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Migrant Selection in Island-Based Optimization

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Metaheuristics

PSO
Particle Swarm Optimization

DE
Differential Evolution

GA
Genetic Algorithm

ABC
Artificial Bee Colony

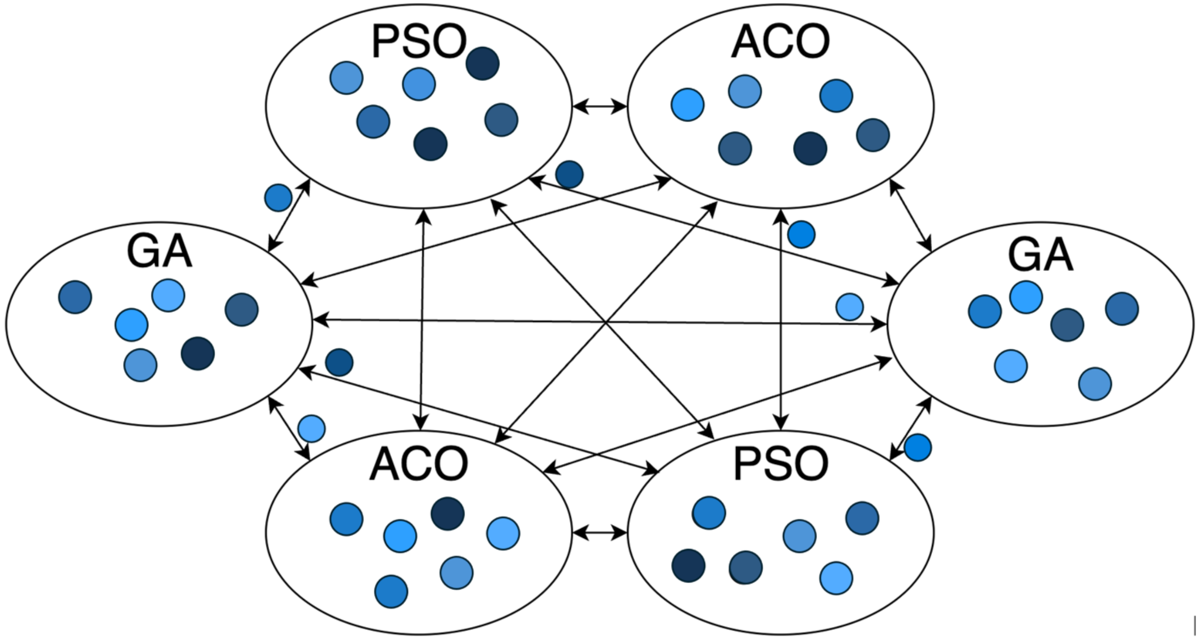
SA
Simulated Annealing

ACO
Ant Colony Optimization

and many more…

Problem: How to choose them?

Cooperating portfolio of metaheuristics (DdCPM)



Algorithm 1 Pseudocode of the baseline DdCPM method.

for each island $I \in \mathcal{I}$ **do**
  initialize $I_{population}$ with random individuals
end for
while *evaluation_budget > 0* **do**
  for each island $I \in \mathcal{I}$ **do**
    if needs_migration(I) **then**
      $I_{population} = I_{population} \cup$ migrate_from($I_{neighbours}$)
    end if
  end for
  for each island $I \in \mathcal{I}$ **do**
    $I_{population}$ = next_generation($I_{population}$, $I_{metaheuristic}$)
    evaluate($I_{population}$)
    evaluation_budget = *evaluation_budget* $-|I_{population}|$
  end for
end while
return the best individual from $\mathcal{I}$

Żychowski, A., Yao, X., Mańdziuk, J.: *Diversity-driven cooperating portfolio of metaheuristic algorithms*.
In: The Genetic and Evolutionary Computation Conference (GECCO 2025) [accepted]

Key challenges in migration strategies

What to migrate?

How many individuals should be migrated?
Which individuals should be selected?
How do different selection criteria affect algorithm performance?

When to migrate?

How frequently should migration happen?
What indicators trigger migration?

Where to migrate?

How should the neighborhood between islands be defined?
What connection topology should be chosen?

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Strategies of migrants selection

S0: Random Selection: Randomly selects *K* individuals without considering fitness or diversity.

S1: Top *K* Fitness: Selects *K* individuals with the highest fitness values from the donor islands.

S2: Top *K* Diversity: Selects *K* individuals that maximize the diversity of the receiving island's population.

S3: Top *K/2* Fitness + Top *K/2* Diversity: This hybrid approach selects half of the migrants based on fitness and the other half based on diversity.

S4: Top *K* (Fitness + Diversity): Selects *K* individuals based on a combined score of fitness and diversity.

Strategies of migrants selection

S5: Weighted Random Selection: Assigns selection probabilities to individuals based on the sum of their normalized fitness and diversity scores.

S6: Weighted *K* (Fitness + Diversity): Selects *K* individuals using a dynamically weighted sum of fitness (χ) and diversity (δ). *j*-th selection maximizes the weighted sum:

$$\frac{j-1}{K-1}\chi + (1 - \frac{j-1}{K-1})\delta.$$

S7: Top 1 Fitness from *K* Clusters: Clusters the population into *K* groups using the *K*-means algorithm based on solution similarity. The best-fitted individual from each cluster is then selected for migration.

Experimental setup

- Diversity-driven Cooperating Portfolio of Metaheuristics (DdCPM)
  Żychowski, A., Yao, X., Mańdziuk, J.: *Diversity-driven cooperating portfolio of metaheuristic algorithms*. GECCO 2025 [accepted]
- number of islands: 6 (ACO, GA, PSO)
- number of individuals in each island: 200

- Benchmark Problems:
  - Traveling Salesman Problem (TSP) - discrete optimization
  - Black-box Optimization Benchmarking (BBOB) - continuous optimization

Results

TSP	*K*							
Strategy	**1**	**2**	**4**	**8**	**12**	**16**	**20**	**24**
S0	36231 ± 107	36165 ± 113	**36211** ± 123	36267 ± 117	36249 ± 110	36255 ± 102	36272 ± 109	36285 ± 115
S1	35795 ± 81	35789 ± 48	35760 ± 66	35746 ± 87	35750 ± 44	35737 ± 42	**35731** ± 52	35768 ± 56
S2	36178 ± 74	36158 ± 55	36120 ± 83	36108 ± 39	**36100** ± 50	36103 ± 61	36105 ± 68	36119 ± 72
S3	-	35737 ± 78	35703 ± 40	35701 ± 53	**35689** ± 61	35696 ± 69	35712 ± 75	35728 ± 79
S4	35622 ± 44	35572 ± 67	35523 ± 49	**35461** ± 62	35475 ± 64	35521 ± 85	35540 ± 88	35562 ± 92
S5	35920 ± 89	35885 ± 92	35894 ± 87	**35884** ± 91	35912 ± 94	35968 ± 97	35985 ± 102	36010 ± 104
S6	-	35746 ± 80	35614 ± 53	35316 ± 76	35302 ± 71	**35238** ± 45	35272 ± 58	35310 ± 63
S7	35795 ± 71	35646 ± 42	35596 ± 59	**35474** ± 82	35485 ± 63	35532 ± 47	35558 ± 64	35582 ± 69

BBOB	*K*							
Strategy	**1**	**2**	**4**	**8**	**12**	**16**	**20**	**24**
S0	2.413 ± 0.13	2.377 ± 0.12	2.269 ± 0.14	**2.268** ± 0.12	2.285 ± 0.13	2.418 ± 0.14	2.506 ± 0.15	2.493 ± 0.14
S1	2.205 ± 0.10	2.122 ± 0.09	2.057 ± 0.10	2.046 ± 0.09	2.054 ± 0.10	**2.040** ± 0.10	2.058 ± 0.11	2.113 ± 0.10
S2	2.598 ± 0.13	2.611 ± 0.11	2.520 ± 0.12	2.555 ± 0.10	**2.504** ± 0.11	2.508 ± 0.11	2.571 ± 0.12	2.576 ± 0.11
S3	-	2.154 ± 0.10	2.140 ± 0.09	2.115 ± 0.09	2.155 ± 0.10	**2.063** ± 0.11	2.094 ± 0.10	2.155 ± 0.11
S4	1.594 ± 0.08	1.606 ± 0.07	1.530 ± 0.07	1.468 ± 0.07	**1.445** ± 0.08	1.455 ± 0.08	1.502 ± 0.09	1.554 ± 0.08
S5	2.090 ± 0.09	2.016 ± 0.10	1.987 ± 0.09	**1.891** ± 0.09	1.956 ± 0.10	2.062 ± 0.09	2.012 ± 0.10	2.005 ± 0.11
S6	-	2.200 ± 0.10	1.964 ± 0.09	1.532 ± 0.08	1.531 ± 0.07	**1.428** ± 0.07	1.478 ± 0.08	1.468 ± 0.08
S7	2.131 ± 0.10	1.854 ± 0.09	1.707 ± 0.08	1.589 ± 0.08	**1.512** ± 0.07	1.522 ± 0.07	1.520 ± 0.08	1.576 ± 0.07

Detailed results

	TSP instance									
Strategy	*rd400*	*fl417*	*pcb442*	*d493*	*att532*	*si535*	*u574*	*p654*	*d657*	*u724*
S0 *K*=4	15825 ± 86	12304 ± 83	52315 ± 89	36112 ± 104	28578 ± 91	49925 ± 91	38080 ± 86	35754 ± 90	50423 ± 97	43244 ± 98
S1 *K*=20	15602 ± 93	12130 ± 94	51611 ± 95	35597 ± 96	28176 ± 97	49222 ± 98	37545 ± 99	35249 ± 100	49725 ± 93	42587 ± 102
S2 *K*=12	15764 ± 101	12253 ± 105	52115 ± 107	35966 ± 101	28461 ± 103	49729 ± 101	37915 ± 106	35603 ± 109	50221 ± 112	43033 ± 109
S3 *K*=12	15583 ± 87	12113 ± 114	51534 ± 115	35565 ± 116	28143 ± 117	49181 ± 118	37485 ± 119	35181 ± 120	49646 ± 121	42568 ± 122
S4 *K*=8	15475 ± 85	**11870** ± 124	51309 ± 125	35375 ± 126	28004 ± 127	48941 ± 128	37297 ± 129	35006 ± 130	**48971** ± 131	42346 ± 132
S5 *K*=8	15668 ± 78	12177 ± 99	51804 ± 109	35748 ± 107	28295 ± 105	49455 ± 97	37673 ± 87	35375 ± 103	49890 ± 93	42753 ± 92
S6 *K*=16	**15297** ± 86	12011 ± 134	**50841** ± 102	35404 ± 83	**27725** ± 84	**48477** ± 85	37327 ± 86	**34680** ± 87	49414 ± 88	**41971** ± 89
S7 *K*=8	15488 ± 90	12021 ± 91	51350 ± 92	**35046** ± 93	28026 ± 94	48980 ± 95	**36952** ± 96	35034 ± 97	49453 ± 98	42380 ± 99

	BBOB function											
Strategy	*f1*	*f2*	*f3*	*f4*	*f5*	*f6*	*f7*	*f8*	*f9*	*f10*	*f11*	*f12*
S0 *K*=8	**0.000** ± .000	0.017 ± .001	2.845 ± .142	2.212 ± .110	1.876 ± .094	1.437 ± .071	3.542 ± .177	3.031 ± .151	6.124 ± .306	5.273 ± .264	8.235 ± .412	7.176 ± .359
S1 *K*=16	**0.000** ± .000	0.016 ± .001	2.532 ± .127	2.022 ± .101	1.723 ± .086	1.318 ± .066	3.128 ± .156	2.653 ± .132	5.346 ± .267	4.537 ± .226	7.584 ± .379	6.568 ± .328
S2 *K*=12	**0.000** ± .000	0.016 ± .001	3.124 ± .156	2.479 ± .124	2.053 ± .103	1.588 ± .079	4.127 ± .206	3.493 ± .175	6.742 ± .337	5.838 ± .292	8.953 ± .448	7.770 ± .389
S3 *K*=16	**0.000** ± .000	**0.015** ± .001	2.578 ± .129	2.048 ± .102	1.746 ± .087	1.336 ± .067	3.321 ± .166	2.805 ± .140	5.642 ± .282	4.873 ± .244	7.612 ± .381	6.589 ± .329
S4 *K*=12	**0.000** ± .000	**0.015** ± .001	**1.872** ± .094	1.515 ± .076	**1.247** ± .062	**0.968** ± .048	**2.415** ± .121	**2.036** ± .102	**4.127** ± .206	3.501 ± .175	**5.246** ± .262	**4.485** ± .224
S5 *K*=8	**0.000** ± .000	**0.015** ± .001	2.453 ± .123	1.961 ± .098	1.685 ± .084	1.304 ± .065	3.027 ± .151	2.548 ± .127	5.128 ± .256	4.354 ± .218	7.124 ± .356	6.147 ± .307
S6 *K*=16	**0.000** ± .000	**0.015** ± .001	1.895 ± .095	**1.420** ± .071	1.263 ± .063	0.971 ± .049	2.527 ± .126	2.124 ± .106	4.215 ± .211	**3.384** ± .169	5.724 ± .286	4.902 ± .245
S7 *K*=12	**0.000** ± .000	**0.015** ± .001	2.014 ± .101	1.589 ± .079	1.387 ± .069	1.081 ± .054	2.493 ± .125	2.111 ± .105	4.352 ± .218	3.635 ± .182	5.635 ± .282	4.816 ± .241

Migration source

One from each island: In this approach, one individual is selected from each of the *K* islands (in our experiments *K* = 5, as DdCMP considers 6 islands).

Common pool: In this approach, all individuals from all islands are combined into a single pool, and *K* individuals are selected from this pool.

	TSP		BBOB	
Strategy	**One from each island**	**Common pool**	**One from each island**	**Common pool**
S0	**36245** ± 102	36312 ± 108	**2.436** ± 0.15	2.505 ± 0.16
S1	**35737** ± 42	35812 ± 47	**2.049** ± 0.10	2.108 ± 0.11
S2	36103 ± 61	**36078** ± 65	**2.534** ± 0.11	2.5516 ± 0.12
S4	35521 ± 85	**35412** ± 89	1.522 ± 0.08	**1.495** ± 0.09
S5	35968 ± 97	**35845** ± 101	2.014 ± 0.10	**2.001** ± 0.11

Computation time

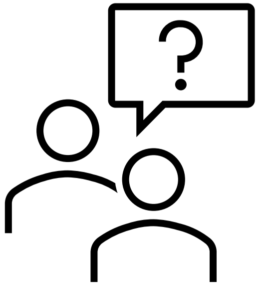
Strategy	TSP	BBOB	Strategy	TSP	BBOB
S0	**45.5** ± 0.7	**62.1** ± 1.0	**S4**	48.6 ± 1.0	65.7 ± 1.5
S1	45.9 ± 1.0	63.3 ± 1.3	**S5**	49.1 ± 1.3	67.2 ± 1.4
S2	47.2 ± 1.1	65.8 ± 1.2	**S6**	49.4 ± 1.2	67.6 ± 1.7
S3	47.8 ± 0.8	64.4 ± 1.1	**S7**	51.7 ± 1.5	70.2 ± 1.8

The selection process itself is not a significant contributor to the overall computation time.

Summary

- Migration strategy significantly impacts optimization performance.
- Moderate migration sizes achieve a balance between exploration and exploitation.
- Combining fitness and diversity yields the best results.

Thank you



Full paper