An approach to study Genetic Algorithm for IIR Adaptive Filters

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ABSTRACT
In this paper we present the approach of Genetic Algorithm in designing of Infinite Impulse Response Adaptive Filters. There are different applications of Adaptive Filters. In this paper we represent the involvement of Genetic Algorithm in the application of Adaptive Filters.

Keywords
Evolutionary Algorithm, Genetic Algorithm (GA), Infinite Impulse Response (IIR), Adaptive Filter

1. INTRODUCTION
The design of Digital IIR filters is a multistage process, which includes the optimization of ordering, structure, coefficient wordlengths and coefficient values .These parameters are traditionally regarded as separate operations and optimal in certain aspects, but not optimal overall .It is possible to perform several of these optimal parameters simultaneously by including the multiple criterion optimization ability of GAs[1] .

Traditionally, adaptive signal processing has been carried out using Finite Impulse Response filters. The uni-modal property of their mean square error surfaces allows adaptive algorithms based on gradient search techniques to be applied. IIR filters are generally less computationally expensive due to their recursive nature and thus give better performance for a given order of filter. Two approaches have been taken in IIR filter adaptation, the equation -error and output-error formulations.

An IIR filter can be described by the following recursive expression:

$$y(n)= \sum_{K=0}^{N} a_k \; x(n-k) - \sum_{k=1}^{M} b_k \; y(n-k)$$

Where a_k and b_k are the coefficients of the filter. x(n) and y(n) are the input and output, and N and M are the number of a_k and b_k filter coefficient, with M≥N. The above expression can be rearranged as

$$\sum_{K=0}^{N} a_k \; x(n-k) = \sum_{k=0}^{M} b_k \; y(n-k)$$

This has the equivalent transfer function of

$$H(z)=\left(\sum_{K=0}^{N} a_k z^{-k}\right)/\left(1+\sum_{k=1}^{M} b_k z^{-k}\right)$$

An important task for the designer is to find values of a_k and b_k which produce the desired response. A common way to realizing IIR filters is to cascade several second order structure together , the output from first feeding is the input of next. This type of filter has a transfer function of

$$H(z)=\prod_{K=1}^{N/2} \left[(a_{0k}+a_{1k}\, z^{-1}+a_{2k}\, z^{-2})/(1+b_{1k}\, z^{-1}+b_{2k} z^{-2})\right]$$

Once suitable filter coefficients have been obtained, finite wordlength (FWL) analysis must be performed in order to determine how the filter will change when it is implemented in a real- world FWL system. When the filter coefficients a_k and b_k are quantized, this can have undesirable effects on the filter's behavior . The few applications of Adaptive filter are as follows:

- Identification
- Inverse modeling
- Prediction
- Interference cancellation

Following figure show the block diagram of Adaptive Filter. Where x (n) is input signal, y (n) is output signal, d (n) is reference signal and e (n) is error signal.

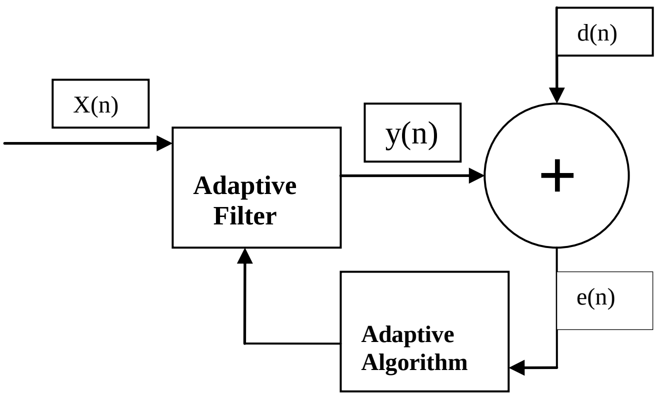

Fig. 1 Block diagram of Adaptive Filter

2. LITERATURE REVIEW

Genetic Algorithms (GAs) are a broader class of Meta-heuristics. It is based on the common idea of adopting principles from natural evolution in simplified ways. In the literature, genetic algorithms are widely used for optimization for Adaptive Filter design and its different applications [3]-[14].

3. NOMENCLATURE IN GA

Since Gas applies operations drawn from the nature, the nomenclature used in this field is closely related to terms we can find in biology.

Table1.Nomenclature in GA

iotype	code ,devised to represent the ameters of problem in the form string
omosome	encoded string of ameters(binary ,Gray, Floating nt,etc
ividual	of more chromosomes with associated fitness value.
ie	encoded version of a ameter of the problem being ved.
ele	ue which a gene can assume
us	position that the gene upies in the chromosome
notype	blem version of the genotype
iess	l value indicating the quality n individual as a solution of blem.
ironment	s is represented as a function ication the suitability of notype
ulation	et of individuals with their ociated statistics.
ection	icy for selecting one individual n the population
ssover	eration that merges the otypes of two selected parents ield two new children.
tation	eration that spontaneously nges one or more alleles of the otype.

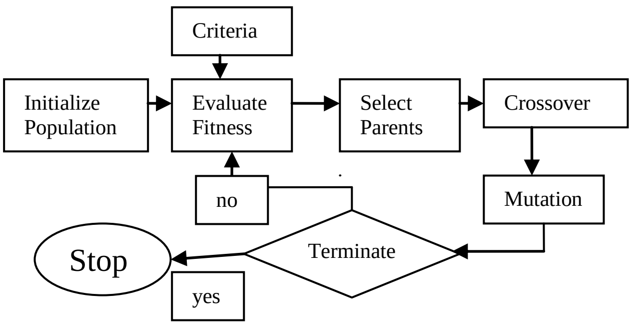

Figure 2.A simple Genetic Algorithm

4. GENETIC ALGORITHM

The modern GA was proposed by Holland [15] to understand adaptation in artificial systems. It is a powerful optimization scheme based upon an evolutionary computation technique that models genetics and natural selection. There are four main characteristics of the GA that set it apart from traditional optimization algorithms. The GA

- Operates on a representation of the problem function, not the function itself.
- Optimizes a set of candidate solutions rather than a single solution.
- Evaluates solutions with payoff and cost rules rather than supplementary knowledge.
- Uses probabilistic, rather than deterministic, transition rules.

Three important concepts of natural evolution theory are variation, selection, and reproduction. Genetic variation within a species population is necessary to provide enough information and resources for evolution to proceed towards the desired result. A lack of variation can lead to sub-optimal species development. Selection is the method of choosing which individuals from a population should be used to build subsequent future generations. The most important requirement of the GA is to balance exploration of the search space with the exploitation of available solution information. Exploration is necessary for the GA to be a global optimization strategy, and exploitation is needed for the GA to perform local searches and fine tune solutions. The balance of the two is achieved through the selection, crossover, and mutation strategies chosen for the GA

.

4.2 Crossover:

The crossover Genetic operator redistributes genetic material within population. It is generally the first genetic operator applied after selection. Several different crossover strategies have been integrated into theGA, but the most common are

- single-point crossover
- double-point crossover
- uniform crossover

4.3 Mutation:

During the optimization and convergence process it is sometimes necessary to remove undesirable genetic material from the population to overcome local optima. Furthermore, there is no guarantee that all necessary optimal genetic information appears in the population at a given generation. Therefore, the mutation operator has been developed to introduce new or lost genetic material into the population.

4.4 Methodology of GA:

The general procedures of the GA are as follows:

a) Initialize a population of binary or non-binary chromosomes.
b) Evaluate each chromosome in the population using the fitness function.
c) Select the chromosome to mate (reproduction).
d) Apply Genetic operators (crossover and mutation) on chromosome selected.
e) Put produced chromosomes in a temporary population.
f) If the temporary population is full, then go to step g), otherwise go to step c).
g) Replace the current population with the temporary population.
h) If termination criterion is satisfied, then quit with the best chromosome as the solution for the problem, otherwise, go to step b).

5. APPLICATION OF GA FOR IIR ADAPTIVE FILTER

- Classical hill-climbing optimization methods have succeeded in certain cases but are less suited to the general design task which can be mixed, can have many local minima, and have high dimensionality [2].GA optimization methods have emerged as a powerful approach to solving the more difficult optimization problem. *Arslan and Horrocks* present the work on single-step design of finite wordlength IIR digital filter that simultaneously satisfy magnitude and phase specification. For details see [2].
- Adaptive IIR filters offer a number of potential advantages over their FIR counterparts if only a reliable method of adaptation can be found. In [4], a method of adapting IIR filters are implemented as lattice structures using a Genetic Algorithm.
- [13] Presents a new paradigm for infinite impulse response (IIR) filter design using GA. By encode or transform the filter design problem into the z-plane the GA optimization procedure will be simplified. Additionally, given the z-plane encoding new mutation techniques are introduced, with the intention to locate promising regions in the search space. With proper design of the fitness function, the proposed algorithm can be used to evolve either full precision or quantized filter structures. For details see [13].
- The design of recursive digital filter which minimizes both the magnitude and group delay simultaneously under the multi-objective optimization is shown in [12]. Multi-Objective problem are solved to generate non-inferior solutions under interactive environment. Multi-Objective problem of magnitude and group delay is solved using Multi-Objective Genetic Algorithm that operates on a complex, continuous search space and is optimized by statistically determining the abilities of commonly used genetic operators.
- There are two important problems encountered in the design of adaptive IIR filters, i.) The filter can not show an intrinsic stable behavior during the adaptation process, it sometimes becomes unstable, ii.) They can not always reach to the optimal solutions because of their multi-modal error surfaces [5]. There has been an increasing interest in adaptive IIR filters because they provide better performance than FIR filters that have the same degree and they also decrease the hardware cost. To overcome the difficulties of the adaptive IIR filter design, evolutionary based optimization algorithms can be used [5].
- A novel algorithm for digital infinite-impulse response (IIR) filter design is proposed in [11]. The suggested algorithm is a kind of cooperative co evolutionary genetic algorithm. It considers the magnitude response and the phase response simultaneously and also tries to find the lowest filter order. The structure and the coefficients of the digital IIR filter are coded separately, and they evolve coordinately as two different species, i.e., the control species and the coefficient species. The simulated annealing is used for the coefficient species to keep the diversity. Comparisons with another genetic algorithm-based digital IIR filter design method by numerical experiments show that the suggested algorithm is effective and robust in digital IIR filter design [11].

6. CONCLUSION

In this paper, we have overviewed the techniques of GAs for IIR Adaptive Filter design. We described the classification, application and main feature of GA for IIR filter design. We presented GA for optimizing the IIR Adaptive Filters. In this paper we presented how Genetic Algorithms work for optimization of IIR Adaptive Filters.
Genetic Algorithms have some possible extension of the work in terms of optimization of Adaptive Filter design via hybridization. We can use different search method for optimizing the different parameter of Adaptive filters.

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