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Intuitionistic fuzzy logic control of metaheuristic algorithms' parameters via a generalized net

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Abstract: In this paper a Generalized Net (GN) model of Intuitionistic fuzzy logic (IFL) control of metaheuristic algorithms' parameters, is proposed. IFL controller is used to tune dynamically algorithm parameters. The GN-model describes the process of parameters control, trying to improve the algorithm performance.

Keywords: Generalized Net, Intuitionistic fuzzy logic, Parameters control, Metaheuristics.
AMS Classification: 03E72, 65Q85, 68T20.

1 Introduction

In recent years metaheuristic techniques have been successfully applied in a variety of optimization tasks. Metaheuristic is a top-level strategy that guides an underlying heuristic solving of a given problem [21]. Following Glover [10], "metaheuristics in their modern forms are based on a variety of interpretations of what constitutes intelligent search". The family of metaheuristics includes, but is not limited to, adaptive memory procedures, tabu search, ant systems, greedy randomized adaptive search, variable neighborhood search, evolutionary methods, genetic algorithms, scatter search, neural networks, simulated annealing, and their hybrids [18].

One of the main challenges of the field of optimization computation is appropriately varying parameter values during an algorithm run (parameter control) [9]. In order to increase the performance of the regarded algorithms it is necessary to provide the adjustments of their parameters depending on the considered problem.

Finding robust control parameters setting is not a trivial task, since their interaction with algorithm performance is a complex relationship and the optimal one are problem-dependent [11]. An optimal or near-optimal set of control parameters for one metaheuristic algorithm does not generalize to all cases. This stresses the need for efficient techniques that help finding good parameter settings for a given problem, i.e. the need for good parameter tuning methods.

In [9] authors present that any static set of genetic algorithm parameters, having the fixed values during the algorithm run, seems to be inappropriate. It is intuitively obvious that different values of parameters might be optimal at different stages of the evolutionary process [13]. For instance, large mutation probability can be good in the early generations helping the exploration of the search space and small mutation probability might be needed in the late generations to help fine tuning the individuals.

The problem of finding optimal control parameters for Genetic algorithms (GA) has been studied by [8, 9, 13] and fuzzy control of evolutionary algorithm parameters has been discussed in [11, 20]. In [15], the use of Intuitionistic fuzzy logic (IFL) [4–6] has been investigated for control of GA parameters. Authors propose a generalized net (GN) model describing the IFL control of crossover and mutation probability.

IFL and Intuitionistic fuzzy sets (IFS) have gained recognition as a useful tool for control uncertain phenomena. In [1] authors described the development of an IFL controller for heater fans, developed on the basis of intuitionistic fuzzy systems. Intuitionistic fuzzy inference systems and defuzzification techniques are used to obtain speed of the heater fan from an intuitionistic fuzzy input – ambient temperature. The speed of the heater fan is calculated using intuitionistic fuzzy rules applied in an inference engine using defuzzification methods.

Up to now, using the apparatus of GN [3] few GN-models, regarding GA performance, were developed. The first GN-model describes the GA search procedure [2, 7]. The apparatus of GN is also applied to a description of different GA operators – crossover operator [12] and mutation operator [16].

In this paper, we use the model presented in [15] to propose IFL controller for parameters control of any metaheuristic algorithm. The main idea is to use i number of IFL controllers. The controllers inputs are current algorithm performance measures and which outputs are algorithm control parameters – p_i. Current performance measures of the metaheuristic algorithm are sent to the IFLCs, which computers new control parameters values that will be used by the metaheuristic algorithm. The proposed strategy for updating of p_i is to consider the changes of the average objective function value in the algorithm decision compared to the defined maximum and minimum objective function value.

2 IFL controllers

According to Atanassov [4–6], an IFS on the universum $X \neq \varnothing$ is an expression A given by:

$$A = \{\langle x, \mu_A(x), \nu_A(x)\rangle \mid x \in X\}, \tag{1}$$

where the functions

$$\mu_A, \nu_A : X \to [0, 1] \tag{2}$$

satisfy the condition

$$0 \le \mu_A(x) + \nu_A(x) \le 1 \tag{3}$$

and describe, respectively, the degree of the membership $\mu_A(x)$ and the non-membership $\nu_A(x)$ of an element x to A. Let

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x), \tag{4}$$

therefore, function π_A determines the degree of uncertainty.

Considering objective function of the solution in the metaheuristic algorithm it can be assigned intuitionistic maximum and minimum values ($OF_{\max}$ and $OF_{\min}$). So, if the average fitness function (OF_{ave}) of the current decision set falls between these values, then it cannot be determined unambiguously whether it is a “good algorithm performance” or “poor algorithm performance”. Conversely, values outside the intuitionistic limits can be unambiguously assigned to one of the two categories. The following membership functions are defined:

$$\mu_A : OF_{\text{ave}} \le OF_{\min}, \tag{5}$$

$$\nu_A : OF_{\text{ave}} \ge OF_{\max}, \tag{6}$$

$$\pi_A : OF_{\min} < OF_{\text{ave}} < OF_{\max}. \tag{7}$$

In a minimization problem, when average objective function value at the algorithm iteration t ($OF_{\text{ave}}(t)$) is less than $OF_{\min}$ we have “well-performing” operators, so the algorithm parameter p_i will keeps it value. If $OF_{\text{ave}}(t)$ is greater than $OF_{\max}$ we have “poorly performing” operators, so the algorithm parameter p_i has to be changed based on the predefined scheme [15]. If $OF_{\text{ave}}(t)$ fall between $OF_{\min}$ and $OF_{\max}$ than the algorithm parameters have to be changed based on the predefined scheme.

The change of the p_i value is updated using the following equations:

$$p_i(t) = p_i(t-1) \pm \Delta p_i(t), \tag{8}$$

where $\Delta p_i(t)$ is calculated by the i-th IFL controller.

3 Generalized net model

In this paper, we use the model presented in [15] to propose IFL controller for parameters control of any metaheuristic algorithm. The generalized net model is illustrated in Figure 1.

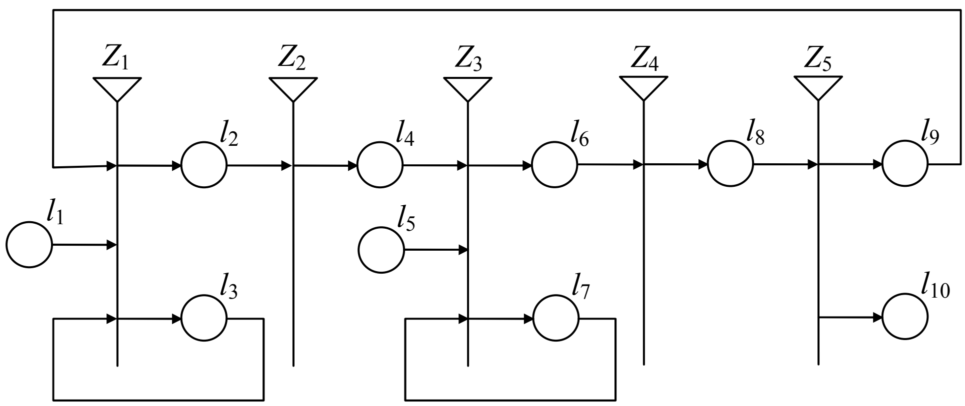

Figure 1. GN-model of IFL control of metaheuristic algorithm parameters

The token α enters GN through place l_1 with an initial characteristic "Algorithm parameters". The form of the first transition of the GN-model is

$$Z_1 = \langle\{l_1, l_3, l_9\}, \{l_2, l_3\}, r_1, \vee(l_1)\rangle,$$

$$r_1 = \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & true & false \\ l_3 & true & true \\ l_9 & false & true \end{array}$$

The token α obtains the characteristics "Metaheuristic algorithm" in place l_2 and characteristics "$\Delta p_i(t)$" in places l_3 and l_9. In the place l_2 could be replaced any GN-model of metaheuristic algorithm. For example, GN-model of standard GA [2], GN-model of Multi-population GA [19], GN-model of Firefly algorithm [17], GN-model of Bat algorithm [14].

The form of the second transition of the GN-model is

$$Z_2 = \langle\{l_2\}, \{l_4\}, r_2, \vee(l_2)\rangle$$

$$r_2 = \begin{array}{c|c} & l_4 \\ \hline l_2 & true \end{array}$$

In place l_4, the token α obtains the characteristic "$OF_{\mathrm{ave}}(t)$". The token β enters GN through place l_5 with an initial characteristic "$OF_{\min}$, $OF_{\max}$".

The form of the third transition of the GN-model is

$$Z_3 = \langle\{l_4, l_5, l_7\}, \{l_6, l_7\}, r_3, \wedge(l_4, l_5, l_7)\rangle,$$

$$r_3 = \begin{array}{c|cc} & l_6 & l_7 \\ \hline l_4 & false & true \\ l_5 & true & false \\ l_7 & true & true \end{array}$$

The tokens α and β are combined in a new token γ in place l_6. The new token γ obtains the characteristics "Algorithm performance". In place l_7, the token α keeps the characteristics "$OF_{\mathrm{ave}}(t)$" in place l_3.

The form of the fourth transition of the GN-model is

$$Z_4 = \langle\{l_6\}, \{l_8, l_9\}, r_4, \vee(l_6)\rangle,$$

$$r_4 = \begin{array}{c|c} & l_8 \\ \hline l_6 & true \end{array}$$

The token γ obtains the characteristics "$\Delta p_i(t)$" in place l_8.

The form of the fifth transition of the GN-model is:

$$Z_5 = \langle\{l_8\}, \{l_9, l_{10}\}, r_5, \vee(l_8)\rangle,$$

$$r_5 = \begin{array}{c|cc} & l_9 & l_{10} \\ \hline l_8 & W_{8,9} & \neg W_{8,9} \end{array}$$

where $W_{8,9}$ = "end of the process is not reached".

The token γ obtains the characteristics "$\Delta p_i(t_{\text{end}})$" in place l_{10}.

4 Conclusions

One of the main challenges of the field of metaheuristic computation is the parameter control. In order to increase the performance of the algorithms it is necessary to tune the algorithm parameters during the computation. Such procedure is not a trivial task. In this paper, the Intuitionistic Fuzzy Logic for control of metaheuristic algorithm parameters is used. A Generalized Net model describing the algorithm parameters IFL controllers is considered. Proposed GN-model performs fine-tuning of considered parameters, during the algorithm run, using IFL controllers.

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