# Introduction to the Special Issue on Nature-Inspired Optimization Methods in Fuzzy Systems

## I. Introduction

THESE days, nature-inspired optimization methods are a wide range of the different algorithms which are very often used to solve complex optimization problems that cannot be efficiently solved by traditional optimization algorithms. Optimization of fuzzy systems is also a complex optimization task involving continuous, integer, and combinatorial problems. For example, selection of input attributes of the fuzzy system, design of fuzzy system structure, selection of membership functions, and selection of inference operators can be seen as combinatorial optimization problems, whereas selection of the parameters in membership functions and fuzzy rules are continuous optimization problem. In addition, optimization of a fuzzy system becomes a multiobjective optimization problems when we take both interpretability and accuracy of the fuzzy systems into account. Thus, applications of nature-inspired optimization methods and their hardware implementation are of great importance. It is our great pleasure to present this special issue of the IEEE TRANSACTIONS ON FUZZY SYSTEMS dedicated to "Nature-inspired optimization methods in fuzzy systems." The special issue focuses on the development, adaptation, application, and hardware implementation of the methods inspired by nature for optimization of fuzzy systems. Thirty six articles have been submitted to our special issue, and based on the reviewers' comments, 13 articles have been accepted for publication. These 14 accepted articles have been grouped into the four thematic sections based on the type of nature-inspired algorithm, which was used. These thematic sections are as follows:

1) evolutionary algorithms;
2) swarm intelligence algorithms;
3) hybrid nature-inspired optimization methods;
4) other nature-inspired optimization methods.

We will give a brief introduction to the articles presented in this special issue according to the aforementioned four categories.

## II. Evolutionary Algorithms

In this thematic section, we have five accepted articles. In the first article, "Semi-supervised approach to surrogate-assisted multiobjective kernel intuitionistic fuzzy clustering algorithm for color image segmentation" by Zhao *et al*., the authors present a semisupervised surrogate-assisted multiobjective kernel intuitionistic fuzzy clustering algorithm to improve the segmentation performance and time efficiency of multiobjective evolutionary clustering algorithms on the color images. Experimental results show that the proposed approach outperforms the state-of-the-art methods in the segmentation performance and time cost.

The second article is "A preference-based evolutionary biobjective approach for learning large-scale fuzzy cognitive maps: An application to gene regulatory network reconstruction" by Shen *et al*. It presents a preference-based iterative thresholding evolutionary biobjective optimization algorithm for learning fuzzy cognitive maps. The proposed strategy focuses on the knee area of the Pareto front with a preference on the solutions near the true sparsity. The experimental results demonstrate that the proposed method can obtain the proper solution providing the best tradeoff between two objectives for decision makers.

The novel multitasking genetic algorithm for fuzzy system optimization is presented in the third article, "Multi-tasking genetic algorithm (MTGA) for fuzzy system optimization" by Wu *et al*. This article proposes a novel easy-to-implement multitasking genetic algorithm, which copes well with significantly different optimization tasks by estimating and using the bias among them. The results obtained using proposed approach were compared with the eight state-of-the-art single-task and multitask approaches on nine benchmarks. The MTGA method outperformed all of them, and had lower computational cost then six of them. Also, in this article, the simultaneous optimization strategy for fuzzy system design is proposed. Using the MTGA method, fuzzy logic controllers for couple-tank water level control are optimized. The obtained results demonstrate that the MTGA method can find better fuzzy logic controllers than other approaches.

In the fourth article, "An optimized type-2 self-organizing fuzzy logic controller applied in anesthesia for propofol dosing to regulate BIS" by Wei *et al*., presents a novel data driven surrogate model and genetic programming based strategy for optimization of the type-2 self-organizing fuzzy logic controller parameters offline to handle interpatient variability. Different optimization strategies are tested and compared using pharmacological model. The results obtained using presented approach show that the proposed optimization strategy can achieve better control performance in terms of steady-state error and robustness.

The fifth article is "Intelligent approach to the prediction of changes in biometric attributes," written by Zalasinski *et al*. It presents a new approach to predicting the changes in the handwritten signature over the time. The population-based algorithm is applying to select the parameters and structure of the fuzzy

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systems, and to select reference signature for each user separately to maximize the prediction accuracy. In order to verify the effectiveness of the considered approach, the simulation using the ATVS-Signature Long-Term (SLT) signature database was performed. The obtained results confirmed that the automatic selection of signatures increases the prediction effectiveness.

## III. Swarm Intelligence Algorithms

In this section, we have three accepted articles. The first article, "Regression based neuro-fuzzy network trained by ABC algorithm for high-density impulse noise elimination" by Caliskan *et al*., presents a novel salt and pepper noise elimination method that employs a regression-based neuro-fuzzy network for highly corrupted gray scale and color images. The multiple neuro-fuzzy filters are trained using artificial bee colony algorithm combined with a decision tree algorithm. The effectiveness of the proposed method is tested on the well-known test images and the obtained results are compared with the results using other well-known methods taken from the literature. The presented results show that the proposed approach has superior performance in terms of all comparison metrics.

The article "A new type of fuzzy rule-based system with chaotic swarm intelligence for multi-classification of pain perception from fMRI" by Anter *et al*. presents a new fuzzy rule based hybrid optimization approach for dimension reduction and multiclassification problems using chaotic map, crow search optimization algorithm, and self-organizing fuzzy logic prototype. In the presented method, the chaotic map-based crow search optimization algorithm is employed to find the optimal features from ultrahigh-dimensional functional magnetic resonance imaging (fMRI). Also, the fuzzy-rule based self-organizing fuzzy logic prototype is employed for multiclassification of pain levels. Results show that the presented method can decode levels of pain and identify predictive fMRI patterns with higher accuracy, higher convergence speed, and shorter execution time. The proposed approach holds great potential to predict pain perception in clinical uses.

The third article, "Optimizing a neuro-fuzzy system based on nature inspired emperor penguins colony optimization algorithm" by Harifi *et al*., is dedicated to the optimized adaptive neuro-fuzzy inference system (ANFIS) based on the newly elaborated emperor penguins colony algorithm. The results obtained using optimized ANFIS are compared with the results obtained using other nonderivative algorithms on benchmark datasets. The presented results show that the proposed ANFIS based on the emperor penguins colony optimization algorithm possesses less error and better performance concerning the other state-of-the-art algorithms.

## IV. Hybrid Nature-Inspired Optimization Methods

We have included three accepted articles in this section. In the first article, "Multi-population nature-inspired algorithm (MNIA) for the designing of interpretable fuzzy systems," Słowik *et al*. propose a new multipopulation nature-based optimization algorithm, which uses a variety of search formulas. This algorithm is used for selecting the parameter values and the structure of fuzzy system. Also, in article paper, the interesting solutions for the interpretability of fuzzy systems with trapezoidal membership functions are presented, and the new approach of setting up trapezoidal functions, which prevents them from overlapping with each other, is proposed. The approach shown in this article was tested using well-known classification benchmarks. The results obtained using proposed method have a good compromise between the accuracy and the interpretability of the fuzzy system.

The second article concerns a new hybrid method that is based on particle swarm optimization (PSO) algorithm and genetic algorithm (GA); it is "A new hybrid particle swarm optimization and genetic algorithm method controlled by fuzzy logic" by Dziwinski *et al*. In the proposed algorithm, some of the particles in the PSO algorithm are modified by crossover and mutation operators used in GAs. For better control of the impact of genetic operators on the optimization process in the current state of PSO algorithm, the neuro-fuzzy system is introduced for the dynamical determination of the strength with which the genetic operators will affect the process of finding the optimal solution. The results obtained using proposed approach demonstrate advance of the presented method over the original PSO algorithm and its selected modifications.

In the third article, "A hybrid intelligent approach to integrated fuzzy multiple depot capacitated green vehicle routing problem with split delivery and vehicle selection," Mehlawat *et al*. propose a hybrid genetic algorithm to produce efficient solutions in the vehicle routing problem with generalized fuzzy travel times, multiple depots, split delivery (including interdepot split), and heterogenous, capacitated alternative fuel driven vehicles. Five alternative fuel vehicles, such as diesel, hybrid, electric, CNG, and biodisel, are evaluated using fuzzy hierarchical technique for order preference by similarity to ideal solution. The respective scores obtained after evaluation are input in the hybrid genetic algorithm for suitable assignment of vehicles to routes. The experimental results and comparative analysis prove the strength of the presented approach.

## V. Other Nature-Inspired Optimization Methods

This section consists of two accepted articles. The first is "Water cycle algorithm tuned fuzzy expert system for trusted routing in smart grid communication network" by Velusamy *et al*. The authors propose a novel trust evaluation framework that employs water cycle optimization algorithm for automatic tuning of the rule set and membership function for the decision variables. Variables, such as distance, link stability, and node honesty, are taken into consideration for evaluation using the water cycle optimization algorithm. An experimental setup is created using network simulator-2 to check the performance of the proposed trusted routing algorithm in smart grid communication network. From the results obtained during simulation, it is obvious that the rule set and membership function generated by presented approach are small and compact enough to provide reliable routing in smart grid communication network.

The second article is "Small lung nodules detection based on fuzzy-logic and probabilistic neural network with bio-inspired reinforcement learning" by Capizzi *et al*. The authors present an evaluation model based on a composition of fuzzy system combined with a neural network for examination of the internal organs using screening methods. The proposed model was validated by using X-ray images with lung nodules. The results obtained using proposed method shows the higher performance with sensitivity and specificity reaching almost 95% and 90%, respectively (with an accuracy equal to 92.56%).

## VI. Summary

In summary, we would like to note that this special issue covers only a limited part of nature-inspired optimization methods and their applications in fuzzy systems. Nevertheless, it represents the current state of the art of the topics. The Guest Editors expect that the articles presented in this special issue will stimulate further research and will represent a reference point (for a quite long time) for researchers working in this exciting research area.

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