Self-adaptive Search Equation-Based Artificial Bee Colony Algorithm with CMA-ES on the Noiseless BBOB Testbed

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Outline

Pseudo-code of The ABC framework

```
Step 1. Initialization
while termination condition is not met do
    Step 2. Employed Bees Step
    Step 3. Calculate Selection Probabilities
    Step 4. Onlooker Bees Step
    Step 5. Scout Bees Step
    Step 6. Apply Local Search (Optional)
    Step 7. Apply Population Strategy (Optional)
end while
```

Most Effective Components in ABC Framework

Components

- Search equation in Employed Bees and Onlooker Bees steps
- Local search strategy
- Population strategy

Aydın, D. (2015). Composite artificial bee colony algorithms: From component-based analysis to high-performing algorithms. Applied Soft Computing, 32, 266-285.

Improvements introduced by the SSEABC algorithm

For Employed Bees and Onlooker Bees Steps

Self-adaptive search equation selection

For Local Search

Different local search procedures

For Population Size

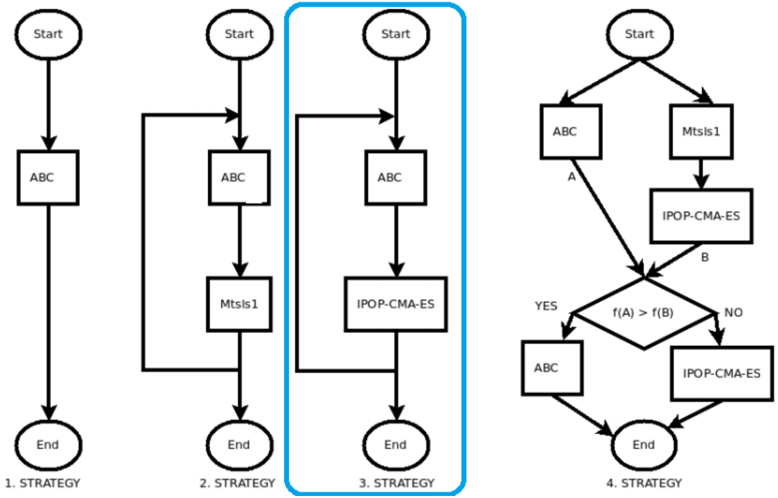
Incremental population size strategy

Population Size Strategy

- In SSEABC algorithm, three population size strategy are implemented: fix, incremental and dynamic population size strategies
- In this work, we only used incremental population strategy which is better than the others
- In incremental population size strategy, a new agent is added to the population by

$$\acute{x}_{new,j} = x_{new,j} + \varphi_{i,j}(x_{Gbest,j} - x_{new,j}) \tag{1}$$

Local Search Strategy



General form of generate search equation

Standard Search Equation

$$v_{i,j} = x_{i,j} + \phi_{i,j}(x_{i,j} - x_{r1,j}) \quad (2)$$

Generalized Search Equation (GSE)

for $t = 1$ to m **do**
  select random dimension j $(1 \leq j \leq D)$
  $x_{i,j} = term_1 + term_2 + term_3 + term_4$
end for

Vers. I (2016): Component alternatives in GSE

Table: Alternative options for each component in the generalized search equation. ϕ_1, ϕ_1 and ϕ_1 can take two possible ranges: $[-1,-1]$ and $[-SF, SF]$ where SF is randomly selected positive real value. These ranges are decided randomly while creating each component of each randomly generated search equation.

m	$term1$	$term2$	$term3$	$term4$
1	$x_{i,j}$	$\phi1(x_{i,j} - x_{G,j})$	$\phi2(x_{i,j} - x_{G,j})$	$\phi3(x_{i,j} - x_{G,j})$
k $(1 \leq k \leq D)$	$x_{G,j}$	$\phi1(x_{i,j} - x_{r1,j})$	$\phi2(x_{i,j} - x_{r1,j})$	$\phi3(x_{i,j} - x_{r1,j})$
$[t,k]$ $(1 \leq t < k \leq D)$	$x_{r1,j}$	$\phi1(x_{G,j} - x_{r1,j})$	$\phi2(x_{G,j} - x_{r1,j})$	$\phi3(x_{G,j} - x_{r1,j})$
		$\phi1(x_{r1,j} - x_{r2,j})$	$\phi2(x_{r1,j} - x_{r2,j})$	$\phi3(x_{r1,j} - x_{r2,j})$
		$\phi1(x_{i,j} - x_{GD,j})$	$\phi2(x_{i,j} - x_{GD,j})$	$\phi3(x_{i,j} - x_{GD,j})$
		do not use	do not use	do not use

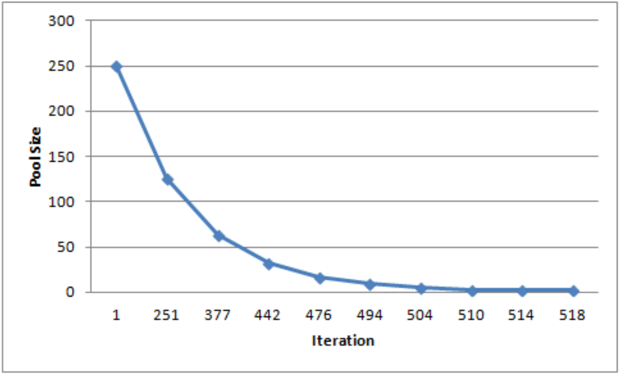
Vers. II (2017): Component alternatives in GSE

Table: Alternative options for each component in the generalized search equation. ϕ_1, ϕ_1 and ϕ_1 can take two possible ranges: $[-1, -1]$ and $[-SF, SF]$ where SF is randomly selected positive real value. These ranges are decided randomly while creating each component of each randomly generated search equation.

m	term1	term2	term3	term4
1	$x_{i,j}$	$\phi1(x_{i,j} - x_{G,j})$	$\phi2(x_{i,j} - x_{G,j})$	$\phi3(x_{i,j} - x_{G,j})$
k $(1 \leq k \leq D)$	$x_{G,j}$	$\phi1(x_{i,j} - x_{r1,j})$	$\phi2(x_{i,j} - x_{r1,j})$	$\phi3(x_{i,j} - x_{r1,j})$
$[t, k]$ $(1 \leq t < k \leq D)$	$x_{r1,j}$	$\phi1(x_{G,j} - x_{r1,j})$	$\phi2(x_{G,j} - x_{r1,j})$	$\phi3(x_{G,j} - x_{r1,j})$
		$\phi1(x_{r1,j} - x_{r2,j})$	$\phi2(x_{r1,j} - x_{r2,j})$	$\phi3(x_{r1,j} - x_{r2,j})$
		$\phi1(x_{i,j} - x_{GD,j})$	$\phi2(x_{i,j} - x_{GD,j})$	$\phi3(x_{i,j} - x_{GD,j})$
		$\phi1(x_{i,j} - x_{SC,j})$	$\phi2(x_{i,j} - x_{SC,j})$	$\phi3(x_{i,j} - x_{SC,j})$
		$\phi1(x_{i,j} - x_{MD,j})$	$\phi2(x_{i,j} - x_{MD,j})$	$\phi3(x_{i,j} - x_{MD,j})$
		$\phi1(x_{i,j} - x_{WO,j})$	$\phi2(x_{i,j} - x_{WO,j})$	$\phi3(x_{i,j} - x_{WO,j})$
		$\phi1(x_{SC,j} - x_{MD,j})$	$\phi2(x_{SC,j} - x_{MD,j})$	$\phi3(x_{SC,j} - x_{MD,j})$
		$\phi1(x_{MD,j} - x_{WO,j})$	$\phi2(x_{MD,j} - x_{WO,j})$	$\phi3(x_{MD,j} - x_{WO,j})$
		$\phi1(x_{G,j} - x_{WO,j})$	$\phi2(x_{G,j} - x_{WO,j})$	$\phi3(x_{G,j} - x_{WO,j})$
		$\phi1(x_{r1,j} - x_{MD,j})$	$\phi2(x_{r1,j} - x_{MD,j})$	$\phi3(x_{r1,j} - x_{MD,j})$
		$\phi1(x_{G,j} - x_{MD,j})$	$\phi2(x_{G,j} - x_{MD,j})$	$\phi3(x_{G,j} - x_{MD,j})$
		$\phi1(x_{r1,j} - x_{WO,j})$	$\phi2(x_{r1,j} - x_{WO,j})$	$\phi3(x_{r1,j} - x_{WO,j})$
		$\phi1(x_{SC,j} - x_{r1,j})$	$\phi2(x_{SC,j} - x_{r1,j})$	$\phi3(x_{SC,j} - x_{r1,j})$
		$\phi1(x_{i,j} - x_{AVE,j})$	$\phi2(x_{i,j} - x_{AVE,j})$	$\phi3(x_{i,j} - x_{AVE,j})$
		$\phi1(x_{r1,j} - x_{AVE,j})$	$\phi2(x_{r1,j} - x_{AVE,j})$	$\phi3(x_{r1,j} - x_{AVE,j})$
		$\phi1(x_{G,j} - x_{AVE,j})$	$\phi2(x_{G,j} - x_{AVE,j})$	$\phi3(x_{G,j} - x_{AVE,j})$
		do not use	do not use	do not use

Search Equation Pool

Search Equation 1
Search Equation 2
Search Equation 3
Search Equation 4
...
...
...
...
...
...
Search Equation 248
Search Equation 249
Search Equation 250



SSEABC (Version I) in CEC'16 Competition

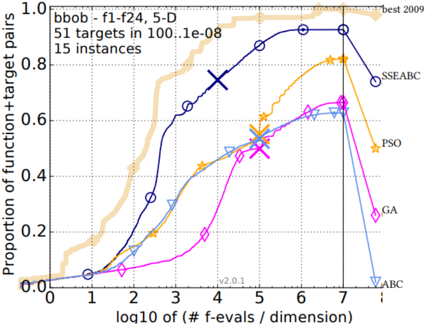
	UMOEASII	iLSHADE	SSEABC	LSHADE_EpSin	AEPDJADE	SHADE4	SHADE44	SPMGTLO	MCSHADE
D=10	1.4440E+03	1.9776E+03	2.1054E+03	1.5056E+03	2.1676E+03	1.8347E+03	1.9068E+03	8.6436E+04	1.9588E+03
D=30	4.3771E+03	5.3241E+03	7.6832E+03	3.1753E+03	8.3564E+03	1.7657E+04	5.9737E+03	2.2819E+06	1.0612E+04
D=50	1.5920E+04	1.8028E+04	1.9148E+04	5.8812E+03	4.4215E+04	1.6548E+05	2.1970E+04	3.8722E+07	4.5461E+04
D=100	2.9613E+04	2.2337E+05	3.0626E+04	3.3286E+04	2.7705E+05	7.7942E+05	3.7566E+05	1.1019E+08	1.9618E+05
Total Score	**5.1354E+04**	**2.4870E+05**	**5.9563E+04**	**4.3848E+04**	**3.3179E+05**	**9.6440E+05**	**4.0551E+05**	**1.5128E+08**	**2.5421E+05**
Rank	**2**	**4**	**3**	**1**	**6**	**8**	**7**	**9**	**5**

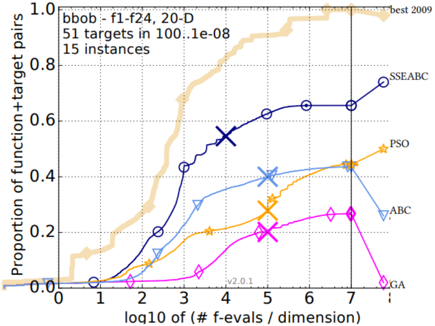
(yellow)	Best
(green)	Second
(blue)	Third

SSEABC (Version I and II) in CEC'17 Competition

	Best		Median		Mean	
Func.	SSEABCv2	SSEABCv1	SSEABCv2	SSEABCv1	SSEABCv2	SSEABCv1
1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	5.675E-01	0.000E+00	5.856E+01	5.856E+01	5.107E+01	4.310E+01
5	0.000E+00	0.000E+00	2.985E+00	2.985E+00	3.144E+00	3.473E+00
6	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7	3.262E+01	4.252E+01	3.416E+01	5.515E+01	3.466E+01	5.576E+01
8	0.000E+00	0.000E+00	2.985E+00	3.980E+00	2.692E+00	3.765E+00
9	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10	1.243E+02	1.134E+01	9.107E+02	1.843E+03	9.291E+02	1.687E+03
11	1.442E+00	9.950E-01	6.651E+00	2.619E+01	1.241E+01	2.967E+01
12	2.485E+02	2.572E+02	1.243E+03	1.261E+03	1.233E+03	1.225E+03
13	3.080E+00	1.983E+01	2.251E+01	9.771E+01	4.865E+01	1.958E+02
14	6.773E+01	6.378E+01	1.205E+02	1.215E+02	1.184E+02	1.267E+02
15	7.517E+00	2.355E+01	9.686E+01	1.386E+02	1.167E+02	1.703E+02
16	3.035E+00	3.251E+00	1.790E+01	1.620E+02	3.554E+01	1.820E+02
17	2.663E+01	2.979E+01	4.892E+01	6.671E+01	5.098E+01	7.512E+01
18	2.147E+01	3.435E+01	7.805E+01	1.236E+02	8.631E+01	1.185E+02
19	2.297E+01	1.500E+01	5.746E+01	6.220E+01	6.167E+01	6.233E+01
20	2.309E+01	8.217E+00	3.812E+01	5.783E+01	3.881E+01	5.780E+01

Results over All Functions in BBOB testbed





Discussion

- SSEABC outperforms PSO, ABC and GA for almost all functions.
- SSEABC solved 11 functions in dimension 5 and 5 functions in dimension 20 with 100 % success rate
- For 2, 5 and 20 dimensional functions, SSEABC solved 9 functions optimally
- SSEABC is not good in separable functions.

Thank you! Questions?