ABSTRACT

Digital filtering is one of the most powerful tools of Digital Signal Processing (DSP). The use of Digital filters in implementing high-performance circuits in a digital signal environment is becoming increasingly popular. Digital filters are capable of performance specifications that would, at best, be extremely difficult, if not impossible, to achieve with an analog implementation. In addition, the characteristics of a digital filter can be easily changed under software control for further processing.

In general, digital filter design is usually a two-step process. In the first step, a mathematical description of the filter fulfilling the design criteria is derived. This description is then transformed in the second step. The second step deals with the realization of digital filters. Our work only deals with the first step. Digital filters are classified either as finite-duration impulse response (FIR) filters or infinite-duration impulse response (IIR) filters, depending on the form of impulse response of the system. In the FIR system, the impulse response sequence is of finite duration, i.e., it has a finite number of non-zero terms. Digital infinite-impulse-response (IIR) filters can often provide a much better performance and less computational cost than their equivalent finite-impulse-response (FIR) filters and have become the target of growing interest. Since the error surface of digital infinite-impulse response (IIR) filters is generally nonlinear and multimodal, global optimization techniques are required in order to avoid local minima. Hence, the Calculation of coefficients is one of the most recurrent additional complications in the IIR digital filters problem. This thesis investigates the optimization techniques for the design of IIR digital filters. Keeping in view of the various applications and advantages of IIR digital filters, the following are the objectives of the proposed work:

- To ascertain the evaluation of various Evolutionary computations for the optimization of digital filters.
- To find solutions for the Coefficients of IIR digital filters and the Implementation of optimization Algorithms for IIR digital filter designing.
- Simulation and analysis of IIR digital filters using Evolutionary trends and to propose the applications of ACO/PSO in IIR Digital filters.

Analytical or simple iterative methods usually lead to sub-optimal designs. Consequently, there is a need of optimization methods (heuristic type) that can be used to design digital filters that would satisfy prescribed specifications. An alternate approach ADM (analog to digital mapping) has been presented in this work. Metaheuristics way has become greater choice for solving COP (combinatorial optimization problem) because of their multi-solution and strong neighborhood search capabilities in

a reasonable time. Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and Simulated Annealing (SA) are the main class among population and neighborhood search metaheuristics. Hence different GAs and SAs along with hybridization of Genetic Algorithm and Simulated Annealing (GASA) have been proposed for optimal calculation of coefficients of IIR digital filter design.

The performance among different heuristics and metaheuristics-based hybrid approaches has been compared with the help of two performance parameters, i.e., mean square error (MSE) and mean standard deviation (MSD). To check stability, the effects of Poles and Zeros on the filter has been analyzed and discussed. Further, the performance in term of transfer function has been evaluated on the basis of coefficients, which gives magnitude and phase response. To improve transition band performance, managing the frequency response has been considered separately as one of the critical factors.

Experimentation is done for a low-pass filter with following specifications: Pass band ripple 1 dB, Stop band ripple 15 dB, Pass band edge 200 Hz, Stop band edge 400 Hz and a sampling frequency of 1000 Hz. Another simulation is done for design of a high-pass filter with following specifications: Pass band ripple 1 dB, Stop band ripple 75 dB, Pass band edge 700 Hz, Stop band edge 300 Hz with sampling frequency of 1500 Hz. The examples have been used by many authors as a "benchmark filter" for comparison purpose. Simulation is performed on MATLAB with Pentium IV, 2.80 GHz CPU and 1GB of RAM, for instance ranges from 1 to 2 minutes.

The performance analysis of various optimization techniques for IIR digital filters has been carried out in terms of MSE and MSD, Moreover the impulse response is also evaluated with 50 samples. Design of Lowpass and High pass IIR digital filter is proposed to estimate the transition band.

Further, Proposed hybrid GASA, also proves to be an effective approach for optimizing coefficients of IIR digital filters as compared to PSO, GA and SA alone. The main advantage of GASA is that, it provides optimal coefficients and minimum MSE & MSD.

WORK REPORTED IN THE THESIS

After covering the introduction of digital signal processing and digital filters. The detailed literature survey is reported in Chapter 1. This chapter provides the Research gaps, motivation, objectives, research methodology, followed by publications.

The development and design of IIR digital filters are given in Chapter 2. Basic equation of IIR digital filters is introduced. In this chapter mapping technique from s-domain to z-domain has been employed. As analog filters are easier to design, a novel technique to map analog filters into digital filters has been proposed in this chapter. The designed GUI m-file is given as package for IIR digital filters using ADM, which is easier and user friendly. *(This work has been accepted as tool box by MATLAB and available with Mathworks Inc. USA).*

Here, the characteristics of Butterworth, Chebyshev (Type I and II) and Elliptic digital filters are employed. Flow chart for the design of IIR digital filter using analog to digital mapping is discussed. It provides the screenshot for the designed IIR digital filters using ADM. Further, results obtained by ADM have also been shown here for comparison with *fda* tool available in MATLAB. The value of MSE and MSD was found to be 0.3296 and 0.3140 respectively for LP filter. The values of MSE and MSD that we have obtained for the HP filter are 3.0589 and 1.4682, respectively.

Chapter 3 covers design of IIR digital filter using Simulated Annealing. Pseudo code of SA for IIR digital filter is given. It provides the results of IIR digital filter through SA. The best value of MSE and MSD was found to be 0.3284 and 0.3129 respectively for LP filter at a temperature gradient 100, initial temperature of 100 and at finishing condition of 500. At the same specifications, the values of MSE and MSD that we have obtained for HP filter are 2.9967 and 1.4534 respectively. The reported algorithm provides better results in term of coefficients and transition band.

In chapter 4, the optimal design of an IIR digital filter using a Genetic algorithm is presented. Pseudo code of GA for IIR digital filter is used. The results of IIR digital filter through GA are provided in this chapter. The best value of MSE and MSD was achieved to be 0.3275 and 0.3105 respectively for LP filter at population size of 50, generation size of 500, crossover probability of 0.8, mutation probability of 0.02 and at stochastic universal selection. At the same specifications, the values of MSE and MSD for HP filter are 2.9913 and 1.4529 respectively. This algorithm gives modified results, as compared to those in previous chapter.

Chapter 5 shows the design of an IIR digital filter using particle swarm optimization. This chapter pertains to particle swarm optimization for digital filters. This provides the Pseudo code of PSO for IIR digital filters. The results of IIR digital filter through PSO are shown. The best value of MSE and MSD was obtained to be 0.3195 and 0.3101 respectively for LP filter at population size of 50, generation size of 500, maximum weighted factor of 0.95 and with acceleration constants c_1 and c_2 each equal to 2. At the same specifications, the values of MSE and MSD for HP filter are 2.9817 and 1.4503 respectively. This algorithm shows better results than SA and GA as reported in chapter 3 and 4.

Chapter 6 targets the design of IIR digital filter using Hybrid algorithm. Here, the hybridization of GA and SA is proposed. The results of IIR digital filter through GASA are provided in term of coefficients for low and high pass IIR digital filter. The results reveal that among the above techniques used in previous chapters, the GASA gives the best results in terms of coefficients (Numerator and Denominator) for low-pass IIR digital filter are a_0 = 0.3649, a_1 = 0.7281, a_2 = 0.3649, b_1 = 1.0, b_2 = 0.2851 and b_3 = 0.1691. The best value of MSE and MSD was obtained as 0.3177 and 0.3086 respectively for LP filter at a temperature gradient of 100, initial temperature of 100, at finishing condition of 500, population size of 50, generation size of 500, crossover probability of 0.8, mutation probability of 0.02 and at stochastic universal selection. At the same specifications, the values of IIR digital filters in term of coefficients (Numerator and Denominator) for high-pass IIR digital filter are a_0 = 0.0004218886, a_1 = -0.00161024, a_2 = 0.00229933, a_3 = -0.0014555, a_4 = 0.000344561, b_1 = 1.0, b_2 = 3.15992, b_3 = 3.80985, b_4 = 2.069939, and b_5 = 0.426703. The values of MSE and MSD for HP filter are 2.9764 and 1.4497 respectively. The results of designed filters with various proposed heuristic algorithms are concluded with the help of a mean-square-error and mean-standard-deviation.

In the end, Chapter 7 is devoted to concluding remarks, recommendations, and future scope of work.