On detecting the novelties in metaphor-based algorithms

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ABSTRACT

Following recent criticisms of the metaphor-based algorithms, several studies have reported that the basic core ideas of some nature-inspired algorithms are basically the same, so such methods do not bring any novelty at all. The majority of these papers dealt with the problem on the conceptual level. The aim of this study is to show how similar operations of these algorithms are on the operational level, where searching for the best solutions in the genotype space is affected by the exploration/exploitation components of the search process. In line with this, a new method is proposed for comparing the similarity of algorithms considering both levels.

CCS CONCEPTS

• **Theory of computation → Design and analysis of algorithms**.

KEYWORDS

evolutionary algorithms, nature-inspired algorithms

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1 INTRODUCTION

Recently, a flood of nature-inspired algorithms has emerged that hide their internal operations behind a striking metaphor, but actually do not bring any novelty to the computational community. Criticism of this kind of developing the nature-inspired algorithms by [3] triggered a reaction in the opposite way: Now, many contemporary papers are searching for the conceptual similarities among these algorithms and, thus, try to prove that some are only a copy of already existing methods. The majority of these studies [2, 4], however, are focused on comparing them on the conceptual level, where similarities among definitions of variation operators are searched for. There is also a lack of studies comparing the behavior of these algorithms on an operational level, where the population structures are observed on an internal level by transition over the generations [1].

This short paper tries to break this barrier by observing the behavior of the nature-inspired algorithms simultaneously on both levels: searching for new solutions proceeds within the search space (also genotype space), and evaluating their qualities in a problem space (also phenotype space). In this study, we added to the analysis of the algorithms on the conceptual level, focused on the objective function value, also the operational level that can be expressed by a population diversity measure. The measure also indicates how the exploration and exploitation components affect the evolutionary search process.

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2 RESEARCH METHODS

The problem to be solved in our study is defined formally as follows: How to identify if two different runs of the stochastic population-based nature-inspired algorithms are equivalent. A run of a stochastic population-based nature-inspired algorithm can be described in the sense of a Markov chain, as follows:

$$T : P_N^{(g)} \mapsto P_N^{(g+1)}, \tag{1}$$

where the relation designates a transition T of the population P with size N in generation g to the next generation $g+1$ caused by acting the variation operators. In each run, the best solutions according to the objective function can survive and transfer their best characteristics to the next generation, in other words:

$$F : \overline{f}^{(g)} \mapsto \overline{f}^{(g+1)}, \tag{2}$$

where function F is the transition of the average objective function $\overline{f}^{(g)}$ in the population $P_N^{(g)}$ that needs to be increased/decreased (depending on maximization/minimization problem), and the function $f : \mathbf{x}_i^{(g)} \mapsto \mathcal{R}$ maps each solution $\mathbf{x}_i \in P_N^{(g)}$ into real value. The typical run of the algorithm $R = \langle P_N^{(t)}, \overline{f}^{(t)} \rangle$ can be described as:

$$R : P_N^{(0)} \xrightarrow{\overline{f}^{(0)}} P_N^{(1)} \xrightarrow{\overline{f}^{(1)}} \ldots \xrightarrow{\overline{f}^{(G-1)}} P_N^{(G)} \overset{\overline{f}^{(G)}}{\rightleftharpoons} \tag{3}$$

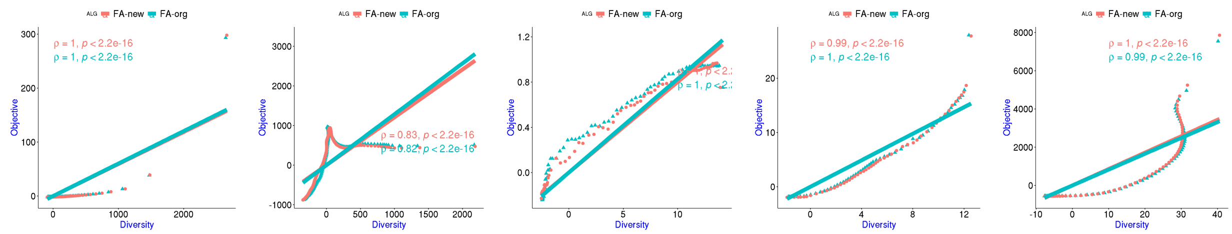
However, a population $P_N^{(g)}$ is represented as a matrix of dimension $N \times D$, and, as such, not suitable for further analysis. The more suitable for these purpose is the so-called diversity of population $I(P_N^{(g)})$ representing an extraction of knowledge collected within the current population. Diversity of population is expressed as:

$$I\left(P_N^{(g)}\right) = \sum_{i=1}^{N} \sum_{j=1}^{D} (x_{i,j}^{(g)} - \overline{x}_j^{(g)})^2, \tag{4}$$

where components of the so-called central vector $\overline{\mathbf{x}} = (\overline{x}_1, \ldots, \overline{x}_D)$ are expressed as:

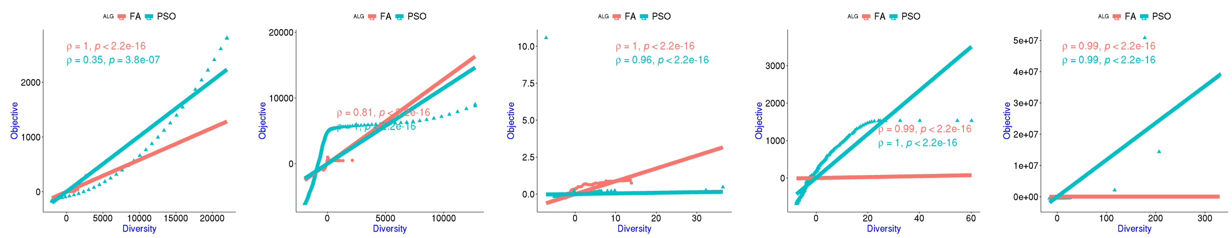
$$\overline{x}_j^{(g)} = \frac{1}{N} \sum_{k=1}^{N} x_{j,k}^{(g)}. \tag{5}$$

In this sense, the problem can be reformulated as: Let us assume runs of two different stochastic population-based nature-inspired algorithms $R_1 = \langle I(P_{1,N}^{(g)}), f_1^{(g)} \rangle$ and $R_2 = \langle I(P_{2,N}^{(g)}), f_2^{(g)} \rangle$ are given. Then, the equivalence between those runs demands that the average



(a) Function f_1 ($\alpha = 0°$). **(b) Function f_2 ($\alpha = 2°$).** **(c) Function f_3 ($\alpha = 1°$).** **(d) Function f_4 ($\alpha = 0°$).** **(e) Function f_5 ($\alpha = 1°$).**

Figure 1: Influence of the stochasticity by two instances of the FA using different seeds.



(a) Function f_1 ($\alpha = 14°$). **(b) Function f_2 ($\alpha = 3°$).** **(c) Function f_3 ($\alpha = 17°$).** **(d) Function f_4 ($\alpha = 39°$).** **(e) Function f_5 ($\alpha = 37°$).**

Figure 2: The objective/diversity measure on two stochastic population-based nature-inspired algorithms FA and PSO.

objective values $\overline{f}^{(g)}$ and the diversities of populations $P_N^{(g)}$ for $g = 1, \ldots, G$ are not significantly different in each generation.

3 EXPERIMENTS AND RESULTS

The goal of the experimental work was to determine a Spearman correlation coefficient between objective (minimization problem) and population diversity by optimizing 5 functions (Table 1) in each generation. The Spearman coefficient measures a non-parametric dependence between rankings of variables $\langle I\left(P_N^{(g)}\right), \overline{f}^{(g)}\rangle$ for $g = 1, \ldots, G$. Relationships between both variables are then illustrated as a regression line for each of the two algorithms in the test.

The experimental setup was set as follows: We tested with Firefly Algorithm (FA) and Particle Swarm Optimization (PSO) nature-inspired algorithms using parameters: $N = 50$, and $G = 200$ (the other parameter settings were taken from corresponding literature). The average results obtained after 51 independent runs were taken into consideration. These results are represented in a scatter plot with the R programming tool (Figs. 1-2), where the first figure,

Table 1: Function benchmark suite.

Nr.	Function	Domain
1	Griewank	$[-600, 600]$
2	Schwefel	$[-500, 500]$
3	Michalewicz	$[0, \pi]$
4	Quartic	$[-1.28, 1.28]$
5	Zakharov	$[-5, 10]$

obtained by running two different instances of the FA algorithm using different seeds of random generator, illustrates the influence of stochasticity, while the second the influence of two different algorithms (i.e., FA and PSO). Indeed, the angle between regression lines α shows the similarity of the algorithms in the test. This means, the smaller the angle, the more similar the algorithms. In line with this, the algorithms in Fig. 1 are similar, while the algorithms in Fig. 2 are not, except in Fig. 2b.

4 CONCLUSION

This short paper defines a measure for assessing if two algorithms are similar on the conceptual, as well as operational levels. This means, if two algorithms are similar, the angle between regression lines constructed from Spearman correlation coefficients between objective and population diversity of two algorithms must be $\alpha \leq 5°$, and, therefore, the algorithms cannot be novel. However, stronger criteria about this measure need to be determined in the future.

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