

Scaling Up Covariance Matrix Adaptation Evolution Strategy using Cooperative Coevolution

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Algorithm 1 Pseudocode of CC-CMA-ES

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1: procedure CC-CMA-ES( $dim, subNum, lambda, ub, lb, maxFEs$ )
2:    $pop(1 : 200, 1 : dim) \leftarrow random\ population$ 
3:    $(best, best_{val}) \leftarrow evaluate(pop)$ 
4:    $fes \leftarrow 200$ 
5:    $C \leftarrow dim \times dim\ unit\ matrix$ 
6:    $x_w \leftarrow dim \times 1\ random\ vector$ 
7:    $\sigma \leftarrow (ub - lb) \div 2$ 
8:    $historyWindow \leftarrow 5$ 
9:    $performanceRecord \leftarrow ones(3, historyWindow)$ 
10:  while  $fes < maxFEs$  do
11:     $(subInfo, decomposerID) \leftarrow adaptiveDecompose(dim, subNum, performanceRecord)$ 
12:     $oldbest_{val} \leftarrow best_{val}$ 
13:    for  $sub = 1 : subNum$  do
14:       $x_{sub} \leftarrow x_w(subInfo(sub), 1)$ 
15:       $C_{sub} \leftarrow C(subInfo(sub), subInfo(sub))$ 
16:       $(best, best_{val}, fes_{used}, newx_{sub}, newC_{sub}, new\sigma) \leftarrow CMA -$   

        $ES(x_{sub}, C_{sub}, \sigma, best, best_{val}, lambda)$ 
17:       $fes \leftarrow fes + fes_{used}$ 
18:       $x_w(subInfo(sub), 1) \leftarrow newx_{sub}$ 
19:       $C(subInfo(sub), subInfo(sub)) \leftarrow newC_{sub}$ 
20:       $\sigma \leftarrow new\sigma$ 
21:    end for
22:     $performanceRecord \leftarrow updateRecord(best_{val}, oldbest_{val}, decomposerID)$ 
23:  end while
24: end procedure
```

Table 1. Experimental Results

1000D		f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8
1.2e5	Best	3.60e+07	1.18e+03	1.42e-02	8.91e+10	7.28e+14	8.91e+03	2.29e+09	7.16e+15
	Median	1.20e+08	1.40e+03	2.28e-02	5.32e+11	7.28e+14	1.04e+06	5.72e+09	2.01e+16
	Worst	2.24e+08	1.62e+03	3.53e-01	1.28e+12	7.28e+14	1.05e+06	1.36e+10	8.34e+16
	Mean	1.14e+08	1.40e+03	3.78e-02	6.09e+11	7.28e+14	7.54e+05	5.81e+09	2.93e+16
	StDev	4.79e+07	1.01e+02	6.62e-02	3.28e+11	2.39e+09	4.23e+05	2.75e+09	2.11e+16
6.0e5	Best	1.82e+03	1.09e+03	1.39e-13	1.24e+10	7.28e+14	5.61e+03	3.11e+08	8.89e+14
	Median	3.57e+04	1.33e+03	1.56e-13	3.00e+10	7.28e+14	1.01e+06	1.13e+09	2.21e+15
	Worst	1.62e+05	1.56e+03	1.74e-13	1.02e+11	7.28e+14	1.03e+06	5.66e+09	5.15e+15
	Mean	3.99e+04	1.33e+03	1.56e-13	3.53e+10	7.28e+14	6.30e+05	1.42e+09	2.30e+15
	StDev	3.80e+04	1.11e+02	9.44e-15	1.96e+10	7.25e+07	4.85e+05	1.10e+09	1.06e+15
3.0e6	Best	3.46e-09	1.09e+03	1.39e-13	4.51e+08	7.28e+14	5.61e+03	6.66e+04	8.48e+13
	Median	6.03e-09	1.33e+03	1.49e-13	1.93e+09	7.28e+14	9.93e+05	2.09e+06	3.44e+14
	Worst	8.15e-09	1.56e+03	1.71e-13	6.87e+09	7.28e+14	1.01e+06	5.27e+07	1.42e+15
	Mean	5.77e-09	1.33e+03	1.51e-13	2.19e+09	7.28e+14	5.83e+05	7.44e+06	3.88e+14
	StDev	1.00e-09	1.11e+02	6.73e-15	1.31e+09	4.65e+06	4.79e+05	1.21e+07	2.87e+14
1000D		f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}	—
1.2e5	Best	4.57e+08	1.51e+06	1.69e+11	1.04e+03	2.29e+10	3.52e+11	5.58e+07	
	Median	7.67e+08	8.05e+06	5.16e+11	2.26e+03	5.53e+10	8.18e+11	1.16e+08	
	Worst	1.02e+09	9.31e+07	1.80e+12	1.73e+04	8.69e+10	1.31e+12	3.41e+08	
	Mean	7.36e+08	2.68e+07	6.04e+11	6.92e+03	5.44e+10	8.18e+11	1.28e+08	
	StDev	1.40e+08	3.57e+07	3.87e+11	6.32e+03	1.48e+10	2.60e+11	5.94e+07	
6.0e5	Best	1.53e+08	1.57e+05	3.73e+09	9.87e+02	6.52e+09	6.32e+10	2.60e+07	
	Median	4.81e+08	1.22e+06	3.35e+10	2.07e+03	1.68e+10	1.64e+11	3.97e+07	
	Worst	7.52e+08	9.03e+07	1.77e+11	1.60e+04	4.96e+10	3.98e+11	7.52e+07	
	Mean	4.48e+08	4.49e+06	5.15e+10	6.17e+03	1.87e+10	1.88e+11	4.24e+07	
	StDev	1.95e+08	1.79e+07	5.03e+10	5.72e+03	9.59e+09	9.28e+10	1.26e+07	
3.0e6	Best	1.29e+08	1.28e+05	3.29e+07	9.77e+02	2.18e+07	1.90e+07	2.31e+07	
	Median	3.59e+08	1.13e+06	1.32e+08	9.85e+02	3.88e+08	3.21e+07	2.85e+07	
	Worst	7.14e+08	1.25e+06	7.97e+08	2.43e+03	4.74e+09	5.77e+08	4.89e+07	
	Mean	3.71e+08	7.55e+05	1.59e+08	1.27e+03	6.69e+08	7.10e+07	3.03e+07	
	StDev	1.83e+08	5.02e+05	1.47e+08	4.26e+02	1.14e+09	1.25e+08	6.08e+06	