ECOLOGY INSPIRED OPTIMIZATION: SURVEY ON RECENT AND POSSIBLE APPLICATIONS IN METALLURGY AND PROPOSAL OF TAXONOMY REVISION

Martin ČECH, Martin LAMPA, Šárka VILAMOVÁ

VSB - Technical University of Ostrava, Ostrava, Czech Republic, EU,
martin.cech@vsb.cz, martin.lampa@vsb.cz, sarka.vilamova@vsb.cz

Abstract

The group of ecology inspired algorithms includes algorithms inspired by weed colony, biogeography and symbiosis. As a part of bio-inspired optimization methods are ecology inspired algorithms generating considerable interest for solving real world problems, therefore are widely investigated across many different science branches. The aim of this paper is to presents the overview of ecology inspired optimization methods, its taxonomy as well as recent and possible future application in metallurgy. Taxonomy revision proposal is being discussed in the context with further research suggestions.

Keywords: Ecology inspired algorithms, invasive weed colony, biogeography, symbiosis, multi-swarm optimization

1. INTRODUCTION

Ecology inspired optimization is one of latest group of algorithms invented within the bio-inspired optimization. It involves algorithms inspired by both interspecies and intraspecies interaction, especially the colonization patterns in weed population, biogeography concept and symbiosis. This group of algorithms may be considered as the advanced generation of methods inspired by social behavior of organisms. There are few recent real world applications of the ecology inspired algorithms in industrial environment. These are being discussed in separate chapters of this article. The main information about each type of algorithm is presented as well as further research suggestions with focus on taxonomy revision.

There is the lack of relevant articles on algorithms taxonomy and nomenclature. The complexity of algorithms taxonomy is increasing as the number of optimization methods inspired by nature is getting higher. This results in very difficult orientation in optimization methods inspired by nature. Below, in separate chapter, is presented the explanation of the need for further research in the field of Bio-inspired optimization algorithms. To a lack of comparative studies is quite difficult to decide what algorithm is the proper one to solve given optimization task. The need of exhaustive comparative study is being discussed in chapter below.

2. BIOGEOGRAPHY-BASED OPTIMIZATION

The BBO algorithm, proposed by Simon [1], uses the concepts and models of biogeography. Furthermore, BBO approaches have demonstrated ability to solve and good convergence properties on various benchmark functions and engineering optimization problems.[1]

Biogeography is the study of distribution of species in nature over time and space; that is the immigration and emigration of species between habitats. The application of this idea allows information sharing between candidate solutions. [2]

These models of biogeography describe how species migrate from a habitat to another one and how species arise or become extinct. Each solution used in the algorithm is considered as a habitat and has a habitat suitability index (HSI) that measure the suitability of the habitat. This index is related to aspects as, for example, rainfall, fauna and flora diversities, topography, and environment temperature. These aspects are also called suitability index variables (SIV).

A good habitat has a high HSI, while a poor habitat has a low HSI. This means that good habitats have more good aspects than the poor ones. Habitats with high HSI have a high immigration rate due to their good aspects, whereas poor habitats have a low immigration rate but a high emigration rate unlike good ones.

The migration rates are directly related to the number of species in a habitat. So, a habitat with many species has a high emigration rate, because it is almost saturated, while habitats with few species have high immigration rate because do not have good conditions to live in. This migration process increases the diversity of the habitat and the miscegenation and contributes to the species information sharing and the mutation probability. [3]

3. INVASIVE WEED COLONY

Invasive Weed Optimization (IWO) is a numerical stochastic search algorithm proposed by Mehrabian and Lucas [4] in 2006.

Invasive Weed Optimization is an optimization algorithm which is inspired from colonizing weeds. It is known that weeds are very robust to environmental changes and also they can easily adapt themselves to environmental changes. This algorithm is designed in order to mimic the robustness, adaptation and randomness of colonizing weeds. The experimental results obtained in the literature through the use of this algorithm have shown that the algorithm is a powerful algorithm. [4]

It is capable of solving general multi-dimensional, linear and nonlinear optimization problems with appreciable efficiency .Adapting with their environments, invasive weeds cover spaces of opportunity left behind by improper tillage; followed by enduring occupation of the field. Their behavior changes with time since as the colony become dense there is lesser opportunity of life for the ones with lesser fitness. [2]

The basic characteristic of a weed is that it grows its population entirely or predominantly in a geographically specified area which can be substantially large or small. [5]

To simulate the colonizing behavior of weeds some basic properties of the process is considered below [6]:

1) A finite number of seeds are being spread out over the search area.
2) Every seed grows to a flowering plant and produces seeds depending on its fitness.
3) The produced seeds are being randomly dispersed over the search area and grow to new plants.
4) This process continues until maximum number of plants is reached; now only the plants with lower fitness can survive and produce seeds, others are being eliminated. The process continues until maximum number of iterations is reached and hopefully the plant with the best fitness is closest to the optimal solution.

The algorithm has mainly four steps which can be explained briefly as follows [7]:

Initialization

A generation of population of initial solutions is randomly dispread over the D dimensional solution searching space.

Reproduction

Based on the fitness of the plant (initial solution), the new seeds (new solutions) will be reproduced.
The number of seeds generated for each plant is proportional to the fitness of it.

Spatial Dispersal

The new generated seeds for each plant are randomly distributed near to their parent plant. The closeness of the seeds to their parent plant is changing as the numbers of iterations are changing.

Competitive Exclusion

It is the mechanism of eliminating the plants with lower fitness in the generation after the number of plants (solutions) reaches the maximum number of plants in the colony. It is the ranking of the generated seeds together with their parent's according to their fitness values and selecting the ones with higher fitness values.

Real world applications of the Invasive Weed Colony Algorithm may be found in designing the time-modulated linear or circular antenna arrays [8], optimization of antenna configurations [6] or in Pid tuning in multivariable system [3]3. Other application may be found in a study of electricity market dynamics [9] or solution of the combined heat and power economic dispatch problem [10].

4. SYMBIOSIS-INSPIRED OPTIMIZATION: PS^{2}O

PS^{2}O algorithm was proposed by Chen and Zhu [11] in 2008. As in nature, individuals interact constantly. Within a species or a population, individual species members use information of other members to find more food more quickly and allocate more time to feed but less to look for predators than individuals do.

Two or more individuals from different species or populations can also interact with each anther to gain food, protection from enemies, a nesting site, or a combination of benefits. In biology, such heterogeneous cooperation and homogeneous cooperation in an ongoing cycle of adaptation are called symbiotic coevolution. Logically, researchers in the fields of evolutionary computation have modeled coevolution as optimization process. [11]

Straight PS^{2}O uses the analogy of a single-species population and the suitable definition of the particle dynamics and the particle information network interaction topology to reflect the social evolution in the population. However, the situation in nature is much more complex than what this simple metaphor seems to suggest. Indeed, in biological populations there is a continuous interplay between individuals of the same species, and also encounters and interactions of various kinds with other species. [14]

For further readings about optimization of decision making in virtual enterprise risk management see [14]. If interested in RFID network scheduling using a discrete multi-swarm optimizer see [12].

5. ECOLOGY INSPIRED ALGORITHMS TAXONOMY AND NOMENCLATURE

Bio-inspired algorithms can be grouped by the area of inspiration [2], as shown in **Table 1** below. So far the most researched and commonly used optimization methods are algorithms inspired by evolution, which use the principle of evolution and genetics to find usable solutions. Swarm Intelligence-based algorithms are the second well known branch of biology inspired optimization. Ecology inspired optimization is one of the most recent groups of optimization algorithms and the taxonomy is not really clear.

In general, taxonomy as a separate science is the practice and study of classification of things or concepts, including the principles that underlie such principles. In biology is taxonomy understood as a field of science that encompasses the description, identification, nomenclature and classification of organisms. In business and economics taxonomy may be described as the hierarchical classification of interest to an enterprise, organization or administration.

Table 1 Various bio-inspired optimization algorithms grouped by the area of inspiration. Source: modified [2]

Bio Inspired Algorithms		
Area of Inspiration:		
Evolution	**Swarm Intelligence**	**Ecology**
Genetic Algorithms Genetic Programming Evolution Strategies Differential Evolution Paddy Field Algorithm	Particle Swarm Optimization Ant Colony Optimization Artificial Bee Colony Algorithm Fish Swarm Algorithm Artificial Immune System Bacterial Foraging Optimization Firefly Algorithm	Biogeography-Based Optimization Invasive Weed Colony Optimization PS2O

6. TAXONOMY REVISION PROPOSAL

According to Binitha [2], as shown in **Table 1**, set of bio-inspired optimization methods is composed of three main areas of inspiration: evolution, swarm intelligence and ecology. According to Fister [13] can be all nature algorithms divided into four major categories: swarm intelligence (SI)-based, bio-inspired (but not SI-based), physics/chemistry-based, and others. In this topics discussion authors claims following about the taxonomy of nature inspired algorithms:

$$\text{SI-based} \subset \text{bio-inspired} \subset \text{nature-inspired.}$$

The classification proposed by Fister [13] is following the model published by Binitha [2]. In fact, neither classification does include a number of other well-known optimization methods that can hardly fit into any of the existing groups. The wider perspective is needed on the issue of bio-inspired optimization methods. One possible direction of the taxonomy revision may be found in biology itself. Such taxonomy would follow the division of biology into main branches such as ecology, evolution, anatomy, biogeography atc. And here the collision with the recent taxonomy may be seen because in that way the Swarm-Intelligence based algorithms will not fit directly into bio-inspired set but it will be the subset of ecology inspired algorithms. The same is true for algorithms inspired by colonization and symbiosis which may stand somewhere between ecology inspired methods and biogeography-based methods, which are now the subset of ecology inspired optimization methods.

CONCLUSION

Although ecology inspired optimization is getting more popular in solving complex multi-objective problems, its potential is still not fully used in metallurgy. There is a wide range of possible applications in various parts of metallurgy, including logistics, economics, manufacturing, scheduling and others. All possibilities should be examined to get answers on unexplored questions. The attention should be aimed to finding similarities between metallurgical problems and other real world cases to apply the similar approach. In recent applications of ecology inspired algorithms and other bio-inspired optimization methods can be found great results proving that exploring such methods is reasonable and can provide high cost savings or new beneficial solutions.

Further research should be aimed at how to compile comprehensive comparative study. This study should include, if possible, all the basic types of bio-inspired optimization methods and test these on the same reference functions. As the result a material that would facilitate orientation in the amount of bio-inspired optimization methods and foremost would become a tool for choosing the right optimization algorithm for solving the problem would be created. This study should also take into account the ambiguity of existing taxonomy of biology-inspired algorithms and it should analyze both the source of inspiration of the algorithms and the way they operate and categorize these methods to a new classification system. The system should take into account both the characteristics of the algorithms in terms of their function and taxonomy of biological sources of inspiration.

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REFERENCES

[1] SIMON, D. Biogeography-based optimization. *IEEE Transactions on Evolutionary Computation*, Vol. 12, No. 6, 2008, pp. 702-713.

[2] BINITHA, S., SATHYA, S.S. A Survey of Bio inspired Optimization Algorithms. *International Journal of Soft Computing and Engineering*, Vol. 2, No. 2, 2012, pp 137-151.

[3] SILVA, M., SILVEIRA, C. A new Biogeography-based Optimization Approach Based on Shannon-Wiener Diversity Index to Pid Tuning in Multivariable System. *ABCM Symposium Series in Mechatronics*, Vol. 5, No. 1, 2012, pp. 592-601.

[4] MEHRABIAN, A. R., LUCAS, C. A Novel Numerical Optimization Algorithm Inspired from Weed Colonization. *Ecological Informatics 1,* Vol. 1, No. 4, 2006, pp. 355-366.

[5] YIN, Z. et al. Improved Invasive Weed Optimization Based on Hybrid Genetic Algorithm. *Journal of Computational Information Systems*, Vol. 8, No. 8, 2012, pp. 3437-3444.

[6] MALLAHZADEH, A. R. Application of the Invasive Weed Optimization Technique for Antenna Configurations. *Progress in Electromagnetics Research*, Vol. 1, No. 79, 2008, pp. 137-150.

[7] GÖK, D. Evaluation of the Performances of Artificial Bee Colony and Invasive Weed Optimization Algorithms on the Modified Benchmark Functions. *Academic Research International*, Vol. 2, No. 3, 2012, pp. 142-147.

[8] BASAK, A. et al. A Modified Invasive Weed Optimization Algorithm for Time-Modulated Linear Antenna Array Synthesis. In *IEEE Congress on Evolutionary Computation.* IEEE, 2010, pp. 18-23.

[9] SAHRAEI-ARDAKANI, M. et al. A study of electricity market dynamics using Invasive Weed Colonization Optimization. In *IEEE Congress on Computational Intelligence and Games.* IEEE, 2008, pp. 276-282.

[10] SHREELAKSHMI, A. Biogeography-Based Optimization for the solution of the Combined Heat and Power Economic Dispatch Problem. *International Journal of Engineering and Innovative Technology*, Vol. 3, No. 1, 2013, pp. 429-432.

[11] CHEN, H., ZHU, Y. Optimization based on symbiotic multi-species coevolution. *Journal on Applied Mathematics and Computation,* Vol. 205, No. 1, 2008, pp. 47-60.

[12] WEI, L. et al. RFID Network Scheduling Using a Discrete Multi-swarm Optimizer. *Advances in Information Sciences and Service Sciences*, Vol. 4, No. 22, 2012, page 429-437.

[13] FISTER, I. et al. A Brief Review of Nature-Inspired Algorithms for Optimization. *Elektrotehniški Vestnik*, Vol. 3, No. 80, 2013, pp. 116-122.

[14] SHAO, Y. et al. A Multiswarm Optimizer for Distributed Decision Making in Virtual Enterprise Risk Management. *Discrete Dynamics in Nature and Society*. Vol. 2012, No. 1, 2012, pp. 1-24.