in at least one run

$n = 10$, $\mathrm{FE}_{\max} = 100000$

	solved functions	success rate	7 Griewank out Bounds 4700	9 Rastrigin Separable 17000	10 Rastrigin Rotated 55000	11 Weierstrass 190000	12 Schwefel 2.13 8200	15 Hybrid Separabl 33000
G-CMA-ES	5	63%	1.0(25)	4.5(19)	1.2(23)	1.4(6)	4.0(22)	[6]
L-SaDE	4	53%	36.2(6)	1.0(25)	[5]	[8]	3.9(25)	1.0(23)
DMS-L-PSO	4	47%	126 (4)	2.1(25)	[3]	[7]	6.6(19)	1.7(22)
K-PCX	3	40%	[10]	2.9(24)	1.0(22)	[10]	1.0(14)	[11]
DE	5	30%	255 (2)	10.6(11)	[9]	1.0(12)	8.8(19)	75.8(1)
L-CMA-ES	2	25%	1.2(25)	[11]	[10]	[6]	11.6(12)	[6]
BLX-GL50	3	17%	12.3(9)	10.0(3)	[5]	[5]	12.1(13)	[9]
BLX-MA	2	15%	[11]	5.7(18)	[7]	[9]	[9]	8.5(5)
EDA	3	9%	404 (1)	[9]	[4]	2.9(3)	4.3(10)	[9]
SPC-PNX	2	1%	383 (1)	[8]	[8]	5.8(1)	[10]	[6]
CoEVO	0	0%	[9]	[10]	[11]	[11]	[11]	[8]

- **First row**: Success Performance $\mathrm{SP} = \frac{\#evals}{p_{\mathrm{succ}}}$ of the best algorithm
- **Table entries**: Success Performance SP normalized (divided) by the first row, (number of successful runs in round brackets), [rank in square brackets]

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Multimodal Functions

Solved in at least one run

$n = 30$, $\mathrm{FE}_{\max} = 300000$

	solved functions	success rate	6100	99000	450000	5000000	180000	
			7 Griewank out Bounds	9 Rastrigin Separable	10 Rastrigin Rotated	11 Weierstrass	12 Schwefel 2.13	15 Hybrid Separable
K-PCX	4	38%	2.5(10)	3.3(18)	1.0(14)	[7]	1.0(5)	[11]
G-CMA-ES	5	37%	1.0(25)	8.0(9)	5.3(3)	1.0(1)	1.3(8)	[1]
L-SaDE	2	36%	21.3(20)	1.0(25)	[4]	[5]	[4]	[2]
DMS-L-PSO	2	22%	9.8(24)	[6]	[5]	[5]	8.3(4)	[4]
EDA	1	20%	21.3(25)	[10]	[9]	[10]	[7]	[4]
BLX-GL50	1	20%	10.2(25)	[5]	[3]	[4]	[8]	[4]
DE	1	20%	32.8(22)	[6]	[6]	[10]	[5]	[8]
L-CMA-ES	1	20%	1.1(25)	[11]	[11]	[3]	[9]	[8]
SPC-PNX	1	13%	60.7(16)	[8]	[7]	[2]	[10]	[8]
CoEVO	1	9%	93.4(11)	[9]	[10]	[9]	[11]	[10]
BLX-MA	1	7%	[11]	6.7(9)	[8]	[8]	[6]	[4]

- **First row**: Success Performance $\mathrm{SP} = \mathrm{mean}(\#evals) \times \frac{\#\text{all runs (25)}}{\#\text{successful runs}}$ of the best algorithm, where $\#evals$ includes only successful runs
- **Table entries**: Success Performance SP divided by SP of the best algorithm (first row), (number of successful runs in round brackets), [rank in square brackets]

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Multimodal Functions

Never solved

$n = 10$, $\mathrm{FE}_{\max} = 10^5$

	mean	8 Ackley Condition 10^2	13 Expanded 6&7	14 Expanded Schaffer F6	16 Hybrid Rotated	17 Hybrid with Noise	18 Hybrid F18	19 Hybrid Narrow	20 Hybrid on Bounds	21 Hybrid F21	22 Hybrid High Condition	23 Hybrid Non-Continuous	24 Hybrid F24	25 Hybrid out B
G-CMA-ES	3.8	5.5	4	7	1	5.5	3	2.5	2.5	5.5	1.5	4	5	2.5
BLX-GL50	4.2	5.5	6	1.5	2.5	3	3	2.5	2.5	5.5	5.5	4	5	8.5
L-SaDE	5.3	5.5	1	6	5.5	3	8	7.5	7.5	5.5	5.5	4	5	4.5
DMS-L-PSO	5.7	5.5	2	3.5	4	3	8	7.5	7.5	5.5	5.5	8	5	8.5
L-CMA-ES	6.0	5.5	3	11	7.5	11	6	5	5	1	3	4	11	4.5
SPC-PNX	6.2	11	8	8	7.5	5.5	3	2.5	2.5	5.5	9	4	5	8.5
EDA	6.2	5.5	10	5	9	8	3	7.5	7.5	5.5	8	4	5	2.5
BLX-MA	6.6	5.5	7	1.5	5.5	7	8	7.5	7.5	10	5.5	10	5	6
K-PCX	7.0	5.5	5	3.5	2.5	1	10	11	10	11	1.5	11	10	8.5
DE	7.0	5.5	11	10	11	10	3	2.5	2.5	5.5	10	4	5	11
CoEVO	8.2	5.5	9	9	10	9	11	10	11	5.5	11	9	5	1

- **Table entries**: Rank of the median of the final best function values from 25 runs measured with two digits of precision

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Multimodal Functions

Never solved

$n = 30$, $\mathrm{FE}_{\max} = 3 \times 10^5$

	mean	8 Ackley Condition 10^2	13 Expanded 6&7	14 Expanded Schaffer F6	15 Hybrid Separable	16 Hybrid Rotated	17 Hybrid with Noise	18 Hybrid F18	19 Hybrid Narrow	20 Hybrid on Bounds	21 Hybrid F21	22 Hybrid High Condition	23 Hybrid Non-Continu	24 Hybrid F24	25 Hyb
G-CMA-ES	4.1	2.5	5	6.5	1	1	6	5.5	5.5	5.5	4.5	1	3.5	6	4
EDA	4.8	7.5	11	6.5	8	7	7	1	1	1	4.5	3	3.5	2.5	4
BLX-MA	4.9	7.5	4	6.5	4.5	10	5	3	3	3	4.5	7	3.5	2.5	4
SPC-PNX	5.0	7.5	8	6.5	8	4.5	2	5.5	5.5	5.5	4.5	3	3.5	2.5	4
BLX-GL50	5.1	7.5	6.5	2	4.5	4.5	3	5.5	5.5	5.5	4.5	5	7	7	4
L-CMA-ES	5.6	2.5	2	10	2	3	10	8.5	8.5	8.5	4.5	3	3.5	9	4
DE	6.1	7.5	6.5	6.5	8	8	8	5.5	5.5	5.5	4.5	6	3.5	2.5	8
K-PCX	6.2	11	10	10	11	2	1	2	2	2	9	9	9	5	4
CoEVO	8.5	7.5	9	6.5	10	9	9	10	10	10	4.5	8	8	8	9
L-SaDE	–	2.5	1	2	4.5	–	–	–	–	–	–	–	–	–	–
DMS-L-PSO	–	2.5	3	2	4.5	6	4	8.5	8.5	8.5	–	–	–	–	–

- **Table entries**: Rank of the median of the final best function values from 25 runs measured with two digits of precision

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Success Rates of the 11 algorithms for 10-D

Func / Algorithms	1	2	3	4	5	6	7	9	10	11	12	15
BLX-GL50	100%	100%	0%	100%	100%	100%	36%	12%	0%	0%	52%	0%
BLX-MA	100%	100%	0%	0.96	0%	0%	0%	72%	0%	0%	0%	20%
CoEVO	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%
DE	100%	100%	80%	100%	100%	96%	6%	44%	0%	48%	76%	4%
DMS-L-PSO	100%	100%	100%	4%	100%	100%	16%	100%	0%	0%	80%	84%
EDA	100%	100%	92%	100%	100%	88%	4%	0%	0%	12%	40%	0%
G-CMA-ES	100%	100%	100%	100%	100%	100%	100%	76%	92%	24%	88%	0%
K-PCX	100%	100%	0%	84%	0%	40%	20%	96%	88%	0%	0%	0%
L-CMA-ES	100%	100%	100%	28%	100%	100%	100%	0%	0%	0%	48%	0%
L-SaDE	100%	100%	64%	96%	0%	100%	24%	100%	0%	0%	100%	92%
SPC-PNX	100%	100%	0%	100%	100%	0%	4%	4%	0%	0%	0%	0%

*In the comparison, only the problems in which at least one algorithm succeeded once are considered.

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Success Rates of the 11 algorithms for 30-D

Func / Algorithms	1	2	3	4	5	6	7	9	10	11	12
BLX-GL50	100%	100%	0%	0%	0%	100%	100%	0%	0%	0%	0%
BLX-MA	100%	0%	0%	0%	0%	0%	0%	36%	0%	0%	0%
CoEVO	12%	32%	0%	0%	0%	0%	44%	0%	0%	0%	0%
DE	100%	0%	0%	0%	0%	0%	88%	0%	0%	0%	0%
DMS-L-PSO	100%	100%	88%	0%	0%	96%	96%	100%	0%	0%	20%
EDA	100%	100%	100%	100%	0%	0%	100%	0%	0%	0%	0%
G-CMA-ES	100%	100%	100%	40%	100%	100%	100%	36%	12%	4%	32%
K-PCX	100%	0%	0%	0%	0%	0%	44%	72%	56%	0%	0%
L-CMA-ES	100%	100%	100%	0%	100%	100%	100%	0%	0%	0%	0%
L-SaDE	100%	96%	0%	52%	0%	0%	80%	100%	0%	0%	0%
SPC-PNX	100%	88%	0%	76%	0%	4%	64%	0%	0%	0%	0%

*In the comparison, only the problems which at least one algorithm succeeded once are considered. -88-

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Medida de Error:

Algunas medidas de tests consideran únicamente la posición relativa de cada algoritmo, y no los valores de error concretos (o su valor para la función objetivo). Dado que ésta es una información muy interesante, calcularemos el error acumulado (EAc) de cada algoritmo. El EAc es una medida que combina los diferentes errores relativos para cada función, y que permite identificar los algoritmos más robustos. El EAc se calcula mediante las Ecuaciones 2.1, 2.2 y 2.3.

$$EAc(Alg_i) = \sum_{fun=1}^{N_{Fun}} RE(Alg_i, fun) \tag{2.1}$$

$$RE(Alg_i, fun) = \begin{cases} 0 & \text{si } \nabla E_{fun} = 0 \\ \frac{E(Alg_i,fun) - Min_{fun}}{\nabla E_{fun}} & \text{si } \nabla E_{fun} > 0 \end{cases} \tag{2.2}$$

$$\nabla E_{fun} = max(0, E_{Max}(fun) - Umbral(fun)) \tag{2.3}$$

donde $Umbral(fun) = 0$, $E_{Max}(fun) \geq E(Alg_i, fun)$ $\forall fun = 1, \cdots, N_{Fun}$, $\forall i = 1, \cdots, NumAlgoritmos$.

Este valor es mostrado gráficamente utilizando un diagrama de barra en el que las columnas son los algoritmos comparados y las alturas son los EAc de cada algoritmo.

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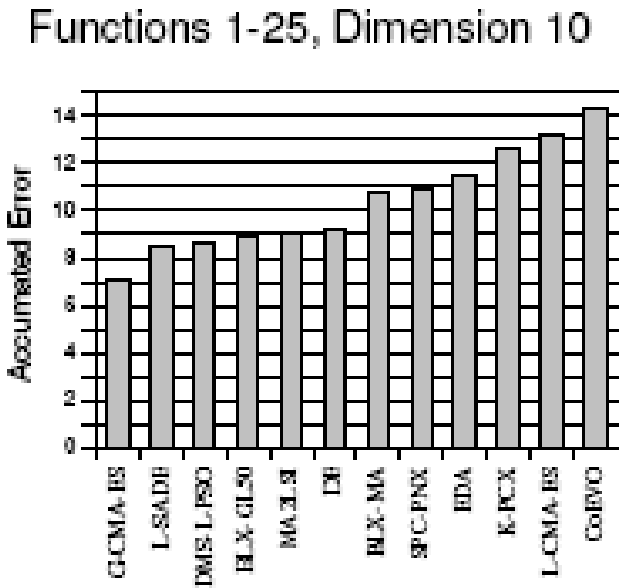

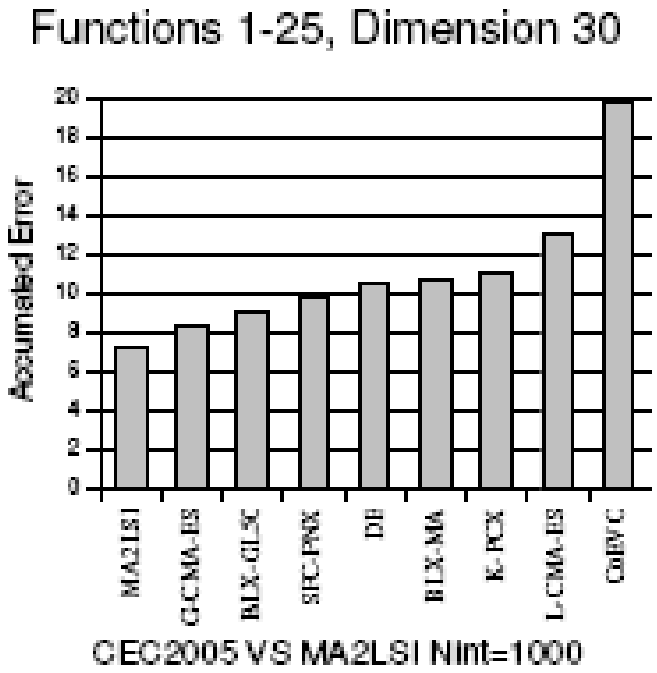

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Resultado de los Algoritmos sobre las funciones seleccionadas para la práctica: F2, F3, F6, F12, F13 y F14.

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