Research on Digital Signal Processing Experiment System Based on Virtual Instrument Technology

To cite this article: Nanquan Zhou et al 2019 J. Phys.: Conf. Ser. 1288 012084

View the article online for updates and enhancements.
Research on Digital Signal Processing Experiment System Based on Virtual Instrument Technology

Nanquan Zhou¹, Xiaoli Quan² and Ying Wang¹

¹Department of electronic engineering, Chongqing Aerospace Polytechnic, chongqing 400021,China
²School of electrical and electronic engineering, chongqing university of technology, chongqing 400054,China
Email: 406833479@qq.com

Abstract. A virtual demonstration experiment system has been designed by using the development environment LabVIEW which is used in digital signal processing teaching in the paper, Nyquist sampling theorem and the relation between circular convolution and linear are introduced in the paper. Teacher could dynamically demonstrate that the variable signal parameters had an effect on experiment phenomenon in these teaching programs. This experiment system has many distinct features such as openness, extension, interaction, digitization, network, modularization, economization, it is both a new way of experimental teaching and a new direction in the experiment teaching innovation, it will powerfully promote the innovation of teaching idea and teaching mode.

1. Foreword
In many universities of science and engineering, digital signal processing course is one of the important professional courses of electronics, communications and other specialties[1]. It is a highly theoretical subject with arithmetic as its core. Theoretically, digital signal processing covers a wide range of areas. In the field of mathematics, calculus, probability statistics, stochastic processes, complex functions and so on are all its basic tools. Because digital signal processing includes a series of arithmetic, deduction and proof, the related concepts of digital signal processing seemed very abstract. As a result, it is difficult for students to connect these theories with practical applications during the study of this course. In addition of single teaching method and limited experimental conditions, this course has been in a "difficult to learn and difficult to teach" situation for a long time. This paper presents an assistant teaching method which is based on LabVIEW. LabVIEW, which was developed by American NI Company, has intuitive graphical environment and powerful data analysis library. By using it, various virtual instruments can be designed, validated and demonstrated for abstract theorems, transformations and computations in teaching flexibly[2][3]. This multimedia teaching method, which combines Powerpoint and LabVIEW, has friendly man-machine interface and easy operation. It can increase the interaction between teachers and students, thus greatly improves the teaching efficiency and quality[4]

2. Introduction of LabVIEW
LabVIEW (Laboratory Virtual Instrument Engineering Workbench) provides a powerful graphical environment for the development of virtual instrument. It is widely accepted by industry, academia and research laboratories and it is regarded as standard software with data acquisition and instrument control. It provides a new way of programming that program code can be substituted by program flow
chart. It’s easy for us to build our own virtual instrument by using it. Also, the graphical interface makes the process of programming vividly and interesting[5]. The developable environment of LabVIEW has a series of advantages. LabVIEW is praised for its flow chart programming, precompile syntax checking, data probe, the function of numerical analysis, signal processing, device driver and so on. Using LabVIEW to design virtual instrument can greatly reduce workload and cost[6][7]. The design process of LabVIEW includes two parts: front panel and rear panel. The front panel is a graphical interface. It is used for simulating the panel operation of real instruments. It can be applied to input values, observe output values, and to display charts, texts, etc. The back panel, which is equivalent to the source code of traditional programs has also been called block diagram program. Block diagram program uses graphic programming language to write program. On the one hand, it is used for transferring the command parameters of the front panel. On the other hand, it can also transfer the execution results back to the front panel to display.

3. The Framework of Virtual Demonstration Experiment Teaching System
The system is mainly used in the simulation of teaching experiments. It completely get rid of the limitations of hardware. According to the content and requirement of the experiment, ten virtual demonstration experiment modules were constructed in the environment of LabVIEW: Nyquist Law, The mapping between z plane and s plane, four forms of Fourier transform, circular shift of sequence, circular convolution and linear convolution, circular conjugate symmetry, time decimation FFT algorithm, frequency decimation FFT algorithm, FIR digital filter design and IIR digital filter design. Each experimental project module has an independent experimental subsystem, so that it can complete specific experiments. The composition of the experimental system is shown in Figure 1.

![Figure 1. Construction of virtual experiment teaching system](image)

Considering that the system is mainly used for simulation of teaching experiment, so the parts that are related to hardware need to be simulated by software. LabVIEW contains a large number of function modules, like signal simulation module, signal conditioning module, signal analysis, processing module and so on. Using these powerful function modules and different types of input and display controls has lots of advantages. It can realize the simulation of test process and analyze the experimental data. Also, it can display the results conveniently and so on.

4. Application of LabVIEW in Teaching
The demonstration experimental system, which has closely connection with digital signal processing course, involves signal basic operation, signal sampling recovery, signal spectrum analysis, filter design and so on. This paper takes Nyquist Law and the relationship between linear convolution and circumferential convolution of finite sequence as examples to analyze the application of LabVIEW in the teaching of digital signal processing.
4.1. Nyquist Law

Sampling is to use periodic sampling pulse sequence to extract a series of discrete values from continuous signals $x(t)$ and obtain the sampled signal, namely discrete-time signal. When a continuous time signal is sampled, its spectrum will be repeated at intervals of $\Omega_s = \frac{2\pi}{T_s}$. This means that the spectrum generates periodic continuation, and each continuation has the same spectral component as the original spectrum component. When the maximum spectrum $\Omega_h$ does not exceed $\text{fs}/2$, the spectrum of the original signal and the spectrum of each continuation component do not overlap with each other, then a low-pass filter with cut-off frequency can be used to restore the original continuous signal without distortion. In contrast, when the maximum spectrum $\Omega_h$ exceed $\text{fs}/2$, the spectrum of each period continuation component overlaps (aliasing phenomenon), so that it cannot restore the original continuous signal. Thus, the Nyquist Law is obtained as follows: if the original signal can be restored without distortion after sampling, the sampling frequency must be greater than twice the maximum frequency of the signal spectrum ($\text{fs} > 2\Omega_h$).

Nyquist Law is the rule followed in the process of sampling band-limited signals. It governs the acquisition, processing, storage and transmission of almost all signals/images. In order to let students understand the relationship between sampling frequency and the highest frequency of analog signals, teachers need to spend a lot of time drawing curves and explaining sampling theory under these three conditions. The teaching process is rather boring for most students. Therefore, Nyquist sampling theorem is not only the focus of teaching, but also the difficulty of teaching. This paper uses LabVIEW software to design a virtual demonstration experiment for this teaching link. Fig. 2 and Figure 3 are the front panel and program block diagrams of Nyquist law virtual demonstration experiment respectively. Users can choose the size of sampling frequency through the front panel, sample continuous signals in time domain Waveform Graph according to this frequency, and get the sampled signals from Waveform Graph Control in frequency domain. Event structure, while loop structure, sinc Pattern. vi, Resample Waveforms. vi and spectrum subroutine. vi are used in the program block diagram to complete the response of five events, generation of continuous signals, sampling of signals and spectrum analysis of signals.

![Figure 2. Front panel of virtual demonstration experiment about Nyquist sampling theorem](image-url)
Figure 3. Diagram of virtual demonstration experiment about Nyquist sampling theorem block

4.2. The Relationship between Circumferential Convolution and Linear Convolution

Point Circumferential Convolution is a linear convolution which is the main value sequence of periodic extension sequences based on as period. When (Length of linear convolution), that based on as period will produce aliasing phenomenon while periodic extension. Its circumferential convolution does not represent linear convolution. When , that based on as period will not produce aliasing phenomenon during periodic extension. Its circumferential convolution can represent linear convolution.

Fast Fourier Transform (FFT) algorithm can be used for circumferential convolution. Compared with linear convolution, the computational speed can be greatly accelerated. However, the general practical problem is linear convolution. In order to overcome the problem of excessive linear convolution, the focus of this section is to find out under what conditions circumferential convolution can replace linear convolution. It is undoubtedly tedious and error-prone for teachers to demonstrate the substitutability of circular convolution and linear convolution through step-by-step repetitive displacement and superposition operations in class. This paper uses LabVIEW software to design a virtual demonstration experiment for this teaching link. Fig.4 and Fig.5 are the front panel and program block diagrams of the virtual demonstration experiment on the relationship between linear convolution and circumferential convolution, respectively. Teachers can dynamically demonstrate the relationship between 5-9 point circumferential convolution and linear convolution through the front panel in class, thus finding out the conditions for circumferential convolution to replace linear convolution. Event Structure, While Loop Structure, For Loop Structure, Convolution.vi and Array Subset are used to complete the response of 9 events in the program block diagram, the generation of original signal and , functions of linear convolution and circumferential convolution.
5. Conclusion
From the above examples, we can see that the virtual demonstration experiment designed\cite{9} by LabVIEW can not only deepen our understanding of the theoretical knowledge, but also visually and dynamically see the influence of the change of signal parameters on the experimental phenomena. The application of virtual instrument design in classroom teaching not only makes teachers full of high-tech atmosphere, fully mobilizes students' learning enthusiasm, stimulates students' experimental interest\cite{10}, but also plays a positive role in improving the teaching quality of experimental courses.

6. References
\cite{1} CHEN Pei-qing, Digital Signal Processing Course[M], Beijing: Tsinghua University Press, 2007.
\cite{2} CHEN Chun-zhao, ZHAO Min, ZHANG Ya-chao, The Design for Virtual Experiment Platform based on LabVIEW[J], China Modern Educational Equipment, 2009, 87 (17) :31-34.
[3] YANG Hong, LI Guo-hui, CHANG Shu-juan, Construction of Virtual Laboratory Based on LabVIEW[J], Modern Electronics Technique, 2010, 318 (7) :154-158.

[4] CHEN Chun-chao, LI Chun-yang, LI Jiu-dong, LIU Ming-fei, Application of LabVIEW Software in Teaching[J], Computer and Modernization, 2010, 175 (3) :89-92.

[5] JIANG Jian-jun, LIU Ji-guang, LabVIEW Programming Course[M], Beijing: Electronic Industry Press, 2008.

[6] WU Cheng-dong, SUN Qiu-ye, SHENG Ke, LabVIEW Virtual Instrument Program Design and Application[M], Beijing: Posts & Telecom Press, 2008.

[7] HE Oi-wen, Usage of OPC Technology in LabVIEW8.0 DSC Module [J], Computer Engineering and Design, 2006, 27(22):4389-4391.

[8] QI Yong-feng, HUO Yuan-lian, ZHANG Wan-peng, Application of LabVIEW in Digital Signal Processing Teaching[J], Automation & Instrumentation, 2008, 2 (136) :60-61.

[9] ZUO Hong, YIN Yan-shu, MA Li-xia, Development of Comprehensive Experimental Teaching Platform Based on LabVIEW[J], Research in Teaching, 2008, 31 (1) :75-77.

[10] Kong Li-jing, Luo Wan-fa, Electrical Simulation Experiments Based on LabVIEW[J], Physical Experiment of College, 2008, 21 (4) :75-79.