Alexandria Engineering Journal 87 (2024) 448–477

Contents lists available at ScienceDirect

Alexandria Engineering Journal

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

Original Article

Reduced order infinite impulse response system identification using manta ray foraging optimization

Shibendu Mahata [a], Norbert Herencsar [b,*], Baris Baykant Alagoz [c], Celaleddin Yeroglu [d]

[a] Department of Electrical Engineering, Dr. B. C. Roy Engineering College, Durgapur, PO 713206, India
[b] Department of Telecommunications, Faculty of Electrical Engineering and Communications, Brno University of Technology, Technicka 12, 616 00 Brno, Czechia
[c] Department of Computer Engineering, Faculty of Engineering, Inonu University, 44000 Malatya, Turkey
[d] Department of Computer Engineering, Faculty of Engineering and Natural Science, Iskenderun Technical University, 31200, Iskenderun, Hatay, Turkey

ARTICLE INFO

Keywords:
Infinite impulse response system
Manta ray foraging optimization
Mean square error
Metaheuristics
Non-parametric statistical tests
System identification

ABSTRACT

This article presents a useful application of the Manta Ray Foraging Optimization (MRFO) algorithm for solving the adaptive infinite impulse response (IIR) system identification problem. The effectiveness of the proposed technique is validated on four benchmark IIR models for reduced order system identification. The stability of the proposed estimated IIR system is assured by incorporating a pole-finding and initialization routine in the search procedure of the MRFO algorithm and this algorithmic modification contributes to the MRFO algorithm when seeking stable IIR filter solutions. The absence of such a scheme, which is primarily the case with the majority of the recently published literature, may lead to the generation of an unstable IIR filter for unknown real-world instances (particularly when the estimation order increases). Experiments conducted in this study highlight that the proposed technique helps to achieve a stable filter even though large bounds for the design variables are considered. The convergence rate, robustness, and computational speed of MRFO for all the considered problems are investigated. The influence of the control parameters of MRFO on the design performances is evaluated to gain insight into the interaction between the three foraging strategies of the algorithm. Extensive statistical performance analyses employing various non-parametric hypothesis tests concerning the design consistency and convergence are conducted for comparison of the proposed MRFO-based approach with six other metaheuristic search procedures to investigate the efficiency. The results on the mean square error metric also highlight the improved solution quality of the proposed approach compared to the various techniques published in the literature.

1. Introduction

The ability of the natural world to evolve and solve complex problems forms the source of inspiration for all nature-inspired metaheuristic algorithms [1]. The application domains of swarm intelligence and evolutionary algorithms encompass nearly every engineering and scientific discipline [2,3]. For instance, such nature-inspired algorithms (NIAs) have demonstrated highly efficient performance in solving complex optimization problems in chaos theory [4], control system [5], biomedical signal processing [6], etc. In recent years, the advent of convolutional neural network (CNN) and deep learning techniques [7,8] have opened up new application paradigms for the metaheuristic algorithms, such as compression of deep neural networks [9], design of CNN and deep CNN architectures for solving image classification problems [10–12], parameter optimization of deep belief networks [13], etc.

The popularity of the NIAs stems from their capability to handle a wide variety of optimization problems, such as linear, nonlinear, unimodal, multimodal, multi-dimensional, large-scale, constrained or unconstrained, and convex or non-convex ones. These algorithms incorporate diversification to explore the search space, followed by intensification to locally search the potential solution space iteratively [14]. Several surveys, trends, and guidelines on the adaptability and implementation of these non-classical algorithms to the real-world scenario continue to evolve the future research direction in this domain [15–17]. In recent years, the incorporation of ensemble strategies, multi-population topologies, etc., have gained prominence for particle

* Corresponding author.
E-mail addresses: shibendu.mahata@bcrec.ac.in (S. Mahata), herencsn@vut.cz (N. Herencsar), baykant.alagoz@inonu.edu.tr (B. Baykant Alagoz), celaleddin.yeroglu@iste.edu.tr (C. Yeroglu).

https://doi.org/10.1016/j.aej.2023.12.054
Received 3 October 2023; Received in revised form 12 December 2023; Accepted 26 December 2023
Available online 5 January 2024