EARIN Lab3
Task number: 3
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Introduction

This report presents the optimization of the Bukin function, a complex mathematical function defined as $f(x, y) = 100\sqrt{|y - 0.01x^2|} + 0.01|x+10|$. Our objective is to minimize this function within a specified search space. We employ the Evolutionary Strategy ($\mu + \lambda$), a population-based optimization method inspired by natural evolution, due to its adaptability and robustness. The algorithm works by evolving a population of potential solutions using selection, crossover, and mutation operations.

We will discuss the Python implementation of the Evolutionary Strategy algorithm and the genetic operators used. Additionally, we will analyze the impact of different algorithm parameters on the optimization process and present the results of various parameter configurations in terms of solution quality and optimization time.

Algorithm Description

In this section, we briefly describe the key components of the Evolutionary Strategy ($\mu + \lambda$) algorithm used for optimizing the Bukin function. The algorithm involves the following steps:

1) Initialize parameters and create an initial population of μ random individuals within the search space.
2) Iterate through a specified number of generations, performing the following operations in each generation:
    a. Generate λ offspring by applying mutation to the μ parents.
    b. Evaluate the fitness of each offspring using the Bukin function.
    c. Combine the parent population with the offspring population.
    d. Select the top μ individuals based on their fitness values to form the new population.
3) After the termination criterion is met (i.e., the maximum number of generations is reached), return the best solution found.

Experimental Setup

In this section, we outline the experimental setup, including the parameters and their ranges used in the optimization process. We will investigate the impact of various parameter values on the optimization performance. The parameters considered are:

1) Population size (μ)
2) Offspring size (λ)
3) Number of generations
4) Search space ranges for x and y
5) Mutation strength
6) Mutation probability

For each experiment, we will measure the optimization time and the quality of the solution found. Additionally, we will visualize the optimization process to gain insights into the algorithm's behavior and convergence.

Results and Analysis

Here, we present the results of the optimization process for different sets of parameter values. We will analyze the impact of each parameter on the solution quality and optimization time, highlighting the trade-offs and parameter combinations that lead to the best results. We will also discuss any observed trends or patterns in the optimization process and provide recommendations for future work.

No.	mu	lambd	mutation_	mutation_	optimal_s	optimal_s	f	optimizati
1	10	20	0.1	0.5	-6.98474	0.487881	0.421662	1.17999
2	10	20	0.1	0.9	-11.1374	1.240468	0.763711	1.018324
3	10	20	0.1	0.99	-13.1649	1.733158	0.29374	1.023306
4	10	20	0.5	0.5	-11.5144	1.325905	0.985131	1.699076
5	10	20	0.5	0.9	-10.1051	1.02105	0.892737	1.108361
6	10	20	0.5	0.99	-9.93471	0.987198	1.463473	1.341318
7	10	20	1	0.5	-13.1574	1.731291	1.137352	1.295352
8	10	20	1	0.9	-5.63999	0.318015	0.938776	0.758411
9	10	20	1	0.99	-7.75233	0.60062	1.933983	0.691039
10	10	100	0.1	0.5	-8.00579	0.640929	0.146365	3.387722
11	10	100	0.1	0.9	-7.54471	0.56922	0.290358	3.828606
12	10	100	0.1	0.99	-8.72882	0.761913	0.310592	4.948124
13	10	100	0.5	0.5	-6.18561	0.382635	0.451335	3.326741
14	10	100	0.5	0.9	-8.66214	0.750324	0.171579	4.373766
15	10	100	0.5	0.99	-3.89304	0.151561	0.2418	3.838723
16	10	100	1	0.5	-14.9976	2.249251	0.593191	3.845203
17	10	100	1	0.9	-9.98961	0.997816	1.036061	4.125175
18	10	100	1	0.99	-6.47255	0.418945	0.27679	3.010953
19	10	200	0.1	0.5	-5.77313	0.333291	0.065045	7.565437
20	10	200	0.1	0.9	-15.0157	2.254713	0.127647	8.391315
21	10	200	0.1	0.99	-10.6789	1.140388	0.284447	7.721609
22	10	200	0.5	0.5	-8.82119	0.778136	0.136153	8.747361
23	10	200	0.5	0.9	-3.82276	0.146138	0.243542	7.780261
24	10	200	0.5	0.99	-9.998	0.999606	0.244076	7.492093
25	10	200	1	0.5	-9.6597	0.933077	0.453538	7.829543
26	10	200	1	0.9	-13.9759	1.95325	0.367039	7.136326
27	10	200	1	0.99	-4.1304	0.170609	0.324159	7.706932
28	50	20	0.1	0.5	-6.0342	0.364102	0.410519	2.271384
29	50	20	0.1	0.9	-6.67906	0.446081	0.446813	2.936622
30	50	20	0.1	0.99	-7.09178	0.502974	0.664133	3.839976
31	50	20	0.5	0.5	-12.1851	1.484773	0.266039	3.169812
32	50	20	0.5	0.9	-5.71351	0.326696	1.635231	3.960599
33	50	20	0.5	0.99	-11.6617	1.35999	0.685192	4.793302
34	50	20	1	0.5	-13.0234	1.696885	2.865066	2.898721
35	50	20	1	0.9	-16.5367	2.73469	0.911235	2.821412
36	50	20	1	0.99	-13.4879	1.818602	2.556857	2.354012
37	50	100	0.1	0.5	-10.6684	1.138145	0.155081	13.02836
38	50	100	0.1	0.9	-5.12914	0.263087	0.289335	12.30963
39	50	100	0.1	0.99	-14.4226	2.080127	0.229197	10.65601
40	50	100	0.5	0.5	-5.07692	0.25778	0.586335	12.57891
41	50	100	0.5	0.9	-11.878	1.410867	0.391222	11.62693
42	50	100	0.5	0.99	-14.7531	2.176557	0.255979	11.29269
43	50	100	1	0.5	-6.0403	0.364865	0.38629	15.35563
44	50	100	1	0.9	-10.0287	1.005886	1.207882	13.68534
45	50	100	1	0.99	-8.53101	0.727751	0.568733	12.58343
46	50	200	0.1	0.5	-10.0606	1.012165	0.088826	22.01756
47	50	200	0.1	0.9	-12.2578	1.502536	0.129246	20.98705
48	50	200	0.1	0.99	-8.80487	0.775263	0.224902	22.39767
49	50	200	0.5	0.5	-12.7648	1.629368	0.501565	22.57366
50	50	200	0.5	0.9	-8.29758	0.688503	0.222646	20.66656
51	50	200	0.5	0.99	-4.62555	0.213928	0.588891	23.59588
52	50	200	1	0.5	-12.005	1.441155	0.627169	21.82639
53	50	200	1	0.9	-6.69073	0.44763	0.570539	19.98237
54	50	200	1	0.99	-13.8561	1.919938	0.417602	23.7194
55	100	20	0.1	0.5	-4.93973	0.244023	0.420183	3.526483
56	100	20	0.1	0.9	-8.80612	0.77545	0.532417	3.528991
57	100	20	0.1	0.99	-6.36049	0.40455	0.325063	3.967654
58	100	20	0.5	0.5	-6.80737	0.463364	0.650078	3.769867
59	100	20	0.5	0.9	-12.496	1.561664	1.321865	3.572475
60	100	20	0.5	0.99	-9.87487	0.974829	1.738055	3.832245
61	100	20	1	0.5	-7.98485	0.637251	1.828251	3.420008
62	100	20	1	0.9	-10.952	1.198444	3.216103	4.881954
63	100	20	1	0.99	-7.16666	0.513949	1.869598	4.022057
64	100	100	0.1	0.5	-11.3336	1.284498	0.326439	18.75448
65	100	100	0.1	0.9	-9.29333	0.863655	0.236291	19.50707
66	100	100	0.1	0.99	-8.33836	0.695289	0.288605	18.49658
67	100	100	0.5	0.5	-5.39378	0.290934	0.280108	18.38185
68	100	100	0.5	0.9	-10.2748	1.055636	0.934791	20.94586
69	100	100	0.5	0.99	-6.59996	0.435596	0.169383	16.6908
70	100	100	1	0.5	-3.81013	0.145172	0.184233	21.58384
71	100	100	1	0.9	-8.51198	0.724599	0.795601	21.39837
72	100	100	1	0.99	-8.47691	0.71865	0.848165	21.93777
73	100	200	0.1	0.5	-13.4924	1.82045	0.218941	41.24798
74	100	200	0.1	0.9	-5.25312	0.275954	0.14919	40.72931
75	100	200	0.1	0.99	-10.7421	1.153926	0.130025	52.43729
76	100	200	0.5	0.5	-7.79409	0.607478	0.086123	47.32286
77	100	200	0.5	0.9	-5.37687	0.289118	0.375406	49.34135
78	100	200	0.5	0.99	-11.4298	1.306384	0.30975	44.88266
79	100	200	1	0.5	-5.1491	0.265138	0.283356	44.0858
80	100	200	1	0.9	-5.39775	0.291347	0.358207	57.81068
81	100	200	1	0.99	-10.2315	1.046846	0.380207	50.07915

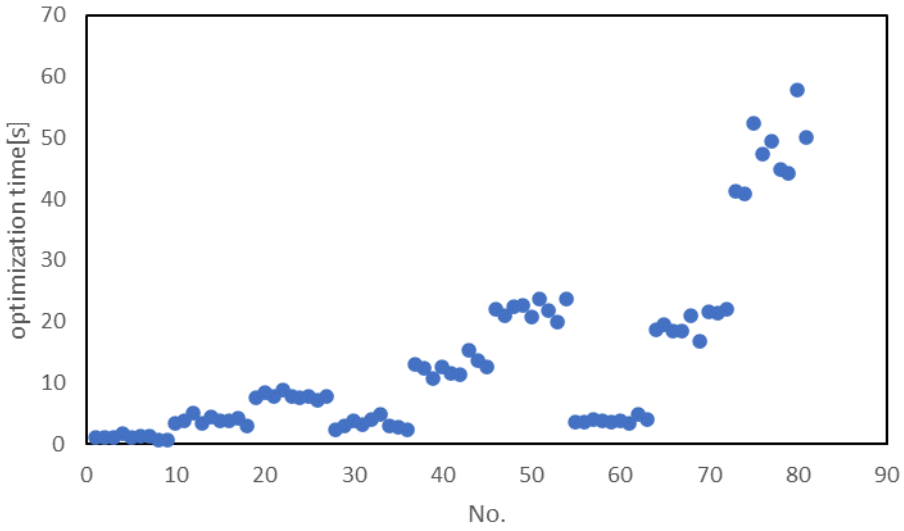

Fig. 1 optimization time

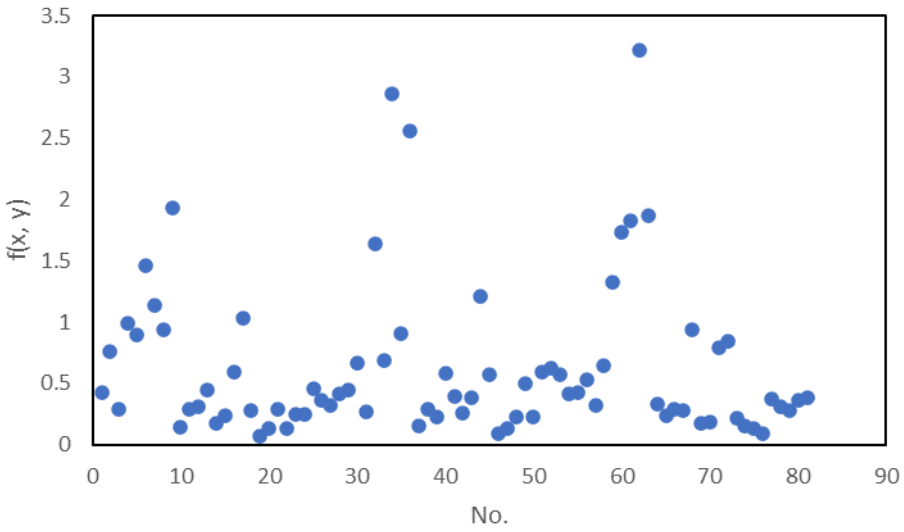

Fig. 2　Bukin function f(x, y)

As can be seen from Figure 1, optimization time increased as the parameter offspring size increased. Also, as the parameter population size increased, the difference in optimization time due to the parameter lambda became more pronounced than when the parameter lambda was small.

As can be seen from Figure 2, the impact of the population size parameter on the results was

not significant; the results also increased when the mutation strength and probability parameters were larger than the population and offspring size parameters. The shortest optimization time, with results near zero, was obtained with parameter(population_size, offspring_size, mutation_strength, mutation_probability)=(10, 20, 0.1, 0.99).

Additional Graph

The following graph is the relation between optimization time and f(x,y)