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Survey Paper of Digital FIR Filter Design

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Abstract—Digital filtering occupies an extremely important position in digital signal processing. There are various classes of digital filter like IIR filter and FIR filter. FIR filter is widely applicable due to stability, linear phase and non recursive nature. The Differential Evolution is a population based algorithm which has been proposed particularly for various numeric optimization problems. In this work, new DE algorithm based on reserved genes known as Eclectic Differential evolution has been applied to the design of digital FIR filter. This method enhances the ability of global search and increases diversity of population.

Keywords— FIR filter, Window Method, Differential Evolutionary Algorithm, Eclectic DE

I. INTRODUCTION

Digital Filter is a system based on mathematical operations which is applied on the sampled and discrete time signal to reduce or obtain certain aspects of that signal. It is of two types- Finite impulse response filter and infinite impulse response filter. Finite Impulse Response (FIR) filters are often used in many phase-sensitive applications because they can always be designed to have linear phase. They are inherently stable due to its poles which lies at the origin.
The transfer function of an FIR filter is given by the equation

And the difference equation describing FIR filter is given by

(2)

When input function x(n) is the unit sample function δ(n) and the output y(n) can be obtained by applying the recursive algorithm on eqn.(2). We get output y(n) due to the unit sample input δ(n) to be exactly the values b(0), b(1), b(2), b(3), . . . , b(M). The output due to unit sample function δ(n) is the unit sample response or the unit impulse response represented by h(n). Then the samples of the unit impulse response h(n) = b(n), which means that the unit impulse response h(n) of the discrete-time system described by the difference equation (2) is finite in length. That is why the system is called finite impulse response filter. It has also been known by other names like transversal filter, non recursive filter, moving-average filter, and tapped delay filter. Hence h(n) = b(n) in the case of an FIR filter, we can represent (1) in the following form:

(3)

FIR filters can be designed by using different types of methods, but most of them are based on ideal filter approximation. The objective is not to enhance ideal characteristics but to achieve sufficiently good characteristics of a filter. The transfer function of FIR filter approaches the ideal as the filter order increases, thus increasing the complexity and amount of time required for processing input samples of a signal being filtered. Due to its simplicity and efficiency, window method is most commonly used method for designing filters. The characteristics of the transfer function and its deviation from ideal frequency response depend on the filter order and window function in use.

II. WHY WE USE EVOLUTIONARY ALGORITHMS

The area of signal processing and mostly design of digital filter is being currently influenced by a number of evolutionary computational mechanisms. Techniques like Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Differential Evolution (DE) have been popularly used in designing FIR and IIR filter over the last few years. Amongst them, DE has particularly developed unique interest amongst researchers because of its inherent simple as well as effective construction along with its limited number of control parameters.

A. Differential Evolutionary Algorithm:

A DE algorithm for global optimization has been proposed by Storn and Price in year 1995. It is a new heuristic approach for minimizing the non-linear and non-differentiable continuous space function. It uses few control parameters, which has made the algorithm very much popular particularly for parallel computation purpose. This particular type of evolutionary approach comprises of four steps: namely Initialization, Mutation, Crossover or Recombination and Selection. It mainly involves the following parameters: (1) size of population N, (2) dimension D (also known as chromosome length) of a individual (also known as variables), (3) Scaling factor F, (4) Crossover probability CR. In DE, N solution vectors are randomly created at the begin. This population is successfully improved by applying operators like mutation, crossover, and selection. The types of DE, are called DE1, DE2, DE3. The basic algorithm of new DE algorithm is DE3.

DE3 (Eclectic Differential Evolution):

1. The evolution of DE3 is described by the equation:

(3)

in which r, r1, r2 ∈[0,N-1] are randomly chosen and they must be different from each other. Fitness of $\vec{x}_{r;G}(t)$ is not less than the fitness of $\vec{x}_{i;G}(t)$. F is usually set between random numbers 0 and 2.

2. Crossover and Selection

The parent vector is mixed with the mutated vector to produce trial vector as:

in which $rnd_t \in [0, 1]$ is also a random number, $CR \in [0, 1]$, $rn_i \in D$. The performance of the produced trial vector and its parent are compared and the better one is selected. Then the better one of the trial solution and its parent wins the competition; this provides the significant advantage of converging performance over the GA.

B. DE ALGORITHM BASED ON RESERVED GENES(Eclectic differential evolution)

In this paper, eDE is the basic form of DE algorithm. The new eDE algorithm employs reserved genes of selected individual to increase the diversity of population during the evolution process. This method enhances the ability of global search. This algorithm is effective to avoid the problem of local optimal solution. The average fitness of the previous generation population is compared with the average population fitness of the present generation to determine whether convergence. If the result of the comparison is same and the fitness of best individual is also equal, it will use reserved genes of selected individuals to be out of local optimum solution.

1. *Array reserved genes*

Initially, population is constructed from the solutions randomly and distributed within the search space uniformly. 2 arrays which are named as elite and loser are used. The elite array stores the best individual and the loser array stores the worst individual. The genes of the individual in these arrays can be replaced with other genes in each generation. One different combination of the genes can form a new individual and this new individual is implemented by using differential evolution with other individuals. The population diversity is improved by this method. 2 arrays which are named as best1 and best2 must be set. They stored the contemporary global best individual and the previous global best individual. These arrays must reserve the contemporary and the previous average fitness, too.

2. *Differential evolution*

Selected an individual from population is named x, then another individual named y whose fitness is not less than the fitness of individual x is randomly selected. The other two individuals are randomly selected. These selected individuals employs the equation (3), (4) to perform crossover and mutation step. This method will not only maintain the population diversity, but also improves the convergence speed. It is known as an eclectic method of selection. It can generate new individual named as z which is compared with x and comparative results are as follows:

a) The fitness of individual z is respectively higher than the fitness of x and y. It will be replaced x with z. The selected part of genes of z are stored in elite array and the selected part genes of x are stored in loser array. In this algorithm, selected part genes are randomly selected from these individuals.

b) The fitness of z is higher than the fitness of x but smaller than fitness of y. It will be replaced x with z. The selected part genes of individual y are stored in elite array and the selected part genes of x are stored in loser array.

c) The fitness of z is smaller than the fitness of x and y. The z is eliminated. But the selected part genes of individual y are stored in elite array and the selected part genes of z are stored in loser array. Then the individual z and elite array employs the equation (3), (4) to perform crossover and mutation. It generates the new individual named z1. If the fitness of z1 is higher than the fitness of x, it will be replaced x with z1. It performs same crossover and mutation process. The purpose is to add new individual to the population.

3. *Mutation*

First, n individuals where $n < N$ is selected. It has been suggested $n = 10$ to be more suitable in this paper. Second, these selected individuals and elite array employs the equation (3), (4) to perform crossover and mutation respectively. Probability of mutation is very small.

4. *To reduce the number of identical individuals*

If each generation population contains many individuals with the same fitness, it will be easy to fall into local optimum and easy to convergence. Hence, it must eliminate the same individuals. But, it reserves a small number of the same individual for the convergence. The number of the same individuals is counted in each generation. It can only reserve m the same individuals in each generation. It has been suggested $m = 5$ to be more suitable in this paper. If the number is equal to m, m_{th} is selected to perform crossover and mutation process with loser array. The generated new individual is named as v.

a) If fitness of v is higher than the fitness of m_{th} individual. It will be replaced m_{th} individual with v. The selected part genes of individual v are stored in elite array and the selected part genes of the m_{th} individual are stored in loser array.

b) If fitness of v is small than the fitness of m_{th} individual. It will also be replaced m_{th} individual with the v. Then the selected part genes of v are stored in loser array and the selected part genes of m_{th} individual are stored in elite array. This can be also considered as degraded. But it increases the diversity of the population. Then the bad individual must replace one of the same individual. But this does not cause degradation to the entire population.

E. Examination whether convergence

While the best individual within both the previous generation and the present generation is equal, the average fitness of the previous generation and the present generation is compared. It is determined whether convergence by this method. If the average fitness of the previous generation and the average fitness of the present generation are same, it will perform differential evolution to use the elite array and the loser array. The evolved new individual is called v1.

a) If the fitness of v1 is greater than the fitness of elite. It will be replaced elite with v1.

b) If the fitness of v1 is smaller than the fitness of loser. It will be replaced loser with v1.

It will replace one individual with the v1.This individual is also randomly selected and differential evolution is run n1 times. A total of m1 individuals are replaced with the different v1.In this paper, n1 is taken as 100.

III. RELATED WORK:

Differential Evolution Particle Swarm Optimization for Digital Filter Design: Particle swarm optimization (PSO) and differential evolution particle swarm optimization (DEPSO) have been used for the design of linear phase finite impulse response (FIR) filters. Two types of different fitness functions have been studied and experimented, each having its own significance. The first study considers a fitness function which is based on the passband and stopband ripple, while the second study considers a fitness function based on the mean squared error between the actual and the ideal filter response. It seems that DEPSO is more suitable for adaptive systems in fast changing environment where quick convergence is the key factor [1].

Design of Low Power, High Performance FIR Filter using Modified Differential Evolution Algorithm: A modified Differential Evolution (MDE) algorithm has been used to generate optimized coefficients for digital FIR filters to reduce it's power consumption. The filters designed using MDE and the standard Remez Exchange method (REM) are synthesized in 90nm technology and their performances are also compared. The critical delay, area and power of MDE implementation are found to be improved by 6%, 12% and 16%respectively with respect to REM [15].

Self Balanced Differential Evolution: Two modifications are proposed in order to avoid stagnation while keeping a good convergence speed for DE: one is the introduction of a new control parameter (Cognitive Learning Factor) and other is dynamic setting of scale factor. Both modifications are proposed in Mutation step of DE algorithm. The proposed Strategy named as Self Balanced Differential Evolution balances the Exploration and the exploitation capability of the DE. Improvement is shown in terms of reliability, efficiency and accuracy through the intensive statistical analysis [16].

Optimization of Control Parameter of Differential Evolution Algorithm for Efficient Design of FIR Filter: In this paper, we have studied the effect of an important control parameter namely, the Weighting Factor, on the convergence speed of the DE algorithm which is associated with the efficient design of low-pass FIR filter being used subsequently as a pulse-shaping filter in a QPSK modulated system. Finally, the optimized value of weighting Factor is 0.7 for the specific design of FIR filter being supported by experimentally measured eye diagram [14].

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IV. CONCLUSION:

The new eDE algorithm has been applied to the design of digital FIR filters of different orders. The new eDE algorithm is proved to be more fit to design the filters with higher order and the eDE or GA is fit to design the filters with lower order. It would perform much better and faster to obtain approximation of the filter coefficients. This method enhances the ability to search the optimal solution of the algorithm. And this algorithm is effective to avoid the local optimal solution.

Future Work:

Further research is required to improve the new eDE algorithm and to be integrated with evolvable hardware.

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