A Parallel Gannet Optimization Algorithm with Communication Strategies (PGOA)

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A Parallel Gannet Optimization Algorithm with Communication Strategies (**PGOA**)

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Outline

- Motivation
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Motivation

- Meta-heuristic algorithms — Complicated and large-scale problems
- Sophisticated mechanisms — Easier escape from local optima
- Higher dimension — Lower convergence and running speed
- Finding appropriate methods for solving high-dimensional problems quickly

Introduction

Gannet Optimization Algorithm (GOA)

Gannet Optimization Algorithm (GOA) (J. S. Pan et al. 2022) is a novel meta-heuristic algorithm designed based on various unique behaviors of gannets.

- Exploration
  - U-shaped
  - V-shaped
- Exploitation
  - Levy
  - Turns
- Shorter runtime in high dimensions

Introduction

Parallel Mechanism

True Parallelism

parallelism on hardware

Virtual Parallelism

communication between groups

Introduction

Parallel Mechanism

True Parallelism

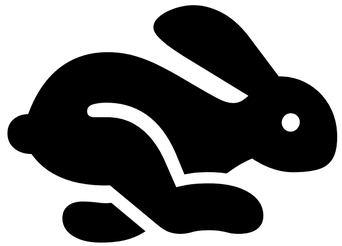
parallelism on hardware

Virtual Parallelism

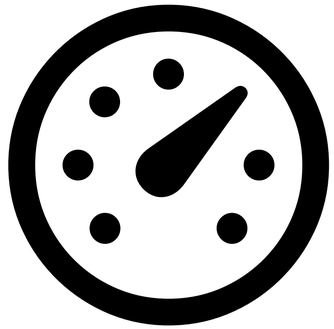
communication between groups

Gannet Optimization Algorithm
+
Parallel Mechanism

Parallel Gannet Optimization Algorithm (PGOA)



Easier escaping
from local optima



Faster convergence
and running speed

Methodology

Parallel Gannet Optimization Algorithm (PGOA)

- **Initialization**

Generate N_p individuals $X_{d,i}^{g}$ for the g^{th} group,

$$d = 1,\ldots,D;\ \ i = 1,\ldots,N_p;\ \ g = 1,\ldots,G.$$

D is the dimension of the problem and G is the total number of groups, which can be completely divided by 2^k (k is a positive integer).

Methodology

Parallel Gannet Optimization Algorithm (PGOA)

- **Update**

Four group arrays are proposed to record different fitness values:

  - $pop\_fit_g^i$
  - $group\_best_g$ and $group\_fmin$
  - $group\_worst_g$ and $group\_fmax$
  - $global\_best$ and $global\_fmin$

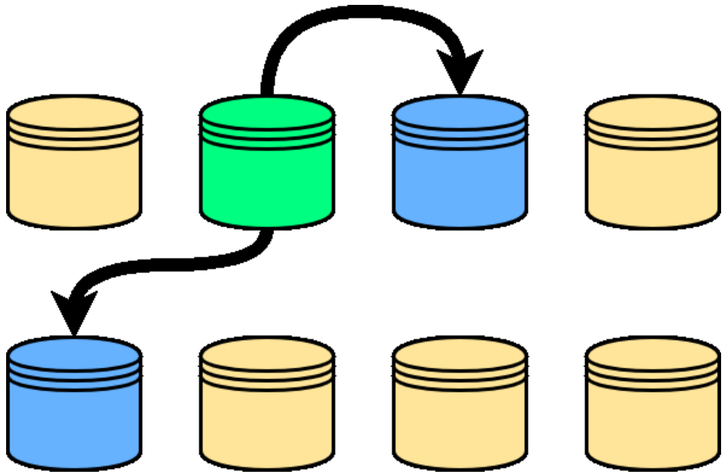
- **Evaluation**

The value of $fitness\_func(X_{d,i}^g)$ of each D-dimensional individual is the evaluation of their execution solution.

Methodology

Parallel Gannet Optimization Algorithm (PGOA)

- Communication strategy 1



Step 1. Random Selection

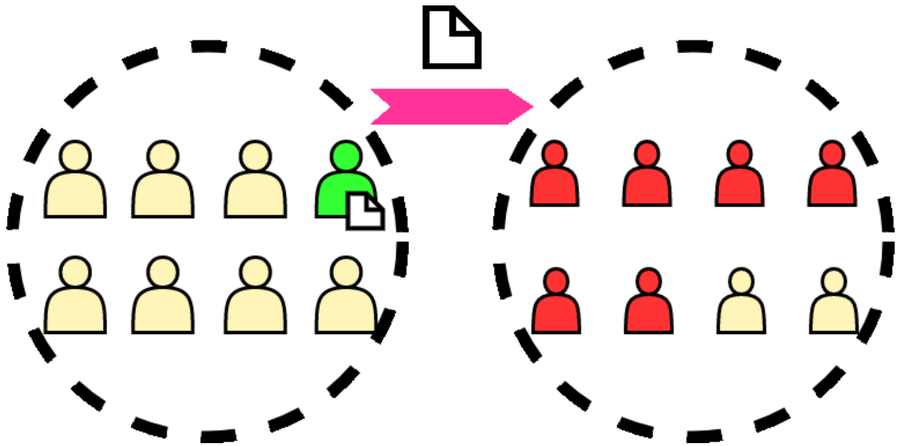
X (repeat times) **non-current** group(s) q will be randomly selected and sorted in **descending** order.

Here, $X = 2$, $g \in [0,\ G)$, $q = g \oplus 2^n$, and $n = 0,\ldots, m-1$, where $G = 2^m$.

Methodology

Parallel Gannet Optimization Algorithm (PGOA)

- Communication strategy 1



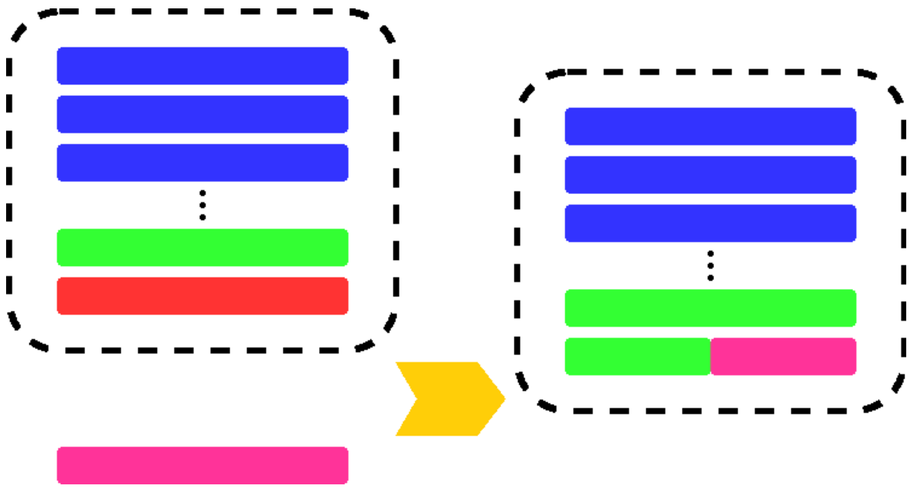
Step 2. Information Communication

Migrate the current group's best solution $group\_best_g$ to replace 75% **worse** individuals in $group_q$ every T iteration(s).

Methodology

Parallel Gannet Optimization Algorithm (PGOA)

- Communication strategy 2



Replace the worst solution of the current group $group^{i}_{worst}$ with a combination of **half** of the global best individual $global_{best}$ and **half** of the best individual in this group $group^{i}_{best}$.

After the substitution, **update** the individuals of $group_{worst}$, $group_{best}$, $global_{best}$ and their fitness value.

Methodology

Parallel Gannet Optimization Algorithm (PGOA)

- **Complexity analysis**

Theoretically, the complexity of the PGOA is $O(T \times N_p \times G) + O(T \times N_p \times G \times D)$, where T is the total iterations of the test; G is the number of groups and N_p is the total individual number in each group, in addition $N_p \times G = N$.

However, according to the experimental results, we find that the running speed of PGOA is faster than the GOA tested under the same conditions, and the more groups are divided, the faster the execution is.

Methodology

Parallel Gannet Optimization Algorithm (PGOA)

- **Complexity analysis**

After analysis, the complexity of the PGOA is equal to that of the GOA since they have the same individual number N.

However, PGOA has N_p individuals per update, and it is easier for the machine to compute tiny matrices than large ones.

Therefore the running time of the PGOA is shorter than that of the GOA although the PGOA has $G-1$more updates per iteration than the GOA.

Experiments

Parallel Gannet Optimization Algorithm (PGOA)

A series of comprehensive experiments are conducted to test the performance of the PGOA on ***100-dimensional*** uni-modal and multi-modal CEC2013 functions and compare it with GOA.

- **Experiment code**

https://github.com/Sue217/PGOA/tree/master/code

- **Benchmark functions**

https://www.rforge.net/cec2013/

Data Analysis

Parallel Gannet Optimization Algorithm (PGOA)

We run each experiment **30** times and average the **best value** and **running time**. The results are shown in the following table and the mean values are displayed in the histogram below.

Data Analysis

Parallel Gannet Optimization Algorithm (PGOA)

	Average Best Solution		*Average Running Time (s)*	
Function	GOA	PGOA	GOA	PGOA
F1	559.26	**37.67**	5.63	**0.90**
F2	54.37	**40.81**	7.27	**1.10**
F3	-687142.08	**-868354.29**	25.78	**3.58**
F4	5.41	**1.97**	5.32	**0.84**
F5	401622.14	**51475.68**	8.51	**1.26**
F6	2635.95	**364.50**	5.69	**0.89**
F7	533.88	**195.87**	8.66	**1.29**
F8	-14601.28	**-17828.41**	7.23	**1.12**
F9	2161.49	**2129.12**	8.41	**1.26**
F10	7.88	**3.58**	13.68	**1.95**
F11	3442.19	**3212.37**	10.40	**1.51**
F12	916459459.72	**51.93**	24.19	**3.30**
F13	47749.57	**10.05**	23.58	**3.25**

Data Analysis

Parallel Gannet Optimization Algorithm (PGOA)

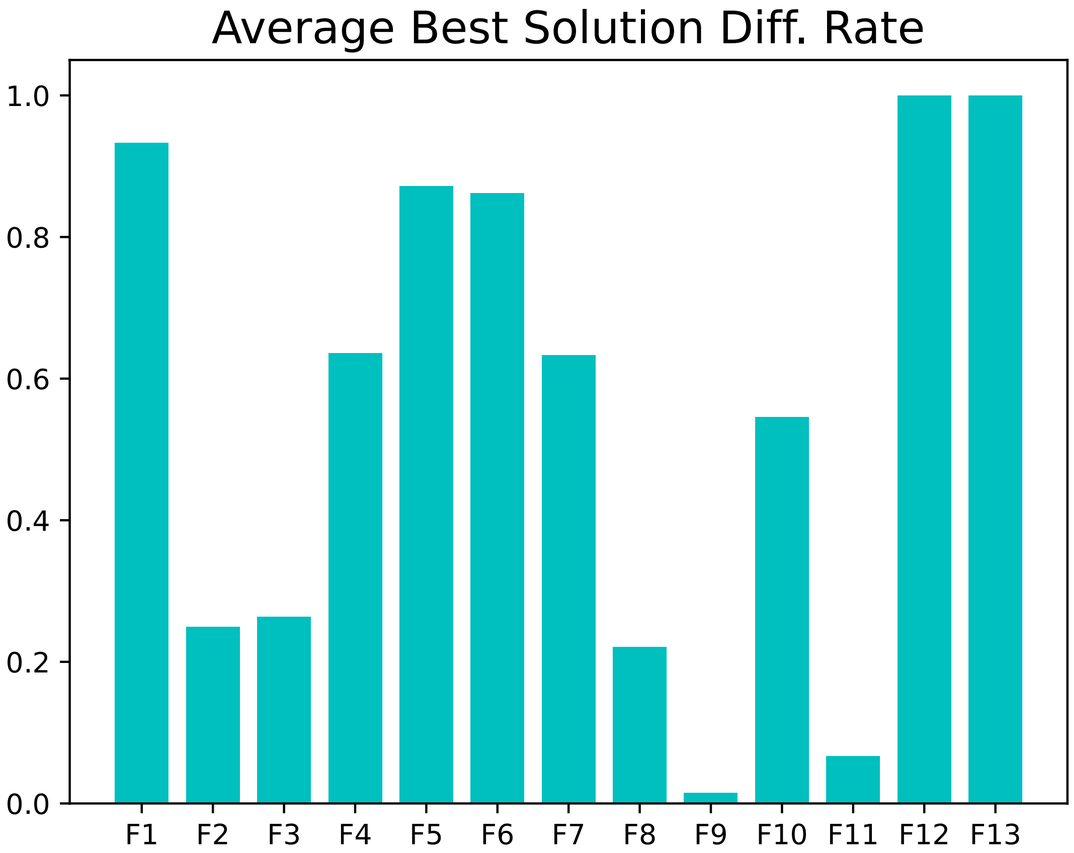
- Average best solution: abs
- Average best solution difference rate: abs_{diff}
- Average running time: art
- Average running time difference: art_{diff}

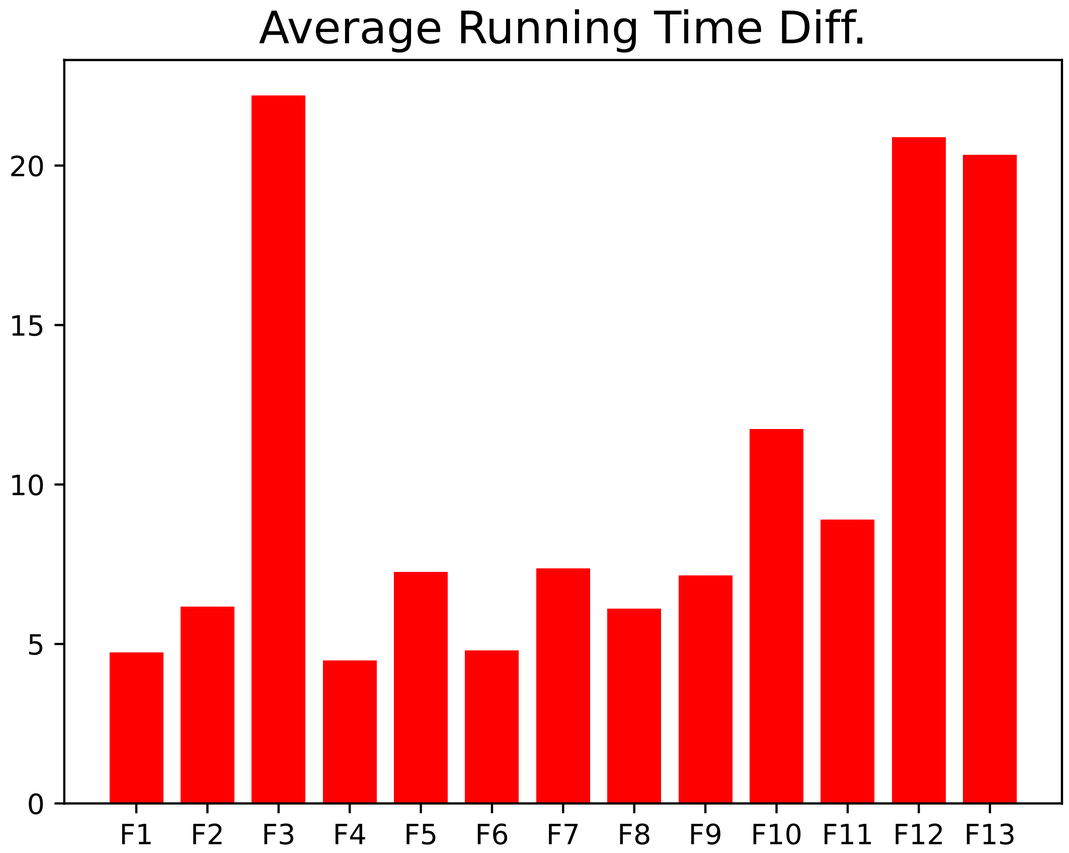
$$abs_{diff} = \frac{abs_{GOA} - abs_{PGOA}}{|abs_{GOA}|}$$

$$art_{diff} = art_{GOA} - art_{PGOA}$$

Data Analysis

Parallel Gannet Optimization Algorithm (PGOA)





56%

Better than the optimal solution of the original algorithm

6.75x

Faster than the original algorithm

Conclusion

Parallel Gannet Optimization Algorithm (PGOA)

In the higher dimension of the benchmark functions, both the optimal value and the execution speed of the PGOA are better than the original GOA because of the randomness and substitution generated by the parallel group communication strategies.

As a consequence, it will be a great attempt to apply the parallel method to solve a series of high-dimensional problems related to data mining, neural networks, and further fields in future work.

Thank you

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