Design of Digital Filters Using Genetic Algorithms

by

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Abstract

In recent years, genetic algorithms (GAs) began to be used in many disciplines such as pattern recognition, robotics, biology, and medicine to name just a few. GAs are based on Darwin’s principle of natural selection which happens to be a slow process and, as a result, these algorithms tend to require a large amount of computation. However, they offer certain advantages as well over classical gradient-based optimization algorithms such as steepest-descent and Newton-type algorithms. For example, having located local suboptimal solutions they can discard them in favor of more promising local solutions and, therefore, they are more likely to obtain better solutions in multimodal problems. By contrast, classical optimization algorithms though very efficient, they are not equipped to discard inferior local solutions in favour of more optimal ones.
This dissertation is concerned with the design of several types of digital filters by using GAs as detailed below.

In Chap. 2, two approaches for the design of fractional delay (FD) filters based on a GA are developed. The approaches exploit the advantages of a global search technique to determine the coefficients of FD FIR and allpass-IIR filters based on the so-called Farrow structure. The GA approach was compared with a least-squares approach and was found to lead to improvements in the amplitude response and/or delay characteristic.

In Chap. 3, a GA-based approach is developed for the design of delay equalizers. In this approach, the equalizer coefficients are optimized using an objective function based on the passband filter-equalizer group delay. The required equalizer is built by adding new second-order sections until the desired accuracy in terms of the flatness of the group delay with respect to the passband is achieved. With this approach stable delay equalizers satisfying arbitrary prescribed specifications with the desired degree of group-delay flatness can easily be obtained.

In Chap. 4, a GA-based approach for the design of multiplierless FIR filters is developed. A recently-introduced GA, called orthogonal GA (OGA) based on the so-called experimental design technique, is exploited to obtain fixed-point implementations of linear-phase FIR filters. In this approach, the effects of finite word length are minimized by considering the filter as a cascade of two sections. The OGA leads to an improved amplitude response relative to that of an equivalent direct-form cascade filter obtained using the Remez exchange algorithm.

In Chap. 5, a multiobjective GA for the design of asymmetric FIR filters is proposed. This GA uses a specially tailored elitist nondominated sorting GA (ENSGA) to obtain so-called Pareto-optimal solutions for the problem at hand. Flexibility is introduced in the design by imposing phase-response linearity only in the passband instead of the entire baseband as in conventional designs. Three objective
functions based on the amplitude-response error and the flatness of the group-delay characteristic are explored in the design examples considered. When compared with a WLS design method, the ENSGA was found to lead to improvements in the amplitude response and passband group-delay characteristic.

In Chap. 6, a hybrid approach for the design of IIR filters using a GA along with a quasi-Newton (QN) algorithm is developed. The hybrid algorithm, referenced to as the genetic quasi-Newton (GQN) algorithm combines the flexibility and reliability inherent in the GA with the fast convergence and precision of the QN algorithm. The GA is used as a global search tool to explore different regions in the parameter space whereas the QN algorithm exploits the efficiency of a gradient-based algorithm in locating local solutions. The GQN algorithm works well with an arbitrary random initialization and filters that would satisfy prescribed amplitude-response specifications can easily be designed.
Bibliography


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