




FIR Filter Design Using Genetic Algorithm Implemented MATLAB and Asp.Net Based Web Educational Interface

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Abstract

Today, the usage of filters in the signal and image processing area has become quite wider. The development in this area has also increased the usage of numerical filters. Understanding the principles and designing steps of these filters well provides a great convenience. In addition to this convenience, in recent years, the usage of Web laboratories in computer-aided education has become widespread. For this purpose, in this study, a new interactional web laboratory is proposed by using MATLAB for the course of numerical signal processing to help engineering students understand the filters and have practice. In the filter design, optimization of filter coefficients was carried out with genetic algorithm that is one of the evolutionary algorithms. For the design of interface, MATLAB Web figure and ASP.NET platform have been used. There is no need to set up MATLAB program in the user computer to use the interface for users/students. Interface can be reached easily by using any free web browser. Thanks to this availability, the laboratory requirement of the students is established without restricting time and place. This web laboratory, which is designed for FIR filter, was tested by the students who are having/had numerical signal processing lecture in Sakarya University, Technology Faculty, Electrical and Electronics Engineering Department and the results are presented in this study.

Keywords: FIR filter, MATLAB Web figure, ASP.NET, Genetic Algorithm, Computer-Aided Learning

1. INTRODUCTION

Web-based education has been expanding its influence on engineering field as in other fields recently. Web-based interfaces help engineering students to improve their knowledge and experience in their field. Regarding the restriction of time and laboratory in traditional education, it can be said that web-based educational interfaces are more flexible, easier, faster and more effective for the education environment. In addition, these user-interfaced applications can be easily reached by devices like computer, tablet, PDA and smart phone by using internet.

In the literature, Web-based education is also called online education, virtual education, internet-based education and computer-mediated education. It provides many opportunities for engineering students for personalized learning, tele-education, distance learning and cooperation without any restriction of time, place or access. In the literature, programs like Java, C, C++, C#, MATLAB and

LABVIEW were used for preparing the web based educational interfaces. In this subject, a web based educational interface to control an electrical motor remotely was designed by BINGOL and AYDOGAN for computer, electrics and electronics fields in 2012[16]. In 2009, IRMAK et al. proposed a web based interface for four-zone speed control of a DC motor using MATLAB web server to use in the electrical engineering education [17]. In 2011, a web interface to test the effectiveness of interactive experimental applications for DC motors, various RLC circuits and real time experiments was designed by COLAK et al [18]. While the authors carrying out this study, mathematical models implemented in MATLAB were combined with ASP.NET web page via .NET platform. After, they tested the page and obtained the numerical and graphical results.

Rapid developments in digital electronics increased not only digital filter usage areas but also the advantages of using them (doing changes easily only by software, low cost, etc.)

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too. Thus, finite impulse response (FIR) and infinite impulse response (IIR) filters take place in many common areas.

In the literature, there are many methods for obtaining the coefficients of FIR and IIR filters [1]-[4]. For these methods, high degree filters should be designed to get the closest ideal frequency responses. On the other hand, increasing the filter degrees also cause many operational challenges in the design procedure.

One of the intuitive calculation methods, genetic algorithms gets the result by producing value from different call points and are used in many application areas where classical calculation methods are insufficient and different solution methods are needed to be produced [5]-[8]. Similarly, obtaining filter coefficients by using genetic algorithms also takes place in [9]-[12].

In this study, both Classical methods and genetic algorithms are used to calculate the coefficients of FIR filters. Accordingly, a web laboratory is designed for educational purpose. This program was developed by using MATLAB Compiler processing on the internet as server-client, MATLAB Builder NE [13], ASP.NET [14] based and C# [15]. Thanks to developed software, FIR filter coefficients are calculated by both classical methods and genetic algorithms according to criteria and demand that are determined by the user. Many features of obtained filters (coefficient list, amplitude response, phase response, impulse response, step response, root-locus graph, group and phase delays etc.) are given numerically and graphically. In addition, these results are presented comparatively with the filter features designed by classical methods. With this program, which can also be used for educational purpose easily, animation-supported theoretical information is given about filter design and the effects of parameters on the filter responses can be tried and seen by the students. Thus, either for theoretical or practical purposes, FIR filter designs are done easily by being online as remote access in the web environment and using the genetic algorithms.

In the second part of this paper, FIR filter designs are summarized and some information about genetic algorithms is given in the third part. In the fourth part, designed web laboratory and its application are told and the fifth part includes the evaluation of designed Web laboratory. Finally, in the sixth part, results are summarized.

2. FIR FILTER DESIGN

The general architecture of the FIR filter, which has linear phase characteristic, stable structure and finite impulse response, is given in Figure 1 and the output is obtained by the following equation.

$$y_n = \sum_{i=0}^k a_i \cdot x_{n-i} \tag{1}$$

Filter coefficients can be symmetrical or asymmetrical according to central value. They can also be designed in four different types as given in Table 1 [1]-[4]. Design methods of FIR filters are generally simple, linear and reliable. Calculation equations of not normalized filter coefficients for ideal FIR filters are given in Table 2 [1]-[4].

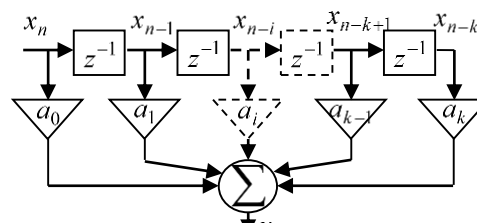


Figure 1. FIR Filter Architecture

Table 1. Features of FIR Filter

Type	Properties			
	Length of filter	Filter coefficients	Frequency response	
			$\Omega=0$	$\Omega=\pi$
I.	Odd integer	Symmetric	Even symmetry	Even symmetry
II.	Even integer	Symmetric	Even symmetry	Odd symmetry
III.	Odd integer	Asymmetric	Odd symmetry	Odd symmetry
IV.	Even integer	Asymmetric	Odd symmetry	Even symmetry

Table 2. Ideal Fir Filter Coefficients

Filter	Central coefficient	Other coefficients
Low pass	$h[0] = \frac{\omega_c}{\pi}$	$h[n] = \frac{\sin(n\omega_c)}{n\pi}$
High pass	$h[0] = 1 - \frac{\omega_c}{\pi}$	$h[n] = -\frac{\sin(n\omega_c)}{n\pi}$
Band pass	$h[0] = \frac{\omega_{c2} - \omega_{c1}}{\pi}$	$h[n] = \frac{\sin(n\omega_{c2}) - \sin(n\omega_{c1})}{n\pi}$
Band stop	$h[0] = 1 - \frac{\omega_{c2} - \omega_{c1}}{\pi}$	$h[n] = \frac{\sin(n\omega_{c1}) - \sin(n\omega_{c2})}{n\pi}$

3. GENETIC ALGORITHM

Based on the biological/evolutional process in the nature and being an intuitive method, genetic algorithm was firstly developed and used in the middle of 1970s. Being the part of the evolutionary calculation, genetic algorithms are iterational and probabilistic solution methods emerging with modeling the related process and they use random search techniques for solution and they are based on parameter encoding. Genetic algorithms are used in solution of optimization problems in different areas, information systems, machine learning etc. [5]. Solution phases of a problem using genetic algorithms can be summarized as in Figure2.

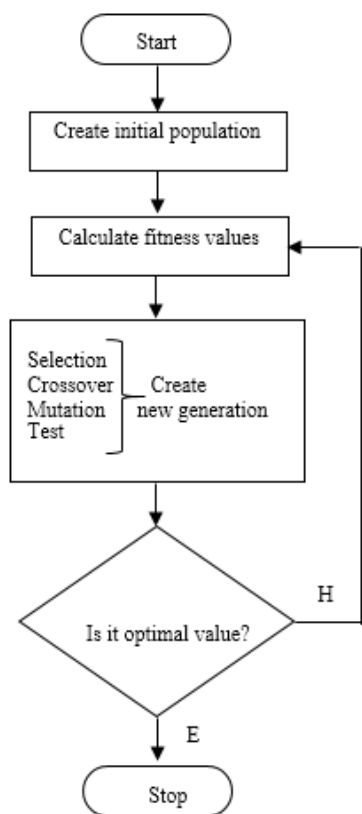


Figure 2. Flow chart of genetic algorithms

4. DESIGN OF WEB LABORATORY AND APPLICATION

In the proposed web interface design, .NET component prepared with MATLAB program and MATLAB Builder NE, and Visual Web Developer 2008 Express Edition program which works with this component compatibly and by which the interface was designed are used. Infrastructure of Web design was chosen as ASP.NET and programming language was chosen as C#. Architecture of the system is shown in Figure 3.

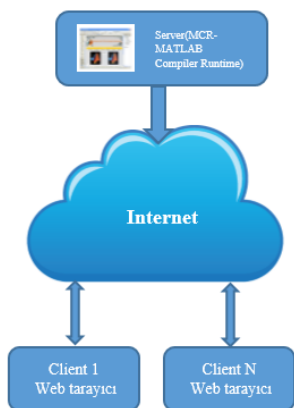


Figure 3. System Architecture

To use MATLAB Web Figure device, the first operation to do is to add “Web Figure Control” device to device box in “Visual Web Developer” program that is used for design as in Figure.4.

As for the second operation, Web figure control device is dragged and dropped in the working area. Name to be used in application is written to “name” part from the web figure features panel and “application” is chosen from the “scope” part.

As the third operation, .NET component prepared with MATLAB should be added as a reference to be used in application.

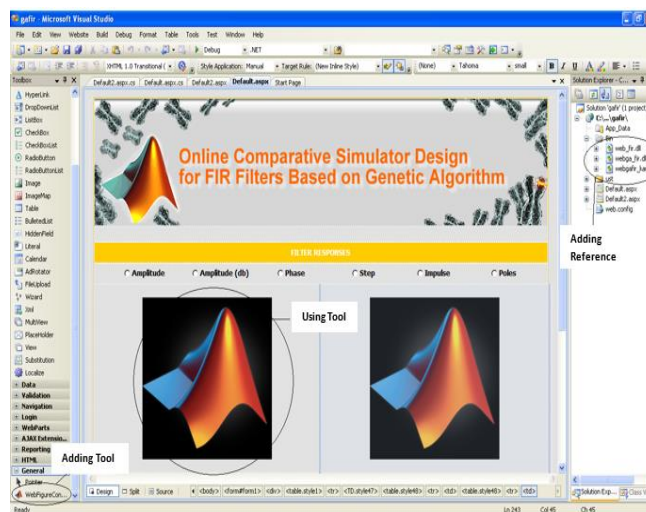


Figure 4. Design of interface

In this Web laboratory design, parameters (filter degree, sampling frequency, lower / upper cut-off frequency) are entered by choosing Filter (Low pass (LPF), high pass (HPF), band pass (BPF), band-stop (BSF)) and type of coefficient (asymmetrical).

A web-based interface is provided for desired FIR filter by organizing the settings of the general algorithms(The size of the population, fitness function {rank, relative peak, linear change} selection function {stochastic uniform, increasing, uniform, roulette, tournament} mutation function {Gaussian, uniform, adaptive}, crossover function {distributed, single-point, two-point, intermediate, heuristic, and arithmetic} and crossover rate) for the simulator both in classical design and by using genetic algorithm.

Firstly, coherence functions are prepared to get low pass filter coefficients by genetic algorithm. After organizing genetic algorithm adjustments/choices, optimization process is done. For example, MATLAB codes according to low pass filter equations given in Table 2 are shown in Figure 5.

```

% Coherence function for the central value coefficient of low
pass filter
function y=h0_lpf(k)
    y=((k*wc1)/(k*pi));
end
% Coherence function for the coefficients of low pass filter
function y=hn_lpf(k)
    y=(sin(k*wc1)/(k*pi));
end
    
```

Figure 5. Sample of coherence function codes

Two screen views of developed Web laboratory design are given in Figure.6. The module in Figure 7 features of filters graphs were given separately whereas in Figure 8, they were given in the same graph comparatively.



(a) first design for web laboratory



(b) second design for the web laboratory

Figure 6. Web Laboratory Designs

When parameters of LPF in the first design is entered and run, result screen in Figure 7 is obtained. Similarly, as the last simulation, the screen view of 20th grade BPF design whose cut off frequencies are 2 kHz and 6 kHz is given in Figure 8.

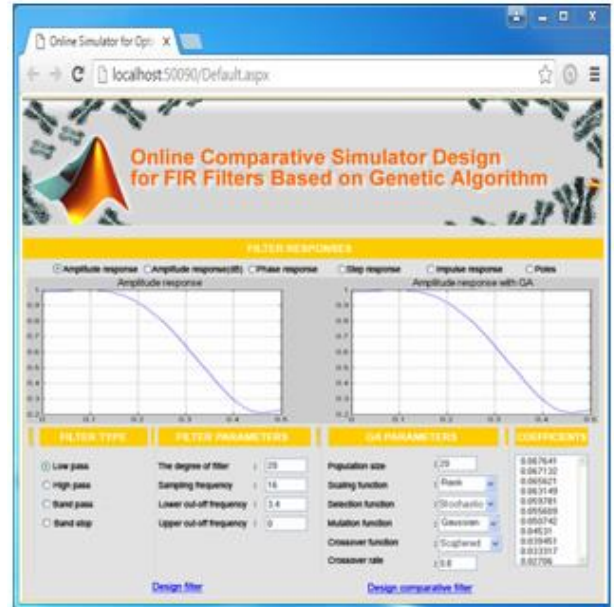
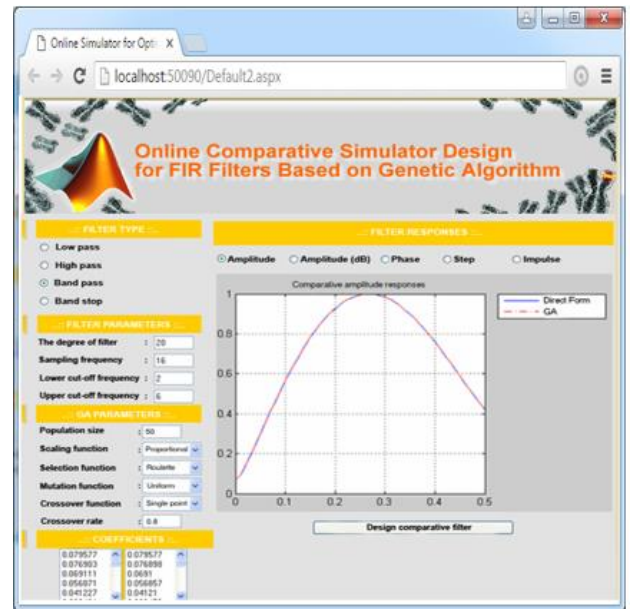
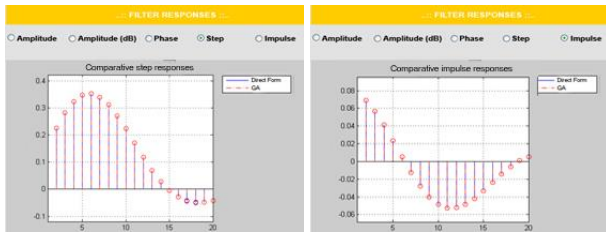


Figure 7. The simulation of first design



(a) The simulation of second design



(b) step and impulse responses obtained from the second design

Figure 8. Simulations obtained from the second design

The web figure graphs that are obtained thanks to this device, can be rotated in three axis by rotating icon, can be got closer to the desired part of the graphic with closing icon and Web Figure environment can be carried to desired place with carrying icon. Fitting in the frame icon reverts the Graph back.

5. EVALUATION OF WEB LABORATORY

To evaluate the prepared web laboratory, which is actually designed for learning and teaching of FIR filters calculated by using classical and genetic algorithms methods, it is presented to the students/users that were studying/had studied numerical signal processing lecture in Sakarya University, Technology Faculty, Electrical and Electronics Engineering Department in 2016 and feedback was got via survey. As processing FIR filter coefficients were taught by classical methods according to the syllabus of numerical signal processing lecture, for a better comprehension of the topic calculated solutions with genetic algorithm are added into the prepared web interface.

The students are surveyed about the prepared web laboratory with the questions seen in Table 3. Likert scale is applied for the evaluation. (5 - strongly agree, 4 - agree, 3 - neither agree nor disagree, 2 - disagree, 1 - strongly disagree). Totally 40 students joined the survey and the results were given in Figure 9. In the survey, neither agree nor disagree, disagree and strongly disagree expressions were accepted as negative.

Table 3. Questions of Survey.

	Please score the following items using the most suitable scales for you.
1	To understand and learn FIR filters, it is useful to use web laboratory.
2	Graphical interfaces support theoretical information.
3	To compare classical and genetical methods in design of FIR filters increases the understanding of the subject.
4	Graphs showing the obtained results from Web laboratory are understandable.
5	Using the Web laboratory is easy and efficient.
6	Working and response time of Web laboratory is enough.
7	Design of the Web Laboratory is successful.
8	Reach to Web laboratory is smooth and easy.
9	Web laboratory can be applied to different subjects in engineering, Please give an example.....

The first two questions were about to understand and learn the Web laboratory. Students/users gave positive answers to the two by the rate of 80% and it is suggested to be used as an educational device as it increases the interaction about the subject. Feedbacks were negative about the third question with the average rate of 60% because it was about comparison of classical and genetical method used in FIR filter design. The reason for the students to give negative answers to this question is that the students did not know the genetical algorithm. From the positive feedbacks to fourth and fifth questions with the rate of average 70%, it can be understood that usage of web laboratory is understandable and easy. Answers to sixth question come out 60% negativity. Reason of this is the delay being too much in the time of work and response.

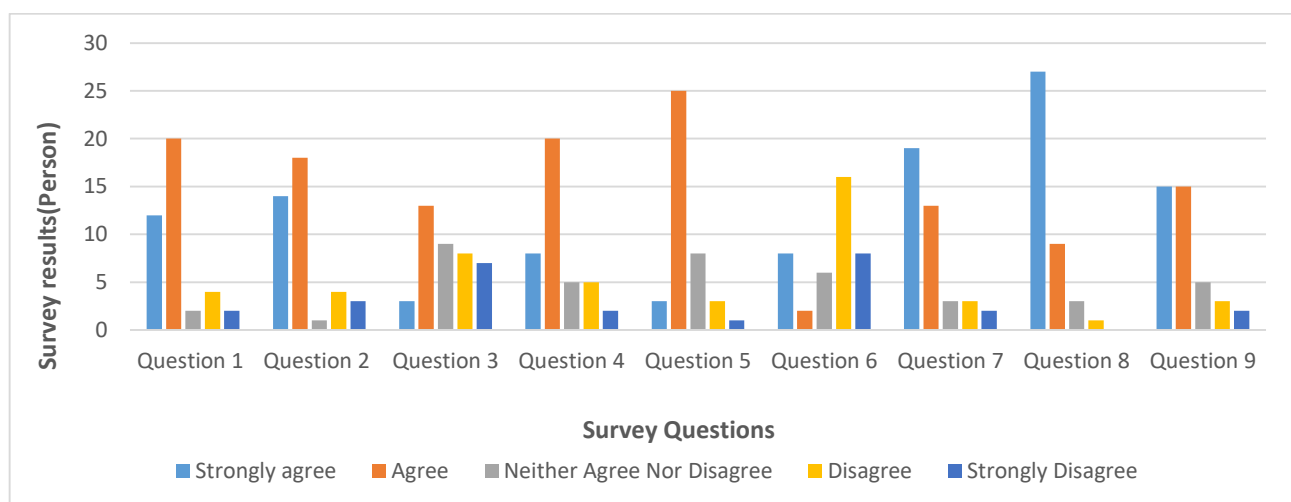


Figure 9. Survey results

Users wait more than one minute as response time, because of the connection between the server and client during the operation. Success of Web laboratory design as seventh factor, was evaluated by the rate of 80% by students/users positively. For the eighth one, 90% positive feedback was got. Due to being an online application, program is easily reached on internet by devices like computer, tablet, PDA, smart phone. The last one is about the applicability on different subjects in engineering area. The given answers about this category are towards that Web laboratory can be usable/applicable interactively in other engineering issues. Given examples to this category are mostly for IIR filters, a subject of numerical signal processing lecture. In this part, Web laboratory is desired to be developed. By this way, interaction with lecture could be increased.

6. CONCLUSION

In this study, to calculate FIR filter coefficients, both classical methods and genetical algorithms are used. In this respect, a web laboratory for educational purposes was designed. Through this program, students/users are provided to see the effects of used parameters for designing filters on filters experimentally through the designed Web laboratory.

The most important feature of the web laboratory is that there is no need for students/users to build MATLAB program in user computer to use the interface.

The interface can be easily reached with any web browser. With this access, the laboratory requirement of the students is satisfied with a flexible, easy, fast and effective education environment without any restriction of time and place. Designed web laboratory was brought into use of the students, feedback was got by the survey method and from the obtained data, it is understood that the program is a useful product in the education of numerical filter design. Furthermore, it is also understood that the program can also be developed for the IIR filters, too.

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