Recombination Operators in Evolutionary FIR Filter Domain

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Abstract – **The paper deals with the design of an evolutionary FIR filter. The function of this filter is based on an evolutionary algorithm. This paper focuses on the modifications of a genetic algorithm for this type of applications. It tests various type of recombination operators.**

I. Introduction

Evolutionary computational techniques (evolutionary algorithms) are profitable tools for the solution of optimization tasks. They are based on the Darwin's theory of evolution and survival of the fittest, and make it possible to solve the optimization tasks that can be defined as a search for global/local maximum/minimum functions.

These algorithms are also used in the design of digital or analog circuits. They look for topology or circuit parameters. In case of digital filters, the algorithm can search for suitable parameters of the filter. This use of evolutionary algorithms is called *Evolvable hardware* or *Evolutionary design*. By this method, we can search for new and innovational solutions to electronic circuits. Unfortunately, there is no exact methodology for the design of these applications. [1]

II. Genetic Algorithm

The basic representative of the group of evolutionary algorithms is the Standard Genetic Algorithm. It is a relatively simple algorithm that is based on an individual. A group of individuals forms a population. An individual represents just one solution of the optimization problem. Various representations can be used for individuals, for example the classical binary format is used very often. Note that a suitable version of representation is very important for correct function of the evolution. At first, the algorithm has to initiate individuals of a population, which is realized by filling them with random values. Afterwards, recombination operators are applied. Generally, only two operators – the crossover and the mutation – are used. These operators change genetic information of the individuals, and thereby the very solution of the task which is represented by the individuals. After recombination, the algorithm has to evaluate the solutions that are represented by the individuals. The fitness function provides this evaluation: it tells us how quality the solution contained in an individual is. If the required solution is found, the algorithm can be terminated. If not, the algorithm will select individuals for a new population and the whole process repeats. We can say that a new generation begins. The algorithm can be terminated if a certain number of generations is achieved. [1]

III. Fir Filter

The FIR (Finite Impulse Response) filter is one of the basic types of digital filters. Its function is based on convolution. The FIR filters excel in simple structure and stability. They consist of a shift register, multipliers and adders. The shift register accumulates input data samples that are multiplied by parameters (the impulse response) of the filter. Afterwards, these multiples are summarized and the consequent result creates the filter output. [2]

Filter parameters determine its kind and its amplitude characteristic. If the impulse response is changed by the evolution, the features of the filter are changed too. The FIR filter is always stable. For that reason, this type of filter is suitable to determine the impulse response by means of evolutionary techniques.

In this project, the symmetric FIR filter with 29 taps is used. The taps of odd numbers are preferable if we want to generate various kinds of filters. Each parameter is represented by 8 bits in the two's complement. In addition, structures of the FIR filter can be very simply implemented by FPGA circuit. The FIR filter also has to be able to undergo quick reconfiguration if we want to use it for cooperation with the evolutionary algorithm.

III. Aim of the Project

The main goal of this project is the design of the evolutionary FIR filter. Parameters (the impulse response) of this filter are obtained by the evolution. It means that no operator intervention is needed for the correct function of the filter. The standard FIR filter has one data input and one data output. In addition, the evolutionary filter will have a special data input – the input for ideal output samples. The evolution will have to find a suitable impulse response that ensures correspondence between the output signal and the ideal output signal. That is why the filter will have an adaptive character.

III. Fitness Function

Systems with an adaptive character is not standard application in the evolutionary algorithm domain. Ussualy, we work in a static inviroment. For that reason, the fitness function can be defined static. However, if adaptive behaviour is required, the fitness function must be time variable because the application has to react dynamically on the environment variable. [1]

Hence, the definition of the fitness function is the most problematic part of the design evolvable system. It is necessary to modify the algorithm and its fitness function so that the algorithm can work with the environment variable. The dynamic fitness function has to transform into the static function; then the algorithm works with the static fitness function, and the adaptive character is conserved at the same time. Suitable transformation into the static function ensures

that all individuals within one generation have the same evaluative criteria.

The work with dynamic fitness function is solved by means of a special sample memory – the samples unit. Principle of this unit is based on shift register. The samples unit accumulates samples of the input and the ideal output signal. If the fitness function is started, last 200 samples (200 input samples and 200 ideal output samples) from the sampler are stored in work registers in a fitness module. The valuation of the whole population within one generation proceeds with the same samples of signals; this way equal conditions for all members of the population are ensured. The dynamic fitness function and adaptive character of the application require other changes in the algorithm. The evaluation of individuals of former population (generation) is needed. It is a significant difference against the static fitness function. The individuals which were not changed will have to be evaluated too, because parameters of the fitness function can be different in comparison with last evaluation.

IV. USED ALGORITHM

The algorithm uses 16 individuals. Each individual consists of 15 parameters of the FIR filter. It is: 15 x 8 bits = 120 bits, then 4 bits for the control of the filter output and 4 bits for the reserve are used. On the whole, the individual consists of 128 bits (16 bytes). If an offspring (max. 16), mutants (max. 16) and a former generation (16) are taken into account, a memory for 64 (16 x 4) individuals (1024 bytes) is needed. Only 15 parameters are in individuals. However, the FIR filter can be created by 30 (only 29 are used in this project) parameters, because the filter is symmetric. The parameters are stored in two's complement. The initialization of a population is made so that individuals are filled by random values.

This algorithm uses these type of crossover: one-point crossover, averaging of individuals, averaging of individuals with the leader.

The situation with the mutation is more difficult as the mutation can be implemented in many ways. In the project the following method of mutation is used: At first, an individual is divided into single bytes (parameter of the FIR filter). Afterwards, the generator of random numbers generates 11-bits random number. First 8 bits determine (according to the probability of the mutation - P_m) whether a certain byte will undergo the mutation. Remaining 3 bits determine the position of the bit for the mutation. The mutation of the bit means its negation. All individuals of the population undergo the mutation duly. It is very profitable if the probability of mutation can change value within a run of the algorithm.

For the selection of a new population, the algorithm uses a principle of tournament. Members are selected from the former population, offspring and mutants. The selection process picks out two random individuals, and the individual with a higher value of fitness is chosen for the new population. However, this principle does not guarantee that the individual added to the new generation will be the best one; hence, this selection is extended by elitism. Elitism is a technique which ensures moving of the best individual (the leader) into the new population.

V. EFFICIENCY OF RECOMBINATION OPERATORS AND CONCLUSION

For testing and verification of the system, special test application was created. It is described in detail in [3]. Individual types of crossover were used. And we observed the number of generations needed to successful evolution of the filter. The next chart shows results of this test.

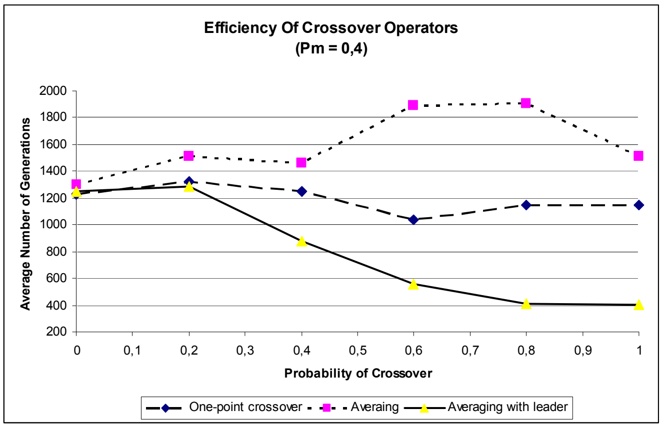

Chart 1: Efficiency Of Crossover Operators

It is clear that *Averaging of individuals with the leader* is very efficient operator against others. If the value of P_c rises, the number of generations needed falls. However, it is necessary to note that this type of the crossover can depresses the population diversity. This fact could negatively affect especially the dynamic characteristics of the evolutionary FIR filter – the adaptability competence could be restricted. Hence, further research in this field is needed.

The next chart shows the efficiency of the mutation operator. The dependence of the number of generations needed on P_m parameter (probability of mutation) is shown. The optimum value of this parameter is approximately 0,4.

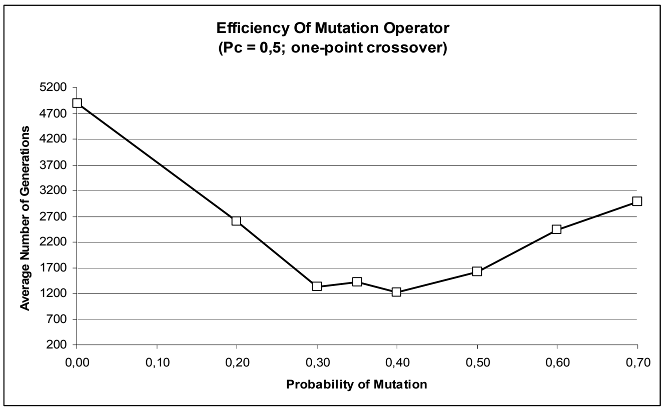

Chart 2: Efficiency Of Mutation Operator

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