Island Based Distributed Differential Evolution: An Experimental Study on Hybrid Testbeds

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Outline

1. Introduction
2. Implementation of dDE
3. Problem Definition
4. Comparative Study
5. Conclusions and Future Work

Introduction

Evolutionary Algorithms (EA) are methods inspired by biological processes to solve optimization problems

- The Differential Evolution (DE) has a simple structure and high performance to treat non-differentiable and multimodal optimization functions

The exploration of the search space performed by EA is time-consuming

- Parallel models are useful tools to improve the performance of the methods

The population of DE could be partitioned into small subsets that evolve independently, by exchanging information to increase diversity

The performance of the distributed DE is shown on a hybrid test suite of continuous functions from the special session on CEC'05 and statistically compared with all participant algorithms in that session

Our implementation shows a high performance to tackle the problems and we even improve the results obtained from specialized algorithms

Implementation of dDE

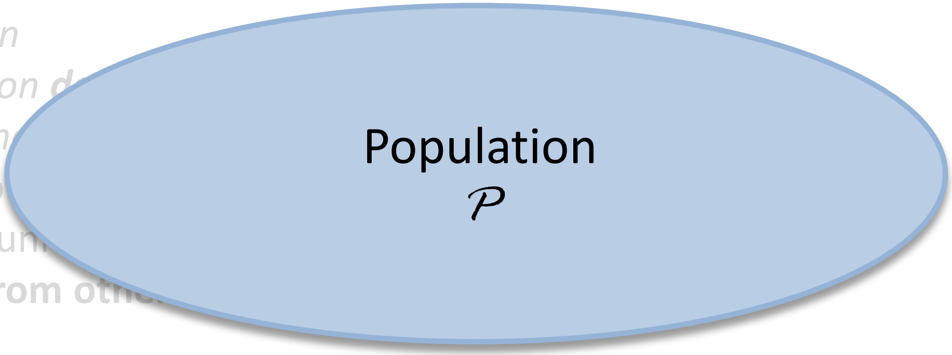
```
pardo for each subpopulation
  initialize subpopulation
  while not stop condition do
    perform a step of canonical DE
    send individuals to other island
/*asynchronous communication*/
    receive individuals from other island
  end while
end pardo
```

Output: best solution found

Implementation of dDE

pardo for each *subpopulation*
initialize *subpopulation*
while not *stop condition d*
perform *a step of can*
send individuals to o
/*asynchronous commun
receive individuals from othe
end while
end pardo

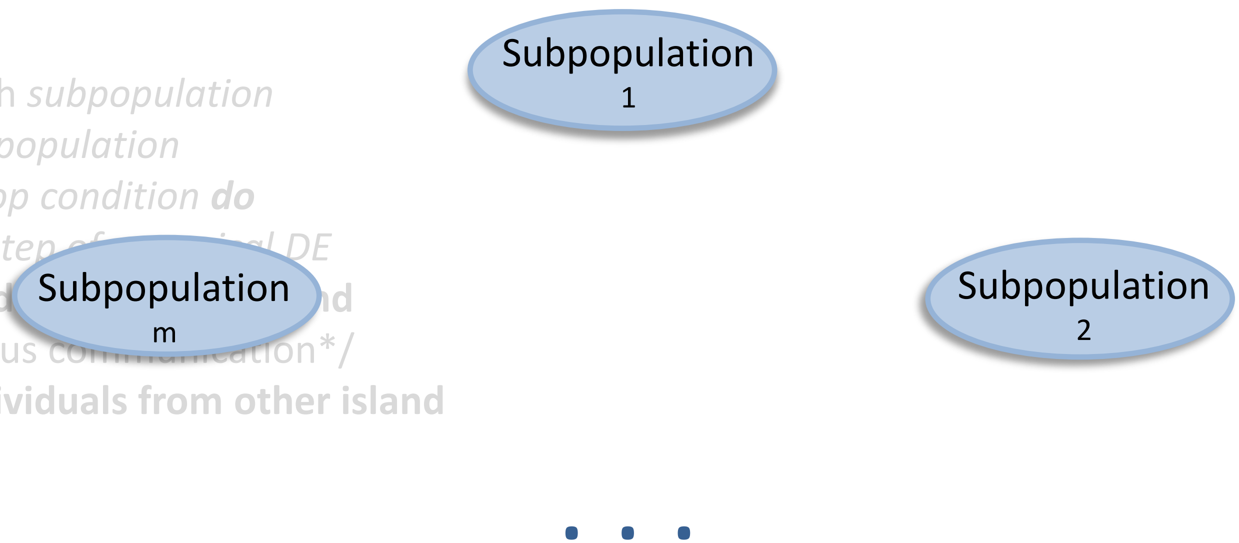
Output: best solution found



Implementation of dDE

pardo for each *subpopulation*
initialize *subpopulation*
while not *stop condition* **do**
perform *a step* ... *DE*
send individ... **nd**
/*asynchronous co...ation*/
receive individuals from other island
end while
end pardo

Output: best solution found



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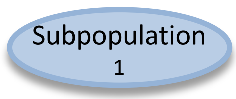

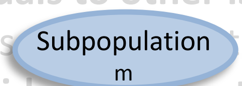

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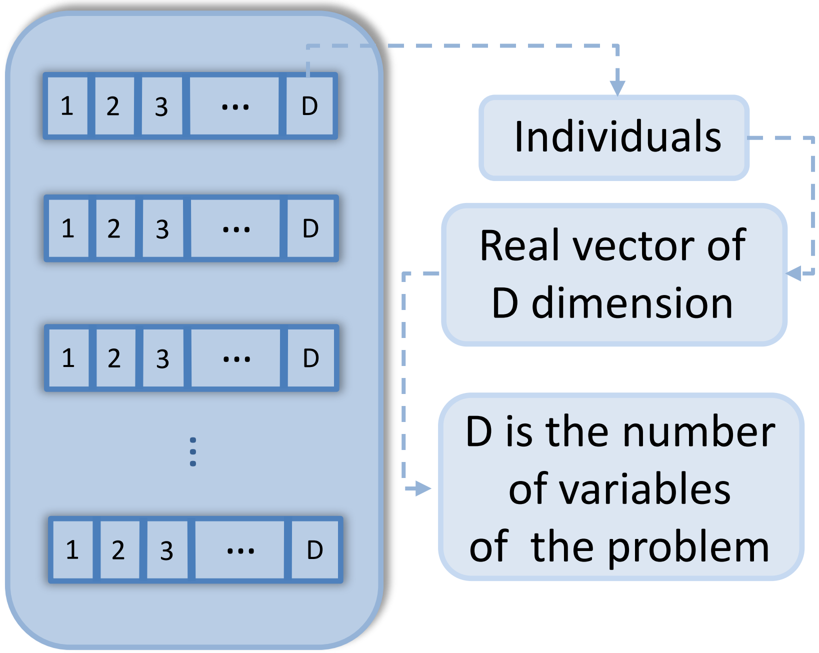

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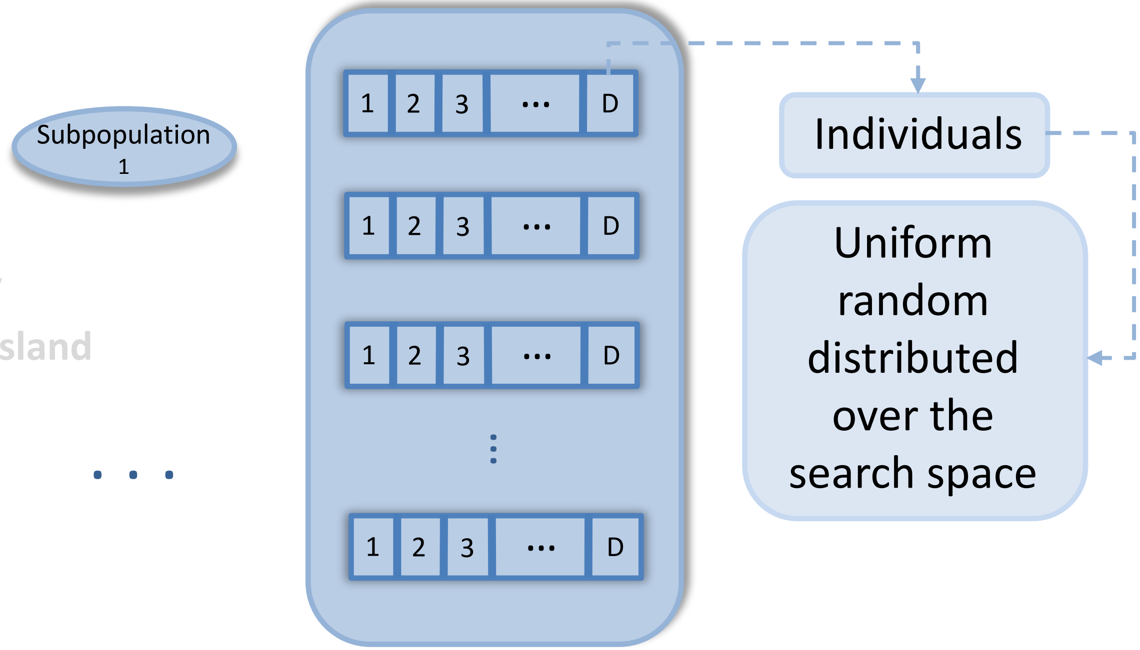

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Output: best solution found

Sp1
evolving...

Spm
evolving...

Sp2
evolving...

. . .

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Sp1
evolving...

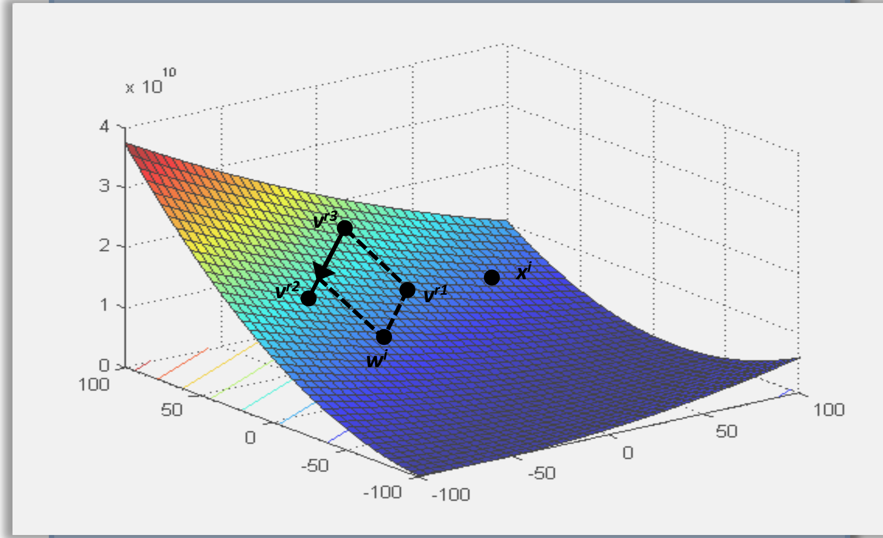
Spm
evolving...

. . .

Output: best solution found

Mutation:

$$w^{i}_{g+1} = v^{r1}_{g} + \mu\,(v^{r2}_{g} - v^{r3}_{g})$$



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Output: best solution found

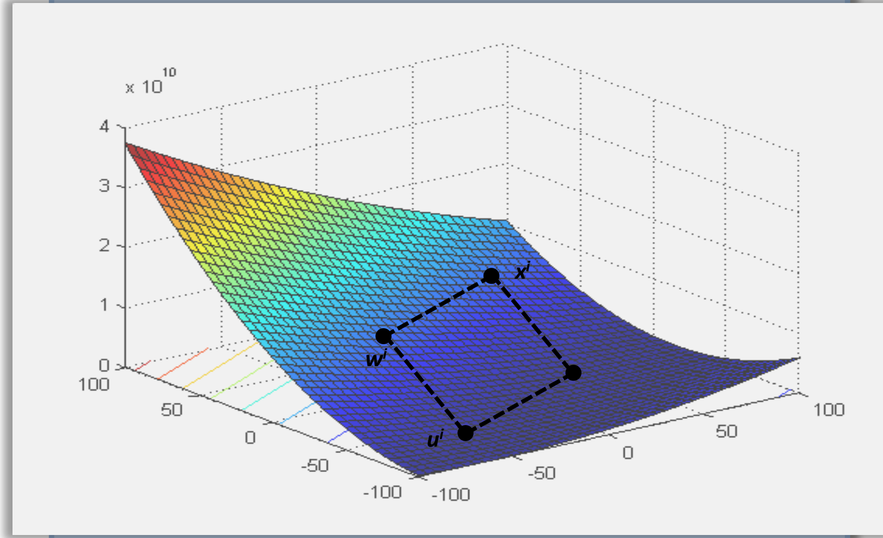
Sp1 evolving...

Spm evolving...

. . .

Crossover:

$$u^i_{g+1}(j) = \begin{cases} w^i_{g+1}(j) & \text{if } r(j) \leq Cr \text{ or } j=j_r \\ v^i_g(j) & \text{otherwise} \end{cases}$$



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receive individuals from other island
end while
end pardo

Sp1 evolving...

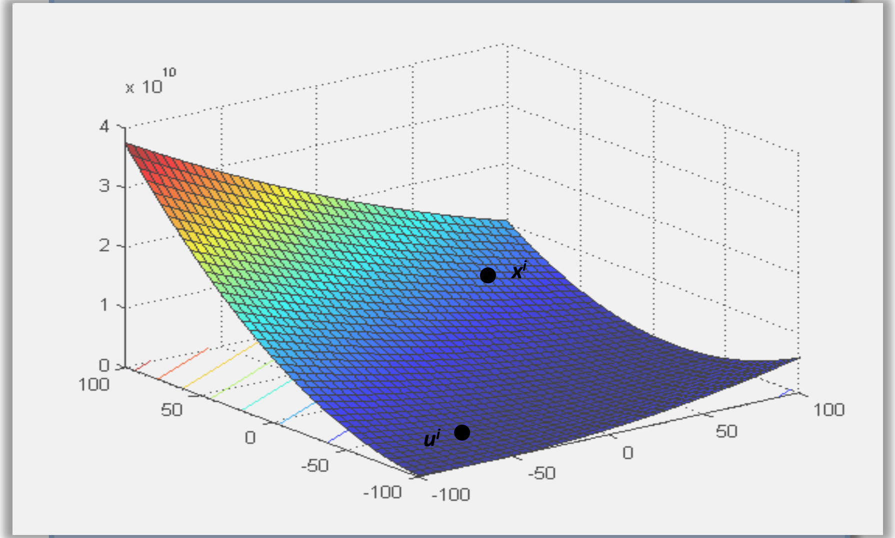
Spm evolving...

. . .

Output: best solution found

Selection:

$$v^i_{g+1} = \begin{cases} u^i_{g+1} & \text{if } f(u^i_{g+1}) \leq f(v^i_g) \\ v^i_g & \text{otherwise} \end{cases}$$



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Implementation of dDE

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/*asynchronous co
receive individuals fro
end while
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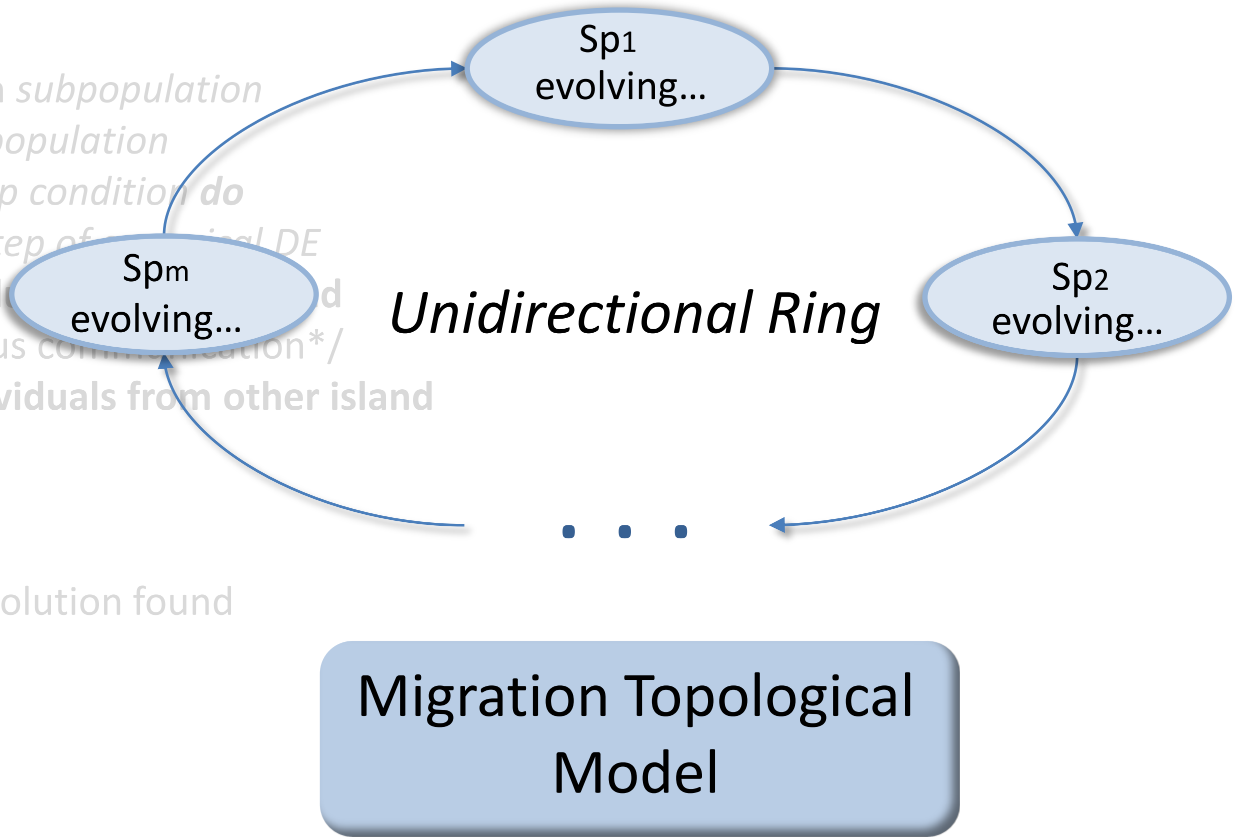
Output: best solution found



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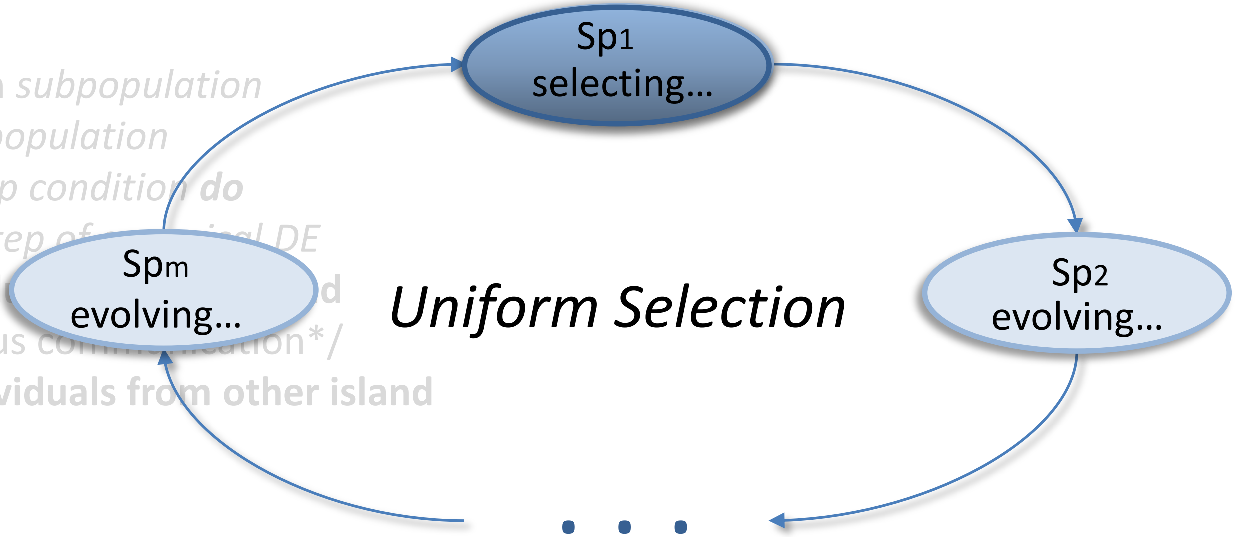
Output: best solution found

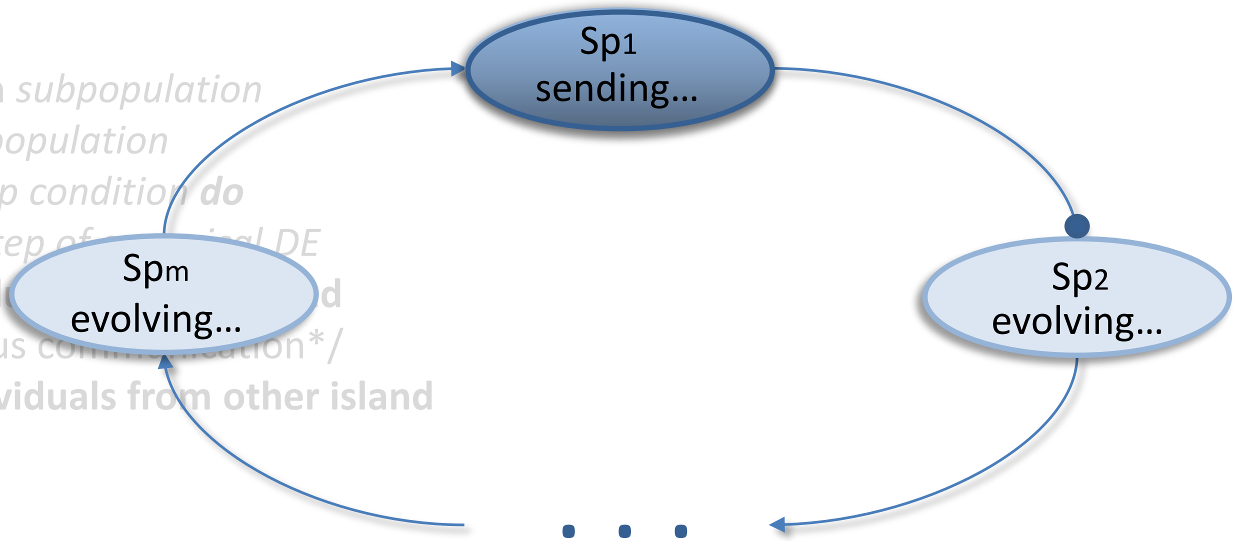


Selection of individuals to send

Implementation of dDE

pardo for each *subpopulation*
initialize *subpopulation*
while not *stop condition* **do**
perform *a step of ... DE*
send individ... d
/*asynchronous co... ation*/
receive individuals from other island
end while
end pardo

Output: best solution found



Send of Individuals

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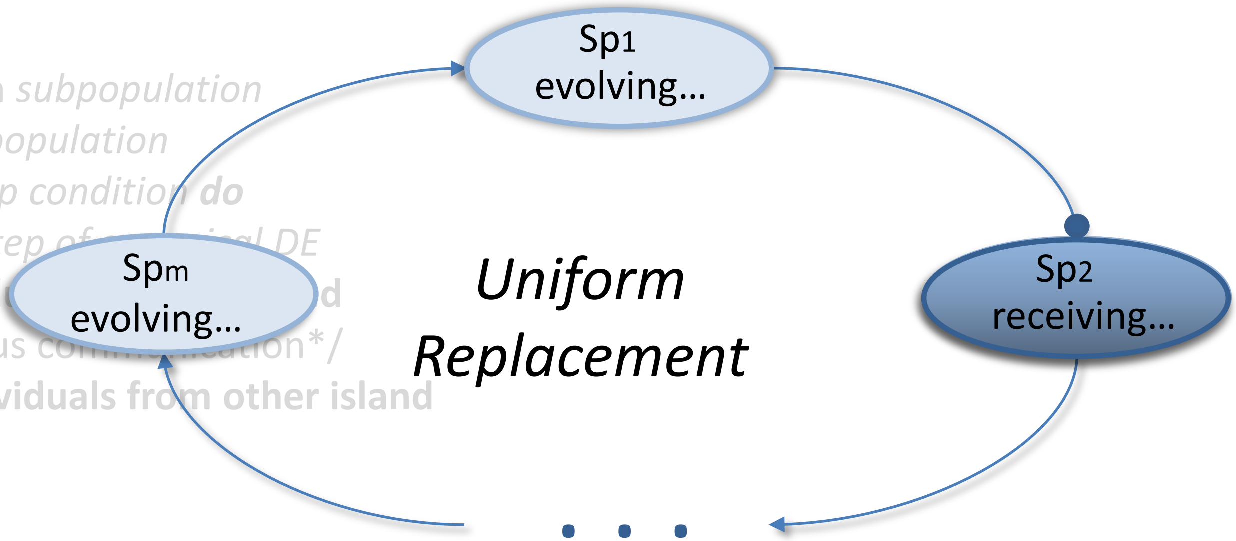
Implementation of dDE

pardo for each *subpopulation*
initialize *subpopulation*
while not *stop condition* **do**
perform *a step of*
send individ
/*asynchronous co
receive individuals from other island
end while
end pardo

Output: best solution found

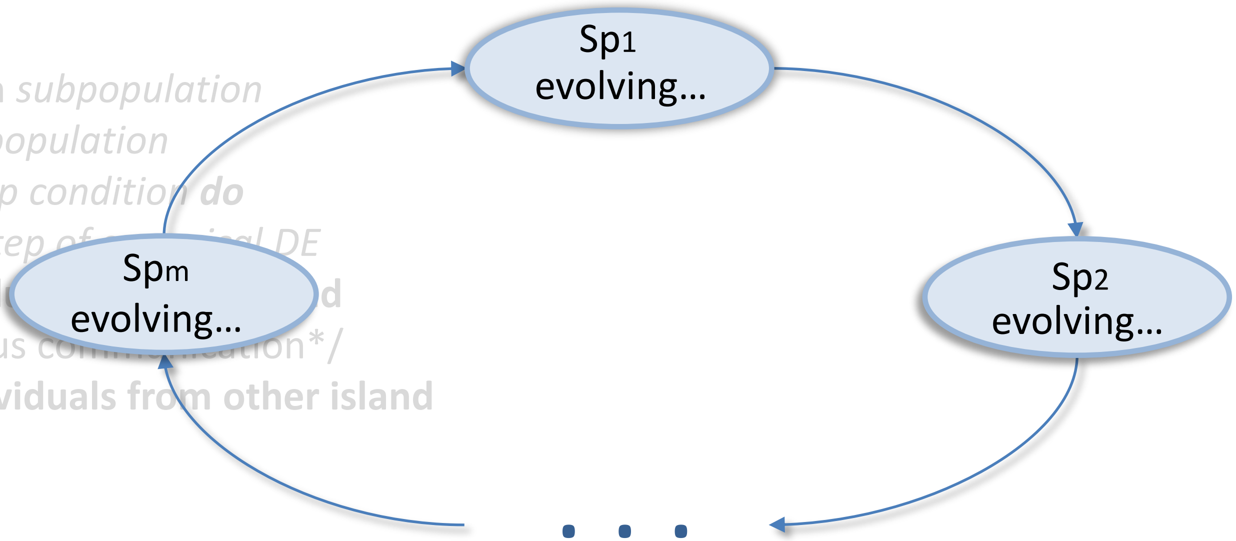


Reception/Replacement of individuals

Implementation of dDE

pardo for each *subpopulation*
initialize *subpopulation*
while not *stop conditio*... ***do***
perform *a step of* ... *DE*
send individ... **d**
/*asynchronous co... ation*/
receive individuals fro... **m other island**
end while
end pardo

Output: best solution found



Problem Definition

The CEC'05 set of functions used to test our distributed Differential Evolution

F6: Shifted Rosenbrock's Function
F7: Shifted Rotated Griewank's Function without Boun
F8: Shifted Rotated Ackley's Function with Global Opt
F9: Shifted Rastrigin's Function
F10: Shifted Rotated Rastrigin's Function
F11: Shifted Rotated Weierstrass Function
F12: Schwefel's Problem 2.13
F13: Expanded Extended Griew
F14: Shifted Rotated Expande
F15: Hybrid Composition Fun

Hybrid Testbed

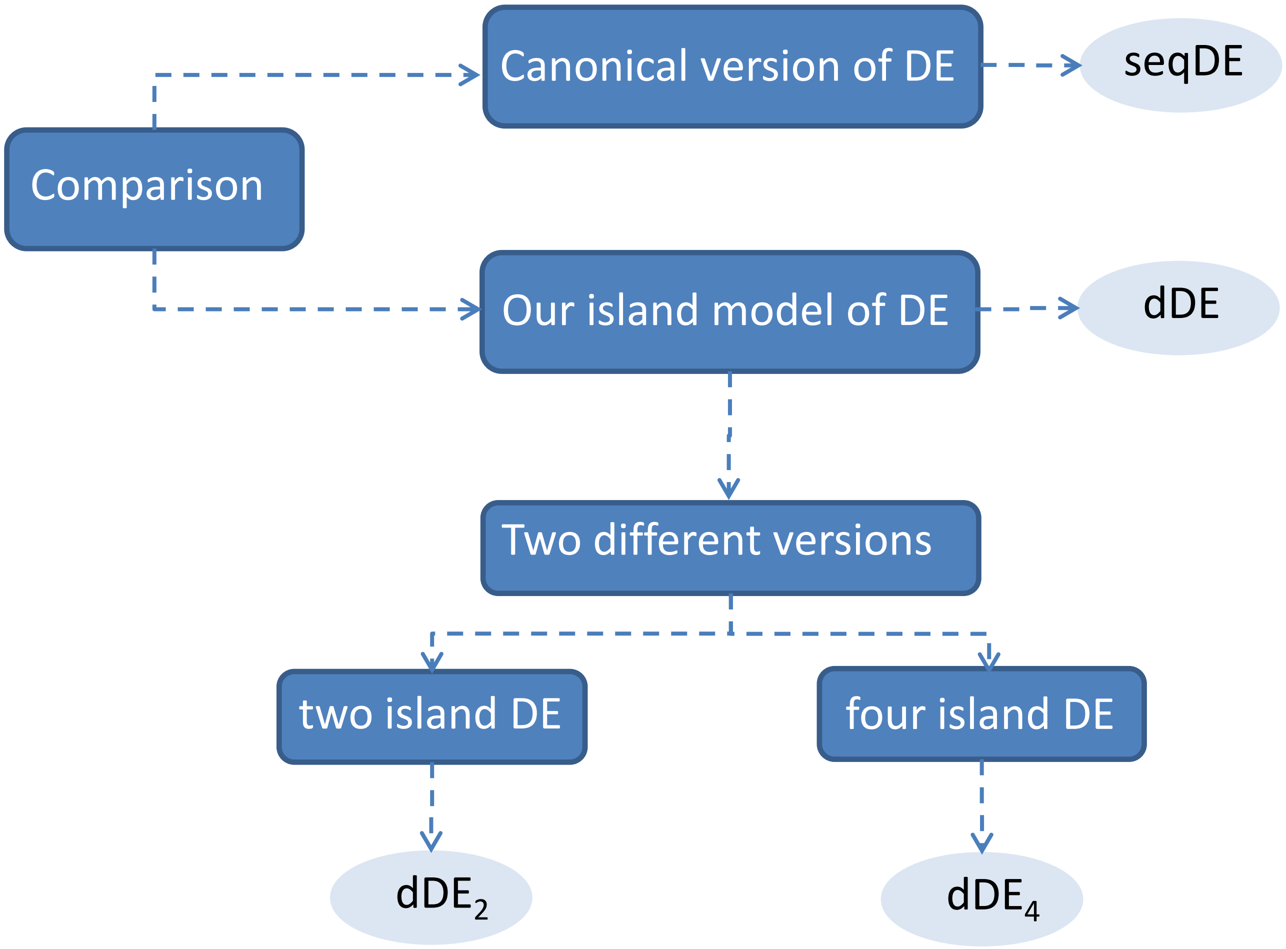
Set of 20 multimodal functions
shifted and/or rotated versions of classical functions

ess
F19: Rotated Hybri... with a Narrow Basin for the Global Optimum
F20: Rotated Hybrid Composition Function with the Global Optimum on the Bounds
F21: Rotated Hybrid Composition Function
...ed Hybrid Composition F... mber Matrix
...ontinuous Rotated Hybri
F24: Rotated Hybrid Composition Function
F25: Rotated Hybrid Composition Function without Bounds

30 Dimensions

50 Dimensions

Comparative Study: A preliminary study (I)



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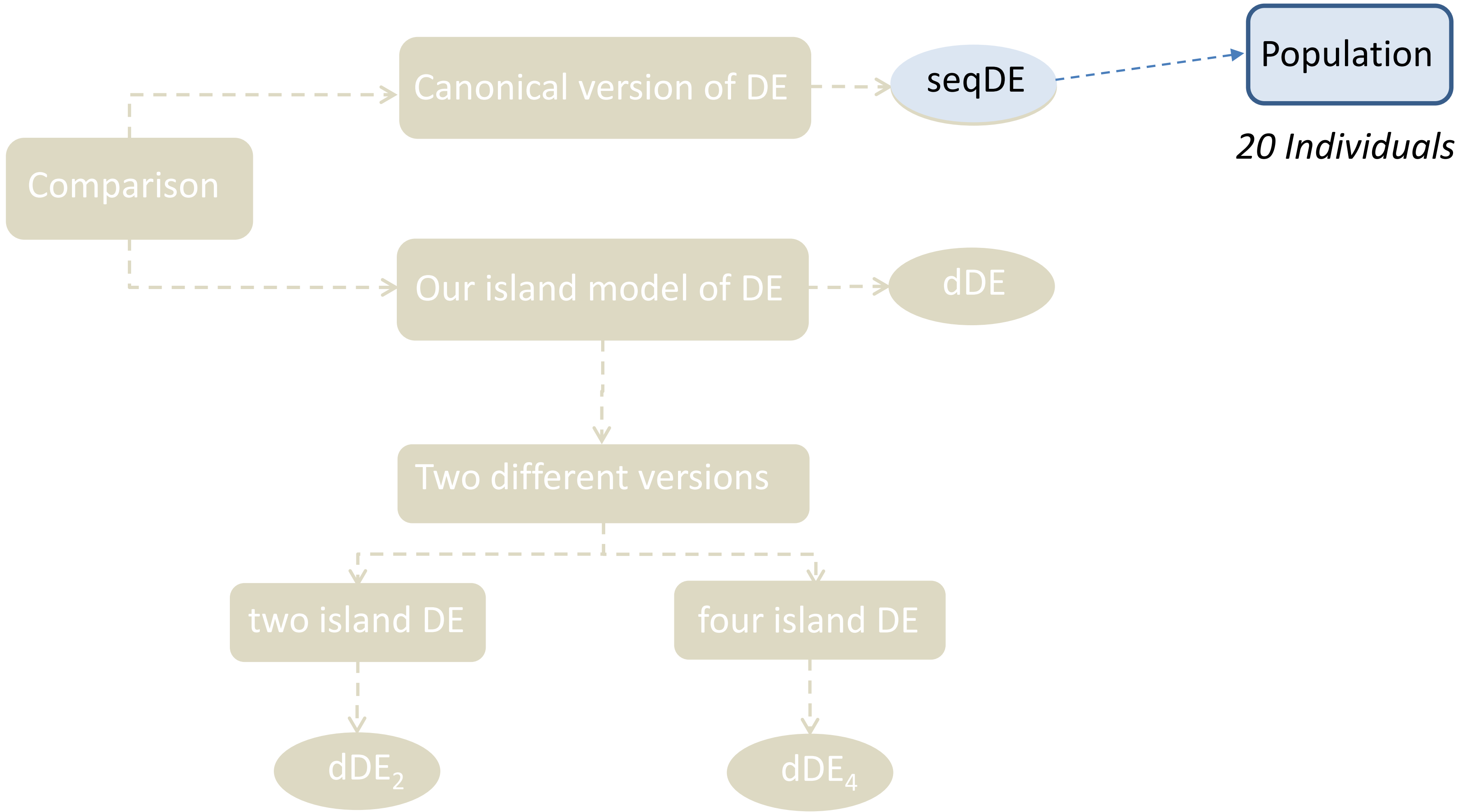

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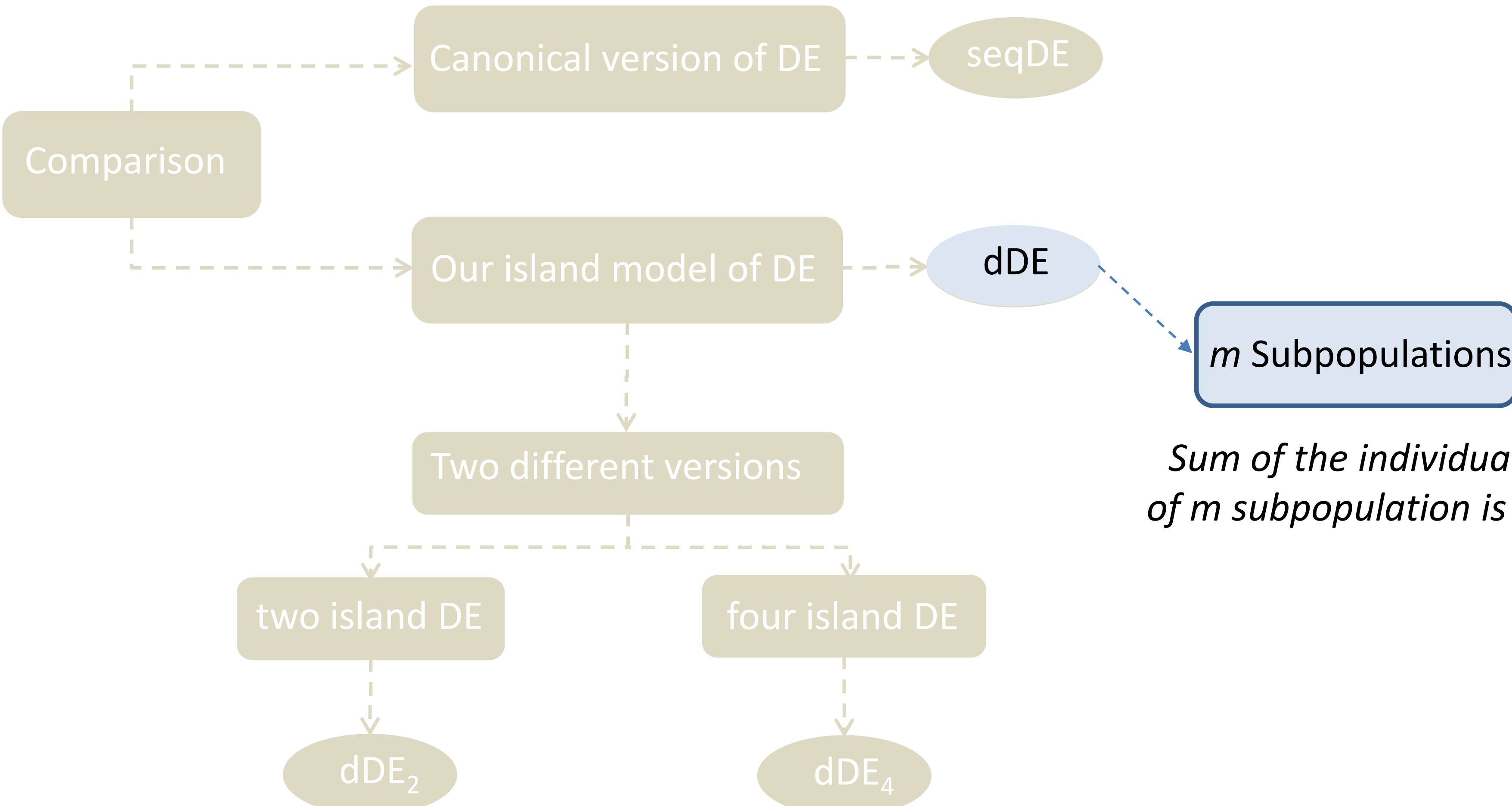

Sum of the individuals of m subpopulation is 20

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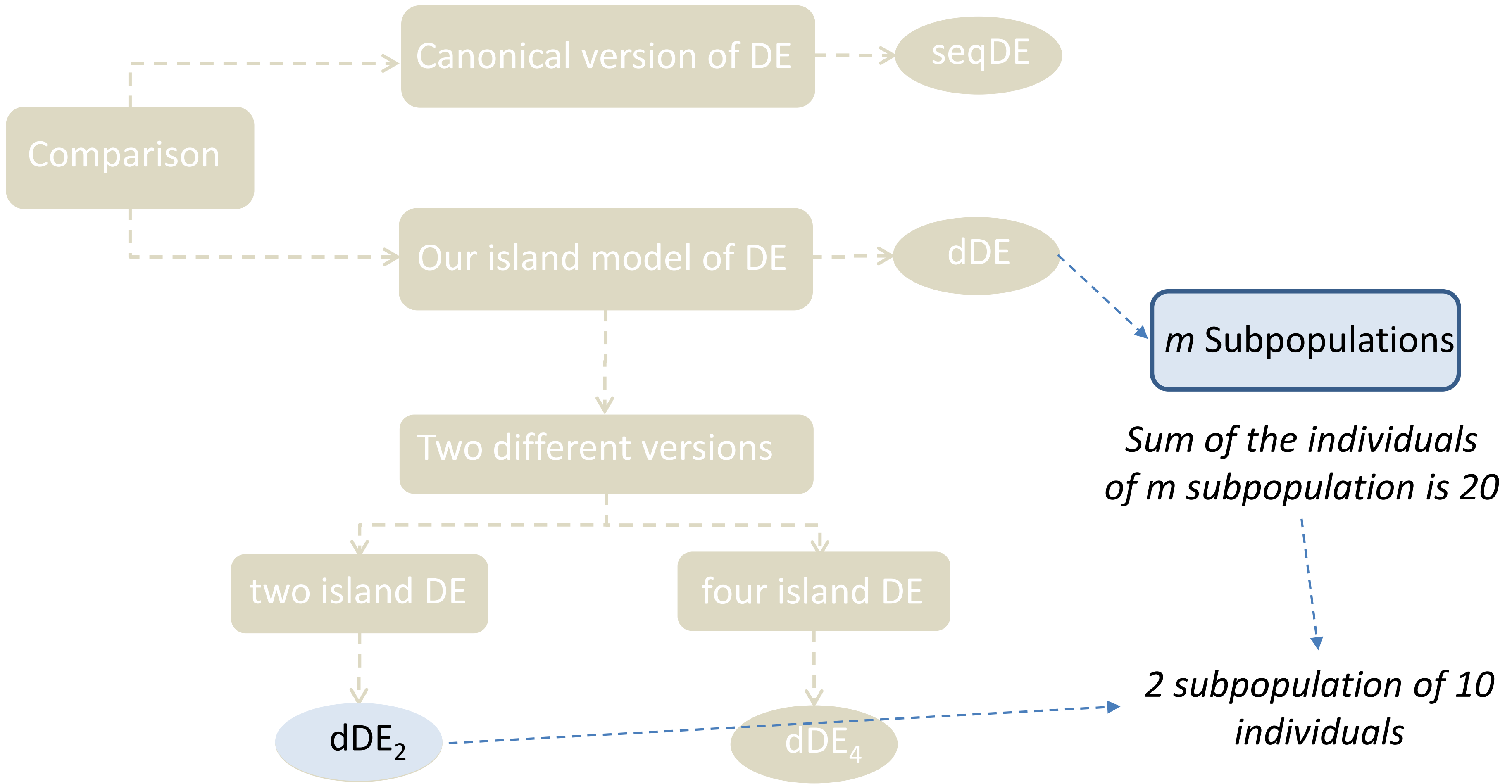

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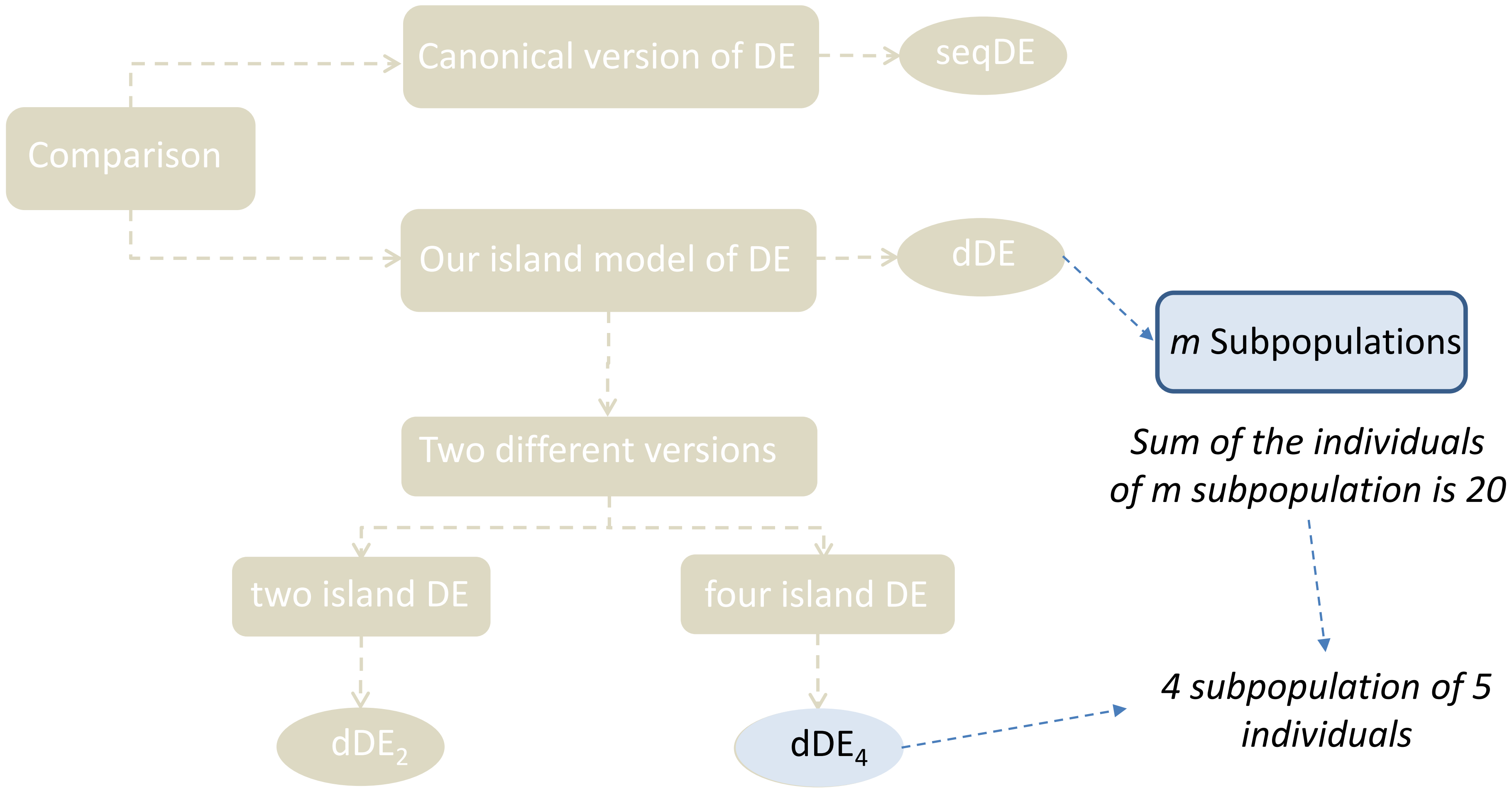


Comparative Study: A preliminary study (II)

Non-parametric statistical rank test

Comparisons

	seqDE ↔ dDE_2		seqDE ↔ dDE_4		dDE_2 ↔ dDE_4	
	30	*50*	*30*	*50*	*30*	*50*
RANK	**dDE_2** seqDE	**dDE_2** seqDE	**seqDE** dDE_4	**dDE_4** seqDE	**dDE_2** dDE_4	**dDE_2** dDE_4

Comparative Study: A preliminary study (II)

Non-parametric statistical rank test

Comparisons

	seqDE ↔ dDE_2		seqDE ↔ dDE_4		dDE_2 ↔ dDE_4	
	30	*50*	*30*	*50*	*30*	*50*
RANK	**dDE_2** seqDE	**dDE_2** seqDE	**seqDE** dDE_4	**dDE_4** seqDE	**dDE_2** dDE_4	**dDE_2** dDE_4

Comparative Study: A preliminary study (II)

Non-parametric statistical rank test

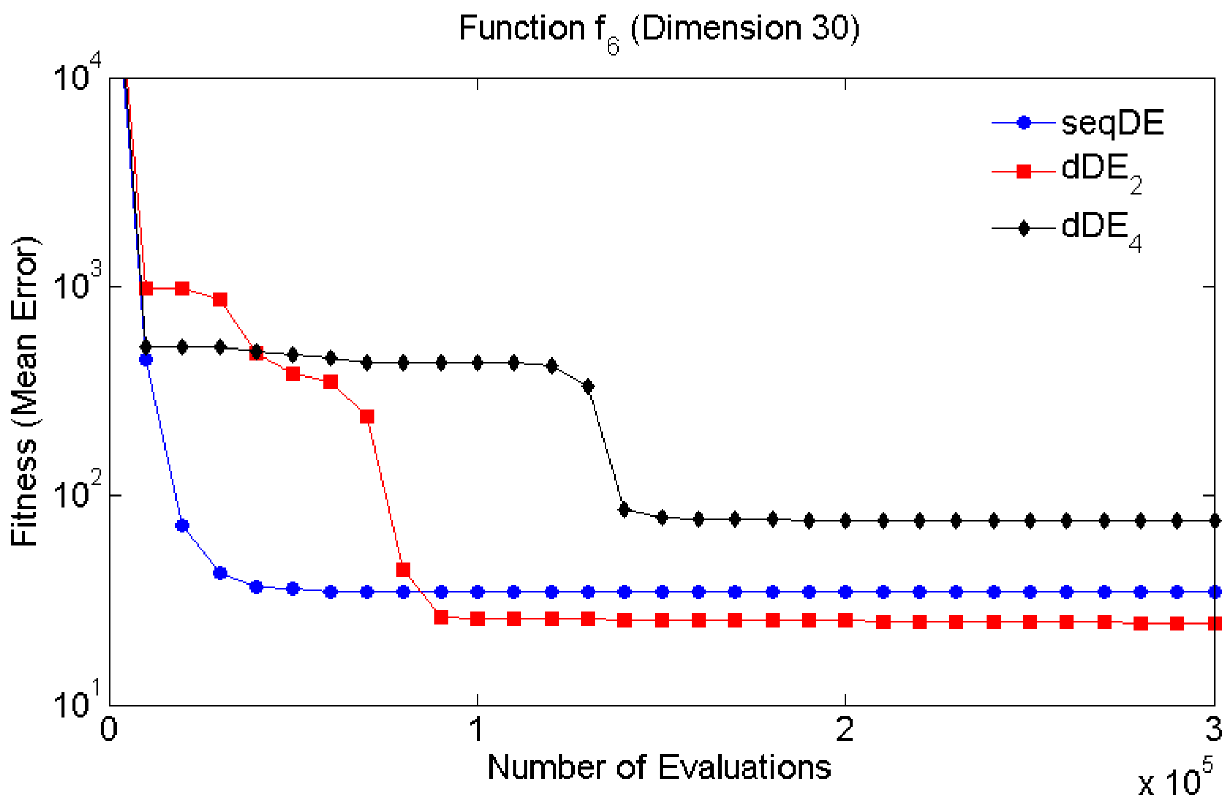
Comparisons

	seqDE ↔ dDE_2		seqDE ↔ dDE_4		dDE_2 ↔ dDE_4	
	30	*50*	*30*	*50*	*30*	*50*
RANK	**dDE_2**	**dDE_2**	**seqDE**	**dDE_4**	**dDE_2**	**dDE_2**
	seqDE	seqDE	dDE_4	seqDE	dDE_4	dDE_4

(3 x 20 x 2 x 25 = 3000 independent runs)

Comparative Study : A preliminary study (III)

Number of function evaluations vs. mean error
(median performance of mean error of 25 runs of f_6 with dimension 30)



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Comparative Study : A preliminary study (III)

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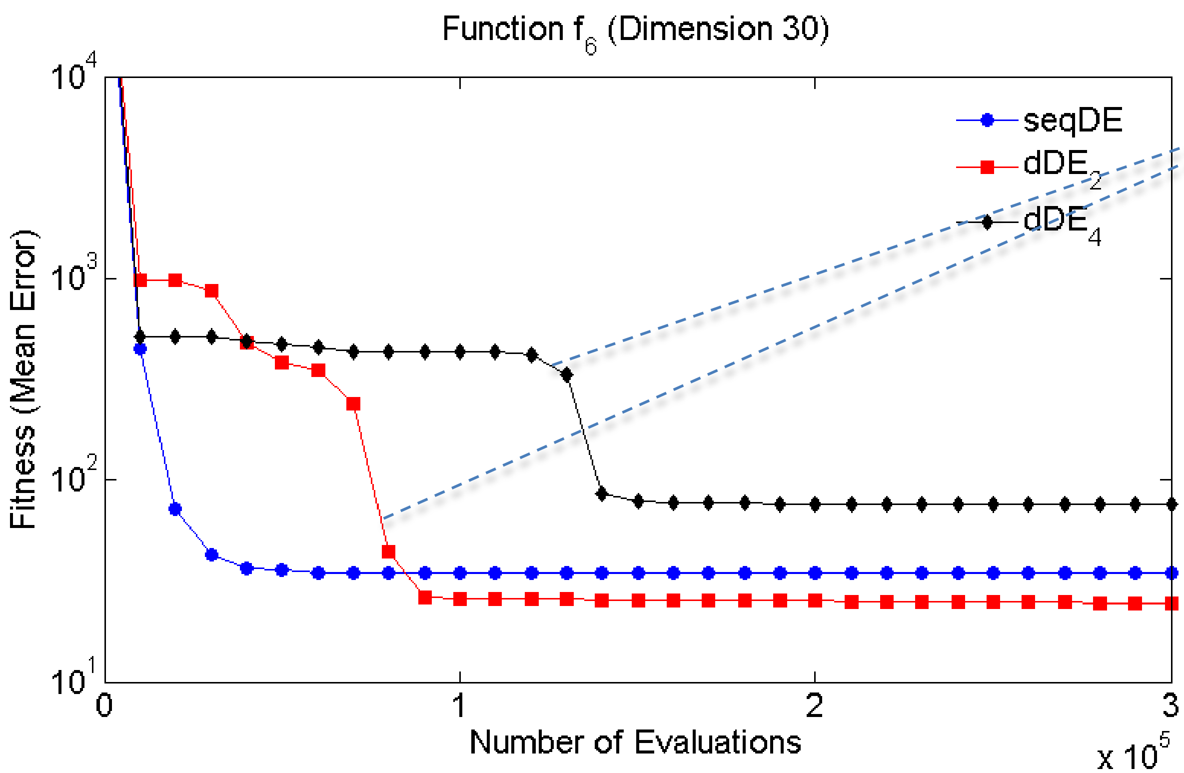

Distributed Version of DE

Migration

Delayed Convergence

Promote Diversity

Improve Final Results

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Comparative Study : A preliminary study (III)

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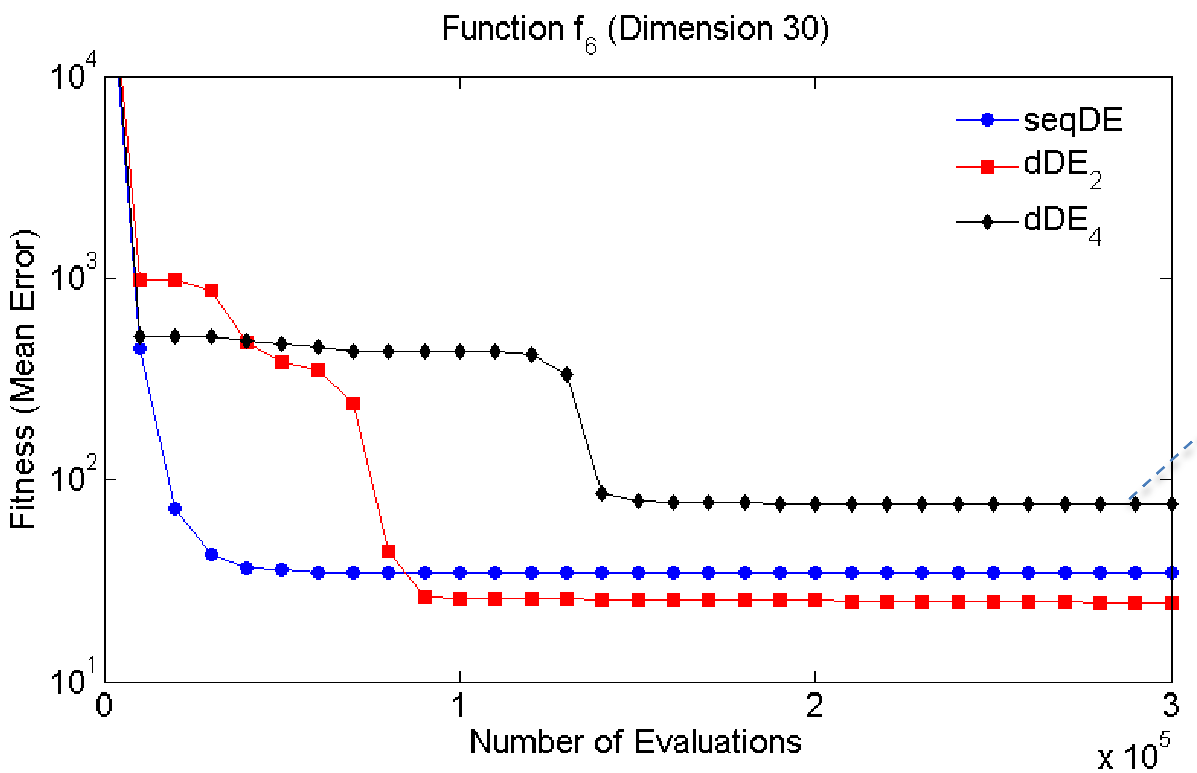

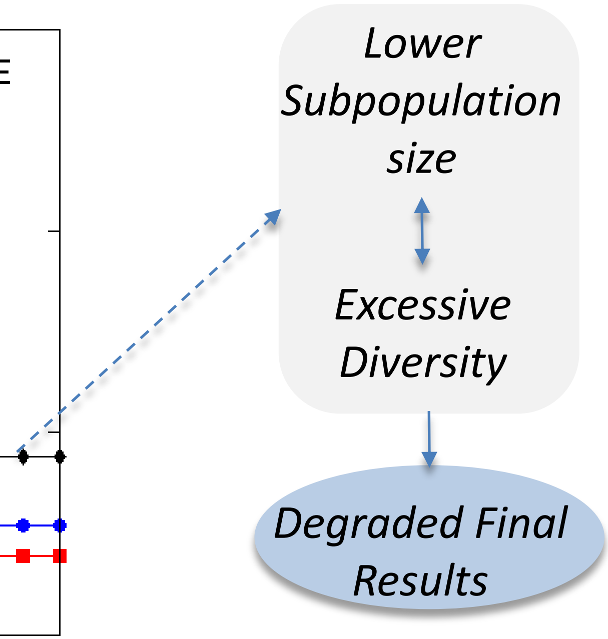

Comparative Study: CEC'05 Algorithms (I)

Comparison with Algorithms presented in the special session of CEC'05

dDE_2
two islands
distributed DE

↔

- **BLXMA** (Real-Coded Memetic Algorithm)
- **CoEVO** (Cooperative Evolution)
- **DE** (clasical DE)
- **G-CMA-ES** (Evolution Strategy Adapting a Covariance Matrix)
- **K-PCX** (Steady-State Optimization Algorithm)
- **L-CMA-ES** (Covariance Matrix Algorithm Improve with a Local Search)
- **SPC-PNX** (Steady-State Genetic Algorithm)
- **BLX-GL50** (Hybrid Genetic Algorithm)

Comparative Study: CEC'05 Algorithms (II)

Non-parametric statistical rank test of dDE_2 vs. CEC'05 algorithms

dDE_2 ↔ Algorithms

RANK

30 Dimensions

G-CMA-ES

dDE_2

K-PCX
BLXMA
BLX-GL50
SPC-PNX
L-CMA-ES
DE
CoEvo

50 Dimensions

dDE_2

G-CMA-ES
L-CMA-ES

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Comparative Study: CEC'05 Algorithms (II)

Non-parametric statistical rank test of dDE_2 vs. CEC'05 algorithms

dDE_2 ↔ Algorithms

RANK

dDE_2 is better ranked

	30 Dimensions	*50 Dimensions*
Better	G-CMA-ES	***dDE_2***
	dDE_2	
Worse	K-PCX, BLXMA, BLX-GL50, SPC-PNX, L-CMA-ES, **DE**, **CoEvo**	G-CMA-ES, **L-CMA-ES**

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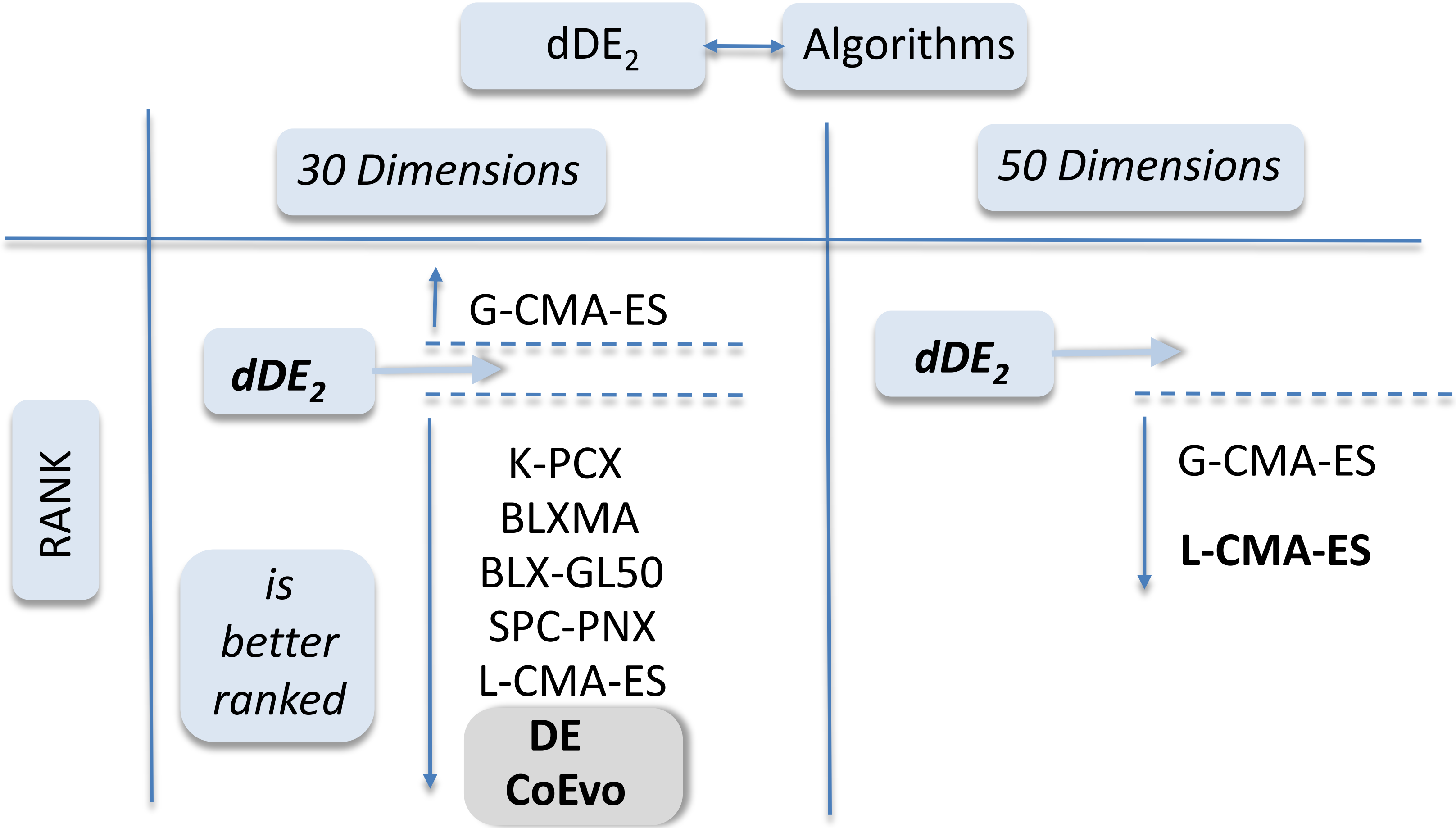
Comparative Study: CEC'05 Algorithms (II)

Non-parametric statistical rank test of dDE_2 vs. CEC'05 algorithms



Comparative Study: CEC'05 Algorithms (II)

Non-parametric statistical rank test of dDE_2 vs. CEC'05 algorithms

dDE_2 ↔ Algorithms

RANK

30 Dimensions

G-CMA-ES

dDE_2

K-PCX
BLXMA
BLX-GL50
SPC-PNX
L-CMA-ES
DE
CoEvo

50 Dimensions

dDE_2

is better ranked

G-CMA-ES
L-CMA-ES

Comparative Study: CEC'05 Algorithms (II)

Non-parametric statistical rank test of dDE_2 vs. CEC'05 algorithms

dDE_2 ↔ Algorithms

RANK

30 Dimensions

G-CMA-ES

dDE_2 →

K-PCX
BLXMA
BLX-GL50
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L-CMA-ES
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CoEvo

50 Dimensions

dDE_2 →

G-CMA-ES
L-CMA-ES

is better ranked

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Comparative Study: CEC'05 Algorithms (II)

Non-parametric statistical rank test of dDE_2 vs. CEC'05 algorithms

dDE_2 ↔ Algorithms

RANK

	30 Dimensions	50 Dimensions
Above dDE_2	G-CMA-ES	
dDE_2		
Below dDE_2	K-PCX BLXMA BLX-GL50 SPC-PNX L-CMA-ES **DE** **CoEvo**	G-CMA-ES **L-CMA-ES**

Conclusions and Future Work

- Experimental study of the performance of the distributed Differential Evolution (dDE)
  - statistically analyzing the quality of solutions in terms of mean error
  - using a hybrid testbed functions (CEC'05)
- dDE_2 shows a highly competitive performance
  - when is statistically compared to
    - canonical DE and dDE_4 versions
    - the proposal algorithms in the special session of CEC'05
      - overcome the performance of specialized algorithms in the testbed
      - due to the diversification incorporated by migration mechanism
- As future work
  - experiments with different variations of the parallel configuration
  - evaluation of other novel large-scale functions test suite

Thanks for your attention!

Any questions?