Design of optimal IIR digital filter using Teaching-Learning based optimization technique

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Abstract: - In this paper an Enhanced Teaching-Learning Based Optimization (ETLBO) algorithm is employed to design stable digital infinite impulse response (IIR) filter using L_p-norm error criterion. The original TLBO algorithm has been remodeled by merging the concept of opposition-based learning and migration for selection of good candidates and to maintain the diversity, respectively. The multiobjective IIR digital filter design problem considers minimizing the L_p-norm approximation error and minimizing the ripple magnitude simultaneously while satisfying stability constraints on the coefficients of the filter. Weighted sum method and p-norm method are applied to solve the multicriterion optimization problem . Best weight pattern is searched using evolutionary search method that minimizes the performance criteria simultaneously. The validity of the method is demonstrated for the design of low pass (LP), high pass (HP), band pass (BP) and band stop (BS) IIR filters. The comparison of simulation results with other existing methods show that the proposed ETLBO algorithm is superior in terms smaller L_1-norm error, L_2 -norm error and smaller pass band and stop band ripples.

Key-Words: - IIR filter, TLBO, magnitude response, stability, L_p-approximation error.

1 Introduction

Filters are mainly used for extorting informative part of the signal and to remove undesirable component of the signal. Extorting of signal is required when a noise or some disturbance contaminates a signal [1]. Digital filters have attracted the attention of researchers due to large number of application like data communication, video processing, radar and optical communications, speech processing and many more. In terms impulse response, digital filters are widely categorized as infinite impulse response (IIR) and finite impulse response (FIR) filters [2]. The selection of digital filter for an application is a tedious task involving finding of optimum structure in order to satisfy certain parameters of frequency response, namely ripples in pass band, transition band width and attenuation in stop band. Digital IIR filters are preferred over FIR digital filters because of higher computational efficiency and accurate frequency selectivity. The two problems with the design of IIR digital filter are [3-4]: (i) tendency of the filter to become unstable (ii) filter error surface is multimodal in nature due to which conventional design optimization algorithms may stuck at local minima. The stability problem is handled by imposing stability constraints on the filter coefficients. Numerous evolutionary and meta-heuristic optimization algorithms have been successfully applied to handle the non-differentiable and multimodal error surface of digital IIR filter. Some evolutionary optimization algorithms recently applied for digital IIR filter are: genetic algorithms [5-10], immune algorithm [11], particle swarm optimization [12-14], seeker-optimization-algorithm [15], predator-prey optimization [16], heuristic search method (HSM) [17], two-stage ensemble evolutionary algorithm [18], gravitation search algorithm [19] and many more.

The main drawbacks of the above algorithms are slow convergence towards optimal solution and the requirement of algorithm specific controlling parameters in addition to regular controlling parameters like size of population, number of iterations, group size etc. In order to overcome the above drawbacks, teaching-learning based optimization (TLBO) algorithm developed by Rao et al. [20-21] has been applied to design the digital IIR filters. TLBO is a heuristic search method inspired by the learning behavior of the students in a class. There is no need to tune any algorithm

The scrutinizing of the results presented in Tables 3-6 reveal that ETLBO obtains smaller L_1-norm approximation errors, the smaller L_2–norm approximation errors, and better magnitude performances in both pass-band and stop-band than HGA [8], HTGA [10], TIA [11] and HSM [17]. The designed LP, HP, BP and BS IIR digital filter with ETLBO are tested for stability by drawing pole-zero diagrams shown in Figure 3. It can be observed from Figure 3 that the designed filters follow the stability constraints imposed in the design procedure as all the poles lie inside the unit circle. The stability of filter is not influenced by the zeros lying outside the unit circle.

5 Conclusion

In this paper a heuristic algorithm ETLBO is successfully applied to design digital IIR filter and gives substantial improvement in terms of results and convergence. The performance of the original TLBO is enhanced with the introduction of the concept of opposition-based learning and migration for starting with good population of learners and maintain the diversity of the learners, respectively. ETLBO is very feasible to design the digital IIR filters, particularly when the complicated constraints, the design requirements, and the multiple criteria are all involved. The designed optimal filters meet the stability criterion, gives better performance in terms of L_p-approximation error for magnitude response and ripples in pass band and stop band in comparison to existing methods. The advantage of applied ETLBO algorithm is that it do not requires to tune any algorithm-specific parameters.

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