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Research on Application of Virtual Instrument Technology in Experimental Teaching

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ABSTRACT

In view of such problems as insufficient experimental teaching facilities for testing technology courses, abstract concepts of digital signal acquisition and processing and the complex computation, the paper provides the virtual simulation software for signal processing with a computer. The software system mainly comprises 6 experiment modules, i.e. signal generator, sampling theorem and FFT, correlation analysis, convolution analysis, signal modulation and demodulation simulation, frequency response function and digital filter. The system is applied to experimental teaching, exhibiting a prominent effect.

Keywords: *virtual instrument, simulation experiment, testing technology*

1. INTRODUCTION

Students are often perplexed and discouraged in learning abstract concepts and complex numerical computation relating to digital signal acquisition and processing as concerned in fundamental technology courses, such as Engineering Testing Technology, Sensor and Signal Processing, and etc., which are generally offered to majors specialized in mechanical and electrical engineering and instrumentation. The perplexity and discouragement are further aggravated by the lack of laboratory facilities. However, with universal use of computer technology, acquisition and subsequent processing of digital signals become focuses and challenges of teaching in such courses, as well as essential content required to be mastered according to teaching programs of the courses. In this paper, the Testing Technology and Signal Processing course is taken as an example for research on application of the virtual instrument technology in experimental teaching.

2. BRIEF INTRODUCTION TO VIRTUAL INSTRUMENT TECHNOLOGY

LabVIEW is a graphic programming language developed by the National Instruments Corporation. As a platform for development of large instrument systems, it has visual interfaces, which make it convenient for development and easy to learn and master. Besides, it is provided with drivers and tool libraries for various instruments. Along with it, a new research method emerges: That is to create instruments and meters on the screen based on software by using the powerful computing and displaying capacity of a computer, so as to realize the idea of "making software instruments". Meanwhile, LabVIEW contains abundant function libraries and advanced analysis subroutines. The user is only required to call function, operation, data processing and output display icons representing corresponding instruments, enter relevant configuration parameters, and link the block diagrams similar to a data flow diagram to complete all programming. LabVIEW makes it possible to develop high-quality simulation software for experimental teaching in short periods and at a low cost, and thus is highly advantageous in this aspect[1-5].

3. FOCUSES AND CHALLENGES OF THE COURSE

Main teaching content of Testing Technology and Signal Processing includes: ways to properly and effectively acquire digital signals, and common signal processing methods. Basic concepts include: sampling theorem; truncation, leakage and windowing; frequency aliasing and frequency resolution; picket fence effect; self-correlation analysis and mutual correlation analysis of signals; power spectrum analysis of signals[6]. According to experience in teaching practice, fresh students of this course are confronted with the following challenges: (1) Transformation of thinking from the habitual time domain to the frequency domain, which is a difficult process since it is hard for many students to establish a clear profile of frequency domain in their mind; (2) Abstract process of signal processing, highly theoretical nature, complex and a large amount of computation that is almost impossible for manual work; (3) No experiment of signal acquisition and processing in many vocational technical institutes, according to investigation, because such experiment requires costly laboratory facilities of the above-mentioned functions. To conquer the above-mentioned challenges, the paper has designed a simulated experimental procedure of signal processing based on the emerging virtual instrument technology.

4. TEACHING CONTENT OF SIMULATION EXPERIMENT

According to the basic requirements of the course outline, analog simulation of digital signal processing shall include:
(1) Sampling theorem and FFT experiment. Set an analog signal sampled and the sampling frequency; observe change

of the time domain waveform and spectrum, to verify the sampling theorem and frequency aliasing.
(2) Signal truncation, frequency leakage and windowing experiments. Set different numbers of sampling points, and observe the change of spectral lines in the spectrogram; set different window functions, and observe change of spectral lines before and after windowing to acquire better understanding of frequency leakage and of reducing leakage by windowing; analyze the superposed spectrum of two signals of similar frequencies, and observe change of spectral lines in the spectrogram before and after windowing to gain better understanding of reducing the frequency resolution by windowing.
(3) Frequency sampling and picket fence effect. Compare the change of spectrum truncated by full cycle and non-full-cycle to verify the significance of full-cycle sampling; set different numbers of sampling points, and observe the influence of sampling time on the frequency resolution in the spectrogram.
(4) Frequency leakage helps estimation of spectral peak. Set sampling points and window functions to verify that leakage of the main valve in frequency leakage caused by signal truncation may reduce the estimation error of spectral peak amplitude incurred by picket fence effect. This concept is hard to understand without experiments.
(5) Correlation analysis. Set different types of simple signals or compound signals for self (mutual) correlation calculation; observe self (mutual) correlation function curves displayed on the computer screen for better understanding of self (mutual) correlation and its characteristics; summarize application of self (mutual) correlation analysis.
(6) Convolution analysis. Set different types of simple signals or compound signals for convolution analysis; observe the convolution curve displayed on the computer screen for better understanding of convolution and its characteristics.
(7) Signal modulation and demodulation simulation.
(8) Frequency response function and digital filter.

5. DESIGN OF SIMULATION PROCEDURE

For the purpose of this paper, the system platform LabVIEW8.x has been used[4] to design an application of complete laboratory functions. The application interface includes the following windows:
(1) Window of simulative generator of analog signal. Through this window, any type of simulated analog signal at any frequency can be generated.
(2) Window for setting signal sampling parameters. The sampling frequency and the number of sampling points can be set through this window.
(3) Window for setting window functions. Rectangular window, Hanning window, Hamming window, Blackman window, exponential window, and other windows can be set through this window.
(4) Window for displaying the time domain waveform and spectrum of sampled signal. The time domain waveform of sampled signals can be observed on this window, and used to derive corresponding spectrogram through FFT.
(5) Window for displaying results of correlation analysis and power spectrum analysis. Result curves of signal correlation analysis and power spectrum analysis can be observed on this window.
The functional interface for analog simulation of laboratory procedures is shown in Figure. 1. The interface (partial) of running module 2 is shown in Figure. 2.

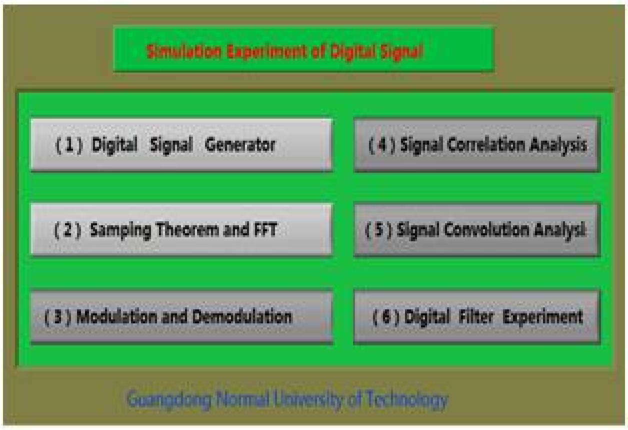

Figure 1 The functional interface for simulation experiment

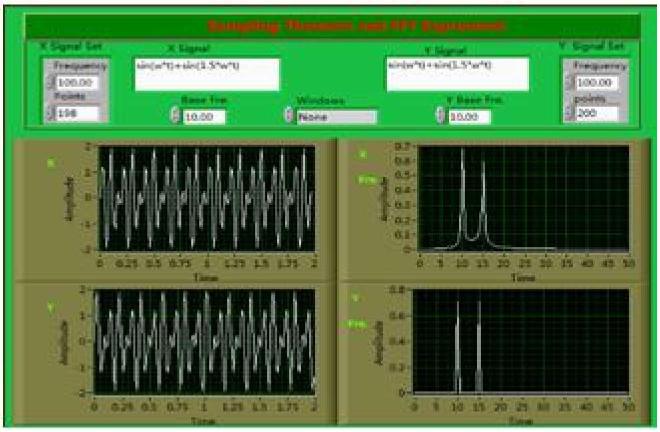

Figure 2 The interface of running module 2

6. DESCRIPTION OF THE SIMULATION PROCESS

Due to the limited length, the sampling theorem, leakage and windowing process are briefly introduced as follows:
As shown in Figure. 2, enter the expression of a sinusoidal signal in the X signal generator window: sin(ω*t), and set the base frequency to 10Hz, so that a continuous sinusoidal signal of 10Hz can be generated; enter the expression of a compound sinusoidal signal in the Y signal generator window: sin(ω*t)+sin(2*ω*t), and set the base frequency to 10Hz, so that a compound complex cyclic signal is generated, which is a superposed signal of a 10Hz sinusoidal signal and a 20Hz sinusoidal signal.
According to the sampling theorem, the sampling frequency of X signal shall be at least 20Hz, and of Y signal shall be at least 40Hz. Suppose for each of the two signals, 195 sampling points are taken and the sampling frequency is 100Hz; when the program is run, relatively continuous

sampling signal can be observed in the time domain waveform window of signals X and Y, and spectral lines corresponding to 10Hz and 20Hz can be observed in the frequency domain window of signals X and Y; but the spectral lines are largely different from theoretical impulse spectral lines because of frequency leakage due to signal truncation that spreads the original energy-concentrated spectral lines on the frequency axis. Theoretically, increase of sampling points for X signal or windowing may reduce leakage; in this simulation test, it is observed that the spread spectral lines are contracted to the peak on the frequency axis, suggesting the leakage is reduced. According to Figure. 2, the spectrum of signal Y suggests obvious reduction of leakage after addition of Hanning window.

When the sampling frequency is set to 41Hz, it can be observed that the time domain waveform of sampled signal X seemed distorted and that of signal Y seemed more seriously distorted; however, in the spectrograms of the two signals, it can be still observed that corresponding spectral lines are 10Hz and 20Hz. When the sampling frequency is set to 40Hz, the time domain waveform of sampled signal Y suffered more severe distortion, while 20Hz spectral lines have disappeared with only 10Hz spectral lines observed in the spectrogram. This is caused by failure of sampling frequency to meet requirements of the sampling theorem. When the sampling frequency is 39Hz, sampled signal Y has not only more severely distorted time domain waveform, but also has two peaks in the spectrum, and the two spectral peaks correspond to 10Hz and 19Hz, respectively. The peak of 19Hz occurs because of frequency aliasing resulted from failure of the 20Hz component in the sampled signal to satisfy the sampling theorem. Theoretically, aliasing frequency is the absolute value of the difference between the signal frequency and the sampling frequency closest the signal frequency. In the paper, the aliasing frequency is $f2=|39-20|=19Hz$. In a similar fashion, when the sampling frequency is 38Hz, the aliasing frequency is $f2=|38-20|=18Hz$. The experiment shows that emergence of aliasing frequency is extremely adverse. Through the experiment, students may, following the instruction and enlightenment by teachers, learn: Upon engineering measurement, to avoid frequency aliasing, it is necessary to use a low-pass filter to remove undesired high-frequency signals before sampling, and samples shall be taken at a frequency 5 times the desired low-frequency signal so as to achieve a good effect.

Use of the virtual instrument technology can conveniently realize simulation of signal correlation analysis, modulation and demodulation, convolution and digital filter. Anyone who is interested in this subject may contact the author for more details.

7. CONCLUSION

The paper has designed, based on the emerging virtual instrument technology, a computer-simulated laboratory procedure in response to challenges presented by abstract concepts, complex computation, lack of laboratory facilities during learning of students. Through this simulated laboratory procedure, students may not only have better understanding of abstract concepts, such as sampling theorem, frequency aliasing, frequency leakage, windowing, frequency resolution, correlation analysis and power spectrum analysis, but also become capable of resorting complex computation to computer, which can instantly present the computation results in form of graphics. This may greatly and remarkably intrigue the learning interest of students.

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