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Research Article

Solving Frequency Modulation Sound Parameter Identification Problem using a Modified Shuffled Particle Swarm Optimization

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Abstract

Frequency-Modulated (FM) sound wave synthesis has an important role in modern music systems to optimize the parameter of an FM synthesizer. This paper proposes a modified version of shuffled particle swarm optimization (SPSO) for solving two versions of the frequency modulation sound parameter identification (FMSPI) problem. i.e nested-modulator FM and double-modulator FM. *In the SPSO* a population is divided into several parallel groups and then each group is improved in an evolutionary process using a particle swarm optimization (PSO). This research on one side, focuses on partitioning stage of SPSO. Three different partitioning strategies are employed and compared together. On the other side, a new methodology to update inertia weigh factor of SPSO is presented and evaluated. A geometric partitioning provides a good exploration of search space and independent local search of each group leads to a deep exploitation. Also new proposed idea to update inertia weight factor prevents for stagnation and a premature convergence of algorithm. The obtained results demonstrate that the geometric partitioning and new method to update the inertia weight factor led to a considerably better performance of algorithm than other compared strategies so that the SPSO using these strategies is very effective and robust. Also, a comparison of the SPSO against other evolutionary algorithms reported in the literature confirms a better or at least comparable performance of our proposed algorithm.

Keywords: Frequency modulation, Inertia weigh factor, Parameter identification, Partitioning, Shuffled particle swarm optimization.

Highlights

- Applying a partitioning method based on the geometric position of the members in the SPSO algorithm.
- Presenting a new strategy for updating inertia weight coefficients based on the structure of the SPSO.
- Applying the SPSO algorithm on two versions of the FMSPI problem for the first time.
- Investigating the effect of applying the methods proposed in this research on the performance of the SPSO.

Citation: [in Persian].

1. Introduction

Frequency-Modulated (FM) sound wave synthesis has an important role in several modern music systems and to optimize the parameter of an FM synthesizer. This problem is called as the frequency modulation sound parameter identification (FMSPI). In order to solve this problem, it is firstly modeled in the form of an optimization problem and then an optimization method is employed to extract its parameters. So this problem can be modeled as a parameter estimation. Parameter estimation utilizes optimization methods to find the best parameter values. Historically, parameters estimation has been primarily treated by the least-squares method. The least-squares method is only suitable for the model structure of system having the property of being linear in the parameters. Once the form of model structure is not linear in the parameters, this approach may be invalid [1]. So tendency of recent researches to solve these problems has been propelled to heuristic algorithms especially with stochastic search techniques. Among heuristic approaches, evolutionary algorithms (EAs) have attracted wide research attention.

In recent decades, EAs are progressively being applied to different parameter estimation problems [2]. Among EAs, the particle swarm optimization (PSO) is an EA which has been attracted many researchers in different fields of optimization problems [3,4]. The PSO simulates the movement of organisms and social behaviour in a flock of birds or school of fishes. To improve the performance of original PSO, various concepts have been proposed in the literature. Ahandani et al. [5] proposed a shuffled PSO (SPSO) by providing a parallel search ability for the pure PSO algorithm. The SPSO partitions the population into several parallel subsets. The different subsets will perform local search using a PSO algorithm.

2. Innovation and contributions

In this paper, the identification of the non-linear parameters of frequency modulation sound parameter identification (FMSPI) problem is formulated in terms of an optimization problem. Then it is proposed a modified version of shuffled particle swarm optimization (SPSO) for solving two versions of the FMSPI problem. Previous studies in the field of evolutionary algorithms with partitioning ability always used a classical method based on the merit of each member to partition the population members. On the other hand, the algorithm proposed in this study tries to provide a new strategy for updating the inertial weight coefficients. The innovations and highlights of this research are as follows:

- Applying a partitioning method based on the geometric position of the members in the SPSO algorithm, comparing with different partitioning methods and selecting the method with the best efficiency based on the simulation results.
- Presenting a new strategy for updating inertia weight coefficients based on the structure of the SPSO algorithm and comparing with other existing methods.
- Applying the SPSO algorithm on two versions of the FMSPI problem for the first time.
- Investigating the effect of applying the methods proposed in this research on the performance of the SPSO algorithm by applying it to the FMSPI problem and comparing the results obtained against other references

3. Materials and Methods

To provide parallel search ability for the PSO, a shuffled PSO (SPSO) was proposed by Ahandani et al. [6]. In these algorithms after generation of initial population randomly from search space, members of population are sorted as a decreasing order according to their value of function evaluation. Then population is partitioned into several parallel subsets. The different subsets perform a local search independently using an evolutionary process to evolve their quality for a defined maximum number of iterations. Then all subsets shuffle together and the stopping criteria are checked that if are not met, the partitioning, local search and shuffling process are continued. The SPSO uses the original PSO in its local search stage as an evolutionary strategy.

There are several strategies to be used for inertia weight factor. These new strategies to update inertia weight factor prevents for stagnation and primary convergence of SPSO algorithm.

Partitioning is one of the main stages of SPSO algorithm. Since the SPSO is a combination of PSO and shuffled frog leaping (SFL) algorithms, so it uses classic partitioning stage employed in SFL. The SFL divides members based on their cost functions value. Another partitioning strategy can be performed using geometric positions of members in the search space. The main idea of this method is based on grouping vicinity members in a same group. In this study, Euclidian metric is used as a distance metric. Beside of cost and geometric partitioning methods, to examine their efficiency, aforementioned partition methods are compared with a random partitioning.

4. Results and Discussion

The SPSO with different partitioning strategies is tested on two versions of the FMSPI problem. The obtained results of clearly confirm a considerably better performance of a SPSO with a geometric partitioning way in terms of all considered aspects. Based on results of this research, the proposed strategies in this paper to update inertia weight factor based on global optimum in first strategy and number of function evaluations in the second one, outperform original strategies.

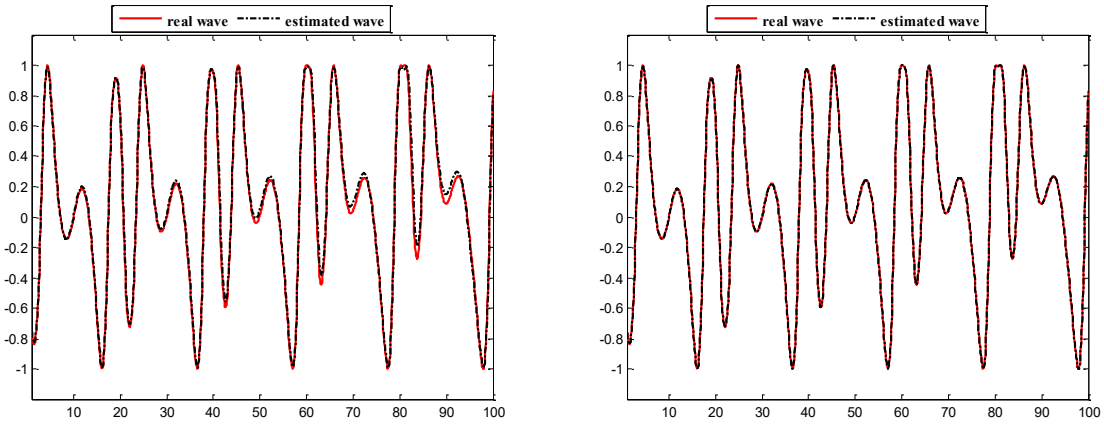
A comparison among SPSO with geometric partitioning, and results of different algorithms proposed in [7] is presented in Table 1. Also Table 2, another study was performed by comparison of the SPSO and algorithms proposed in [8]. In an overall view, this paper employed a geometric partitioning instead of classical cost partitioning for the SPSO algorithm and also a new strategy to update inertia weight factor. The obtained results on FMSPI problems showed that aforementioned strategies are promising and effective ideas to evolve the SPSO. A geometric partitioning provides a good exploration of search space and independent local search of each group leads to a deep exploitation. Also new proposed idea to update inertia weight factor prevents for stagnation and a premature convergence of algorithm.

Table 1. A comparison between the SPSO and results reported in [7] on nested-modulator FM.

Algorithm	Success Rate				The Best Results	
	5E-1	1E-1	1E-2	1E-10	Mean-Best	Min-Cost
SPSO Geometric partitioning	**100**	**100**	**100**	**80**	5.6339e-09	6.1776e-15
GA	15	10	5	0	2.0e-2	3.7e-3
QB	5	5	0	0	4.9e-2	4.9e-2
DE	0	0	0	0	-	5.1E0
PSO	40	40	40	40	**1.7E-21**	**0**
Memetic	10	10	10	0	4.2E-3	5.7E-4
Memetic-QB	10	5	5	0	1.5E-1	1.1E-3
MNM-DE	10	5	5	0	1.3E-2	1.3E-4
MNM-PSO	60	60	60	0	2.0E-5	5.6E-6

Table 2. A comparison between the SPSO and different algorithms reported in [8] on nested-modulator FM.

Mean best-of-run solution (Std Deviation)			
SADE	NSDE	DEGL/SAW	SPSO- Geometric partitioning
7.8354e−02	9.4559e−03	4.8152e−09	6.6918e-05
(5.8254e−03)	(6.924e−01)	(6.2639e−08)	(2.3202e-04)



(a) (b)

Figure 1. The real wave and estimated wave on nested-modulator FM, (a) real and estimated wave for value of cost equal to 0.5, (b) real and estimated wave for value of cost equal to 1.0E-10.

A comparison between the real wave and the estimated wave by SPSO on nested-modulator FM for values of cost function equal to 0.5 and 1.0E-10 are shown in Figure 1.

5. Conclusion

Frequency-Modulated (FM) sound wave synthesis has an important role in modern music systems to optimize the parameter of an FM synthesizer. To extract parameters of FM sound wave, firstly it is modeled as an optimization problem called FMSPI problem, and then an optimization method is employed to estimate its parameters. For solving this problem, this study proposed a modified version of SPSO. The SPSO divides a population into several parallel groups and then improves each of them in an evolutionary process using a PSO. This research focused on partitioning stage of SPSO and updating its inertia weight factor. Three different partitioning strategies was employed and their performance were compared on two FMSPI problem, i.e. nested-modulator FM and double-modulator FM. Also a new strategy to update the inertia weight factor based on number of function evaluations was proposed. The obtained results demonstrate that that the proposed strategies lead to a considerably better

performance of algorithm than its classic strategies. Using aforementioned methods, The SPSO was very effective and robust so that it produced similar and promising results over repeated runs. Also a comparison of the modified SPSO against other evolutionary algorithms reported in the literature confirmed a better or at least comparable performance of our proposed algorithm.

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Morteza Alinia Ahandani: Conceptualization, Methodology, Data curation, Investigation, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **Hosein Alavi-Rad**: Writing – review & editing, Methodology, Visualization; **Mohammad Khoshhal**: Writing – review & editing, Methodology, Visualization.