Information Sciences 285 (2014) 35–49

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

Type-1 and Type-2 fuzzy logic controller design using a Hybrid PSO–GA optimization method

Ricardo Martínez-Soto [a], Oscar Castillo [a,*], Luis T. Aguilar [b]

[a] Tijuana Institute of Technology, Calzada Tecnologico s/n, Fracc. Tomas Aquino 22379, Tijuana, Mexico
[b] Instituto Politécnico Nacional, Ave. Del Parque 1310, Mesa de Otay Tijuana, 22510 Tijuana, Mexico

ARTICLE INFO

Article history:
Received 29 January 2013
Received in revised form 17 June 2014
Accepted 6 July 2014
Available online 15 July 2014

Keywords:
Fuzzy logic controller
Genetic algorithm
Particle swarm optimization

ABSTRACT

In this paper we propose a Hybrid PSO–GA optimization method for automatic design of fuzzy logic controllers (FLC) to minimize the steady state error of a plant's response. We test the optimal FLC obtained by the Hybrid PSO–GA method using benchmark control plants and an autonomous mobile robot for trajectory tracking control. The bio-inspired method is used to find the parameters of the membership functions of the FLC to obtain the optimal controller for the respective plants. Simulation results show the feasibility of the proposed approach for these control applications. A comparison is also made among the proposed Hybrid PSO–GA, with GA and PSO to determine if there is a significant difference in the results.

1. Introduction

Optimization is a term used to refer to a branch of computational science concerned with finding the "best" solution to a particular problem. Here, "best" refers to an acceptable (or satisfactory) solution to a problem, which may be the absolute best over a set of candidate solutions, or any of the candidate solutions. The characteristics and requirements of the problem determine whether the overall best solution can be found [11]. Bio-inspired optimization algorithms are search methods, where the goal is to find a solution to an optimization problem, such that a given objective function is optimized, possibly subject to a set of constraints [11,27,33]. Some optimization methods are based on populations of solutions [33]. Unlike the classic methods of optimization, in this case, each iteration of the algorithm maintains a set of solutions. These methods are based on generating, selecting, combining and replacing a set of solutions. Since they maintain and manipulate a set, instead of a unique solution throughout the entire search process, they require more computer time than other meta-heuristic methods. This fact can be aggravated because the "convergence" of the population requires a great number of iterations. For this reason a concerted effort has been dedicated to obtaining methods that are more aggressive and manage to obtain solutions of quality in a nearer horizon.

This paper is concerned with the generation of Type-2 fuzzy logic controllers using bio-inspired optimization methods, and in particular the Hybrid PSO–GA approach that is proposed in this work. In this case, we combine each of the individual methods (PSO and GA) in order to obtain the best features to design an optimal fuzzy logic controller (FLC) applied to benchmark control problems. Better results are expected of the Hybrid PSO–GA method than those of the traditional methods, like GA and PSO, because of the mixing of the best characteristics of both individual methods. We are also comparing the

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* Corresponding author. Tel.: +52 6646236318.

E-mail addresses: mc.ricardo.martinez@hotmail.com (R. Martínez-Soto), ocastillo@hafsamx.org (O. Castillo), luis.aguilar@ieee.org (L.T. Aguilar).

http://dx.doi.org/10.1016/j.ins.2014.07.012

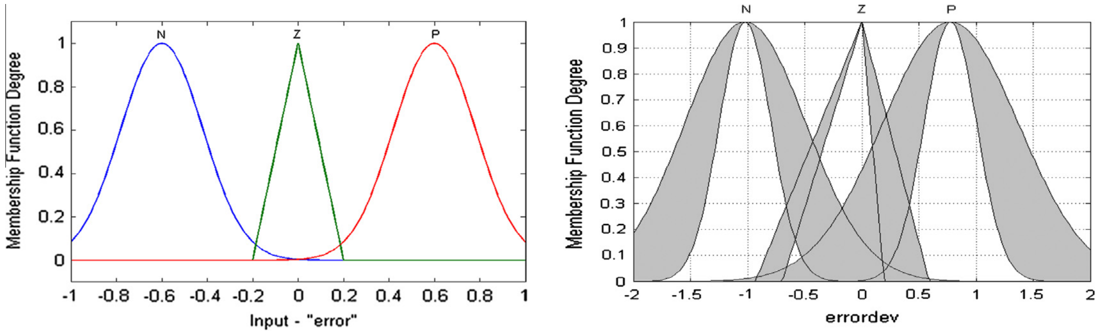

Fig. 1. Gaussian and triangular membership functions and Table 1 show the fuzzy rules.

Table 1
Fuzzy rules of the FLC.

	Negative	Zero	Positive
Negative	N	N	Z
Zero	N	Z	P
Positive	Z	P	P

Table 2
Parameters of the membership functions.

Plant 1				Plant 2			
MF type	Point	Min value	Max value	MF type	Point	Min value	Max value
Gauss	a	0.3	0.6	Gauss	a	1.8	2.8
	b	−1.2	−0.8		b	−6	−4
Triang	a	−0.8	−0.3	Triang	a	−3	−0.5
	b	0	0		b	0	0
	c	0.3	0.8		c	0.5	3
Gauss	a	0.3	0.6	Gauss	a	1.8	2.8
	b	0.8	1.2		b	4	6

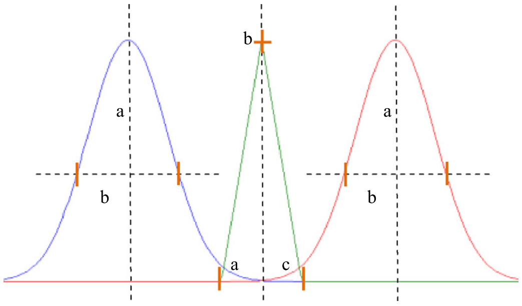

Table 3
Results of the Type-1 FLC obtained by hybrid PSO–GA method for Plant 1.

No.	Individuals/particles	Iterations/generations	C1	C2	Inertia	% Remp	Cross	Mut	Time execution	Average error
1	70	200	0.2706	0.0403	0.3254	0.7	0.7	0.2	1:46:07	0.10956
2	200	70	0.1780	0.4863	0.5381	0.7	0.5	0.2	1:20:14	0.11375
3	200	70	0.8963	0.3534	0.6738	0.7	0.7	0.1	1:18:21	0.11517
4	200	70	0.4743	0.5077	0.5163	0.7	0.6	0.2	1:28:50	0.11559
5	200	70	0.4587	0.6339	0.1024	0.7	0.5	0.5	1:42:23	0.11584
6	150	80	0.7293	0.1387	0.8532	0.7	0.7	0.1	1:15:23	0.11971
7	90	75	0.2521	0.3490	0.9708	0.7	0.5	0.2	0:25:14	0.12240
8	200	70	0.8149	0.9059	0.1314	0.7	0.5	0.1	1:33:46	0.12325
9	80	100	0.5159	0.0732	0.1455	0.7	0.6	0.1	0:48:21	0.12488
10	90	35	0.2110	0.9645	0.1126	0.7	0.5	0.2	0:17:52	0.12853