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An Online Digital Filters and Sound Effects Laboratory Utilizing NI SPEEDY 33 and LabVIEW DSP Module

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Abstract

There has been an increasing use and application of the internet due to the advances in technology. At Makerere University[1], the internet has been used by students to remotely access and share scarce laboratory resources using the iLabs platform. This paper presents the design and implementation of an on-line laboratory that supports experimentation in Digital Filters and Sound Effects based on digital signal processing techniques. In the laboratory design, the National Instruments Signal Processing Educational Engineering Device for Youth (NI SPEEDY 33) is programmed to carry out the different processing on an applied signal at the input using the LabVIEW DSP Module. The input is an audio signal and the output is a modified audio signal whose wave form is be displayed at the client. The online laboratory is developed using the interactive iLabs Shared Architecture that allows more student interaction with the hard ware.

Key Words: *Digital Signal Processing, Interactive iLabs Shared Architecture, LabVIEW, Online Laboratories*

1. Introduction

The application of discrete data and digital instruments has increasingly become important in processing signals in all Engineering fields. Throughout a range of fields as varied as multimedia, telecommunications, geophysics, astrophysics, acoustics and biomedicine, signals and systems play a major role [1]. Their frequential and temporal characteristics are used to extract and analyze the information they contain.

Although physical processes are analog in nature, modern applications are implemented in a digital form by using several signal processing techniques. Signal processing is the action of changing one or more parameters of a signal according to a predetermined requirement, and entails both analogue and digital processing. Digital Signal Processing (DSP) is concerned with the digital representation of signals and the use of digital processors to analyze, modify, or extract information from signals [2].

DSP is a wide field that involves deriving signals from analogue form, sampled at regular intervals and converted into digital form. Therefore, Engineering students need to be trained to use the state-of-the art signal processing techniques. This can best be done by gaining both theoretical knowledge and practical exposure in form laboratory experiments.

The recent surge in technology has led to a significant progress in the development of web-based methodologies that support pedagogical efforts for teaching laboratories in a wide range of engineering discipline [3]. This is done by using online experimentation technological tools - the iLabs Shared Architecture (ISA) [4] is one of the frame works upon which this can be achieved.

Online Laboratories in Digital Signal Processing have been implemented in several universities - mostly in Electrical and Computer Engineering fields. At the University of Seville, a laboratory that provides remote access to DSP devices, named eDSPLab, was implemented using LabVIEW and Development Starter Kit (DSK6711) [5]. At Afeka College of Engineering, Tel-Aviv, DSP laboratories have been setup by combining remote access and on-site experimentation using the EZ-KIT LITE board [6]. The Institute of Communications and Wave Propagation, Graz University of Technology implemented online experiments in ADC quantization noise, measuring the DSP anti-aliasing filter frequency response, the DSP output noise measurement, using Code Composer Studio and MATLAB together with Texas Instruments DSP board [7].

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The primary use of DSP is to reduce interference, noise, and other undesirable components in acquired data [8]. Noise omits and exerts bits which distort or lead to complete loss of information. By analyzing the various noise effects and characteristics, noise can be removed using filters. Therefore, the study of digital filters is of paramount importance in DSP. Also of absolute importance in audio processing are the sound effects. Sound effects are used to modify sound output and this necessitates their study.

It is for these reasons that this paper seeks to describe the extension of the functionality of the iLabs shared architecture to include on-line laboratories in Digital Filters and Sound Effects. The sections that follow give the Rationale, Requirements Specification, Design and Implementation of the Laboratory and Conclusion.

2. Rationale

Due to the rapid advances in software and hardware developments in DSP especially in the areas of audio, image and video processing, it is vital for students to complement their theoretical learning with practical applications. At the Faculty of Technology, Makerere University, Uganda, the Bachelors of Science in Electrical, Telecommunications, and Computer Engineering curricula include courses that deal with the study of Digital Data and Signal Processing as shown in Table 1 below [9]. However, the laboratory resources available vis-à-vis the number of students [9] do not provide comprehensive experience to explore the practical study of Digital Filters and Sound Effects.

In a bid to fully integrate iLabs into the curriculum of Engineering in the University, iLABS@MAK with its ongoing research started with development of Laboratories in courses involving Analog and Digital Modulation techniques and Digital Electronics [10]. Although the iLabs platform has been modified to expand its functionality in order to supplement the conventional laboratories, it had not yet been scaled to include experiments in DSP.

Table 1. Course curricula for DSP fields

Program	YEAR	Course unit	Topics
Telecommunications Engineering	III	TEL3105 Basic Telephony	An introduction to digital communication (basic pulse modulation samples and hold short circuit) programmable digital filters
			Digital data transmission
			Digital speech and bandwidth of voice channel
	IV	TEL4202 Computer systems Engineering and Network	Data processing systems components
Electrical and Telecommunications Engineering	III	ELE3202 Instrumentation	Data acquisition and conversion
			Sampling theorem,
			quantization and filtering
		ELE3204 Communication Engineering I	Signal analysis and signal models
Computer Engineering	IV	CMP4101 Digital Signal Processing	Design of IIR Filters
			FIR filters, frequency and phase response, time domain multi-tap filters, surface acoustic wave filters
			Sampling of signals
		CMP4205 Audio and Speech Signal Processing	Introduction to Digital processing of speech signals

Table 2. Number of students on the Computer, Electrical and Telecommunications Engineering programmes [11]

	Electrical Engineering			Telecommunications Engineering			Computer Engineering		
Year	**I**	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
2008/2009	74	73	74	63	78	75	-	-	-
2009/2010	97	99	121	94	100	88	104	-	-
TOTAL	**171**	**172**	**195**	**157**	**178**	**163**	**104**	**-**	**-**

The on-line laboratory supporting experiments in Digital Filters and Sound Effects will supplement conventional laboratories. This will help students to better appreciate the theoretical concepts in digital signal processing through having practical exposure in form of laboratory experiments. The laboratory will also be available for sharing with other institutions of higher learning. This will be beneficial to the academia since it will enable the sharing of scarce and expensive resources.

3. Requirements specification

The digital signal processing laboratory was designed to be used for practical exposure in the programs of Bachelors of Science in Computer, Electrical and Telecommunications Engineering in the areas where DSP concepts are covered. A detailed study of the current curricula of the programs was carried out to identify the fields which cover Digital signal processing concepts. The course units and the corresponding topics under the different programs were identified as shown in Table 1 above.

A comparison was drawn between the curricula at Makerere University with the requirements and demand of current trends in the applications of DSP to analyze the needs of the end users. The personnel responsible for conventional laboratories were consulted in an effort to evaluate the current status of laboratory.

The available DSP laboratories and equipment were identified. In the Electronics laboratory, there are only four pieces of CK342K boards shown in Figure 1 below. Due to the requirements of the iLabs experimentation platform, there is no possibility of integrating this particular board to the platform since it cannot be interfaced with a computer.

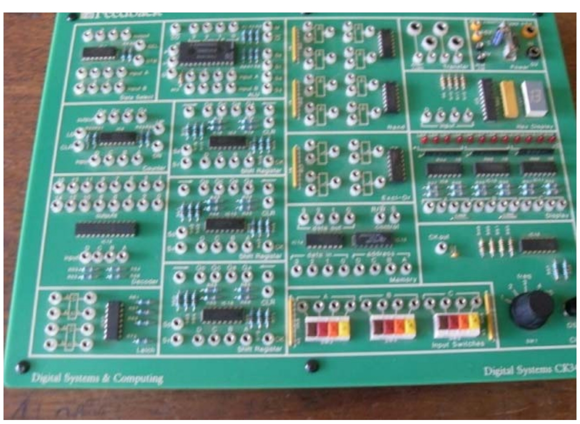

Figure 1. CK342K board

The necessary equipment for the design and implementation of the Laboratory were identified in accordance with the iLabs platform requirements. This includes:

a) The Lab VIEW DSP Module
b) Lab VIEW 8.6
c) NI SPEEDY-33
d) Computer sound card for sound acquisition
e) The interactive ISA

4. Design and implementation

4.1. The digital filters laboratory

In the design of the Digital Filters Laboratory, the main objective is to analyze the effect of a given filter operation on a sound signal, the response of the filter and the characteristic of the input signal. The user is expected to carry out an experiment by selecting an audio file and a specific filter to use for processing the sound file. From the client side, the user specifies the filter type and then changes the cutoff frequency of the filter.

The Digital Filters Virtual Instruments (VIs) were built in LabVIEW, as shown in Figure 2, A and B, to interface with the laboratory hardware. The system inputs are audio files from a defined location on the server computer. From a set of four audio files, the user is expected to choose a specific file as specified in the laboratory user manual.

When the user specifies the input variables, a real signal is generated, processed and the output viewed at the front panel, which will be the client interface. The user interface is as shown in Figure 3 displaying both the input and output inform of a graph for purposes of comparison.

A) Filter Input Stage B) Filter Output Stage

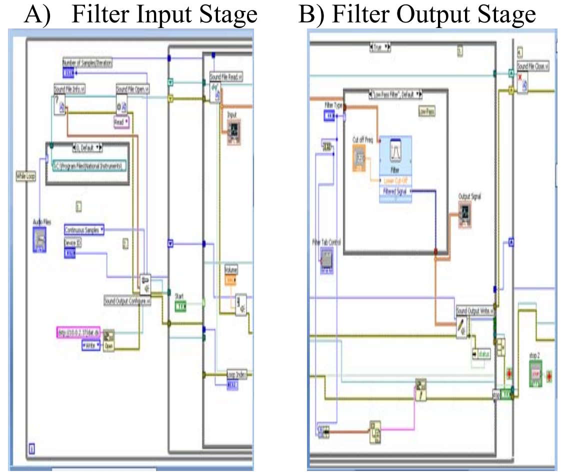

Figure 2. Block diagrams for digital filters

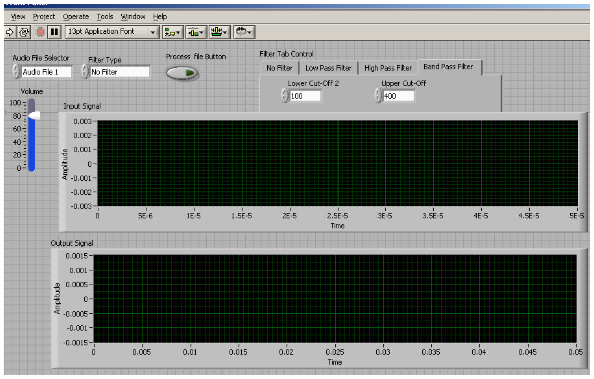

Figure 3. Front panel for digital filters

4.2. Results

Four cases are included in the Digital Filters laboratory. The first case, which is the default, is the no filter case in which the input signal will not be processed through any filter resulting in an output similar to the input. The other cases are the Low Pass, High Pass and the Band Pass filters. While performing the experiment, the user interacts with client side Graphical User Interface (GUI) to specify the input variables to the system and also acquire output from the system. An audio file is acquired from the sound card to constitute the input signal.

At the control panel, the user can configure the parameters of the filters. The client is required to select an audio file, the filter type, and set the cutoff frequency as per the user manual that is provided. Figure 4 shows the results obtained from a Low Pass filter experiment with cutoff frequency set to 100 Hz. The cutoff frequency can be varied from as low as 50 Hz to a value of 10 kHz.

Figure 5 shows the results of a High Pass filter with a cutoff of 400 Hz. As with the Low Pass, the cutoff frequency of the High Pass can be varied up to a value of 10 kHz to analyze the characteristics of the filter. The results of the band pass filter are displayed as shown in Figure 6. The low and high cutoff frequencies are set to 100 and 101 Hz respectively. This results into a clean signal of single frequency as compared to the input. The high cutoff can then be varied and the changes in the outputs observed.

4.3. The sound effects laboratory

In this laboratory, the objective is to analyze the effect of applying sound effects on an audio signal. In this experiment, the reverberation effect and the Wah Wah effect are studied and the response observed on a graphical display. The sound effects VIs were built with three different cases.

Figure 4. Low pass filter result panel

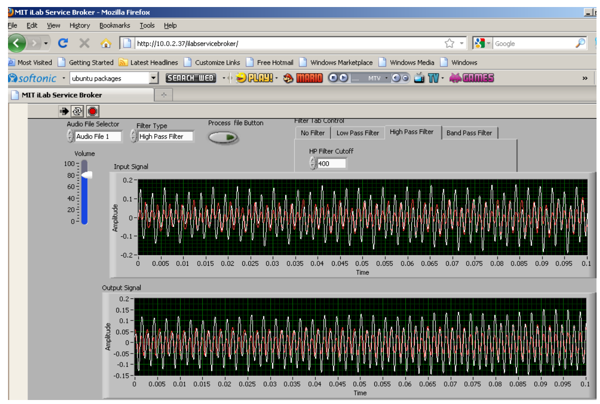

Figure 5. High pass filter result panel

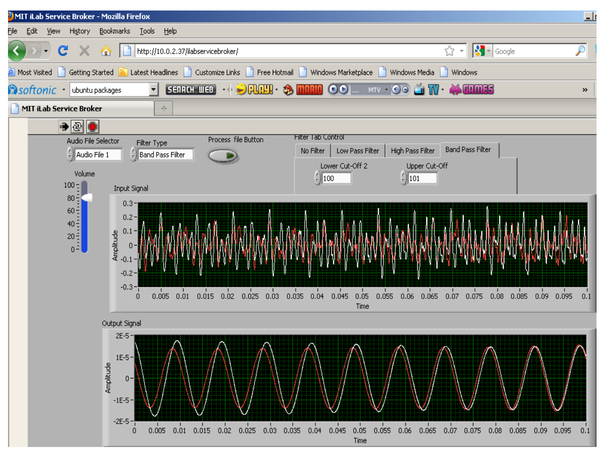

Figure 6. Band pass filter result panel

Figure 7, A and B, respectively show the VI with the processing stage of the Wah Wah and reverberation sound effect cases displayed. The first case is when there is no effect and the output is similar to the input. The other cases are for the Wah Wah, and Reverberation effects. At the front panel, which is the user interface as shown in Figure 8, the user can change the type of effect on a selected audio signal and compares the wave form of the input and output signals.

A) Wah Wah case B) Reverberation case

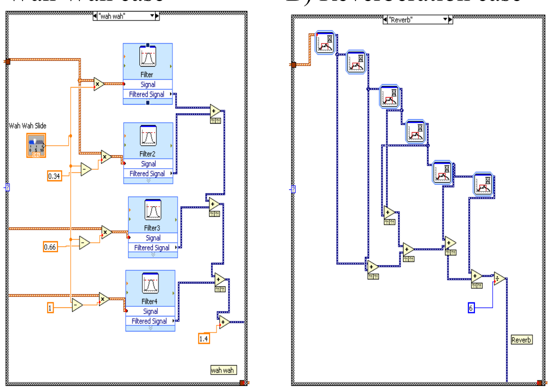

Figure 7. Block diagram for sound effects

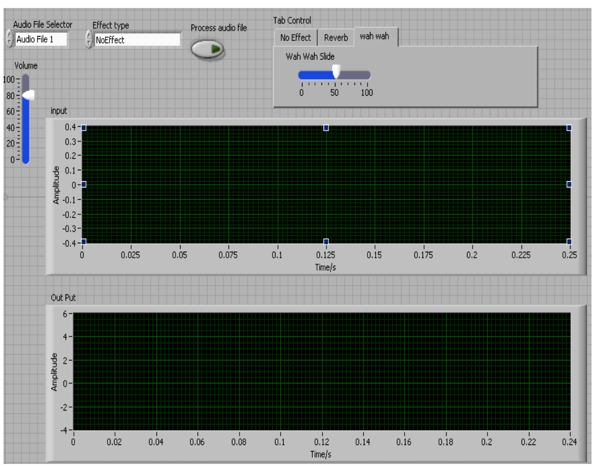

Figure 8. User interface for sound effects

4.4. Results

As with the filters, sound effects are configurable at the control panel. The specific parameters to configure are the effect type, audio file to process, and the parameters of the specified effect. The wah wah effect has a slider to vary the frequency of the passed signals. Figure 9 shows the resulting input and output signal waveforms.

The Reverberation effect results are shown in Figure 10. The output was observed to be a signal that decreases in amplitude and then the amplitude increases again. The behavior is repeated for as long as an input signal is present.

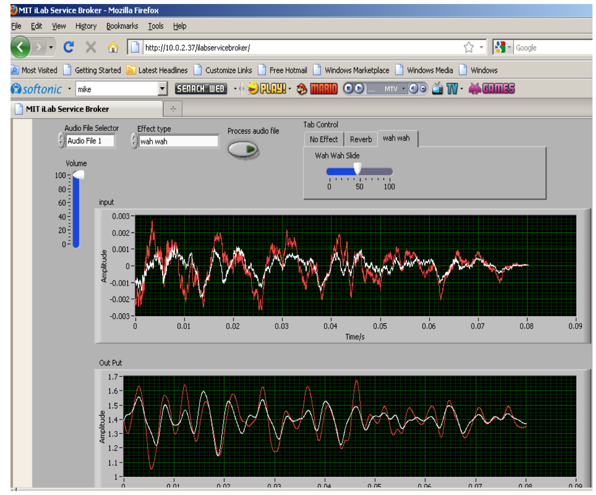

Figure 9: Wah Wah effect

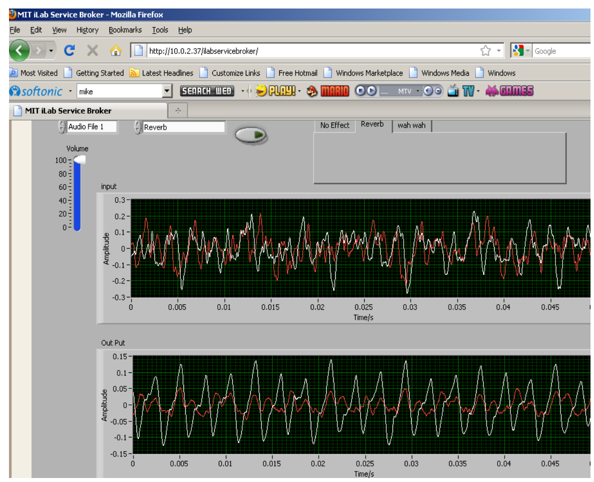

Figure 10. Reverb effect

5. Conclusion

In this paper, the design and functionality of an online Digital Filters and Sound Effects laboratory Utilizing NI SPEEDY 33 has been presented. The system was implemented using the interactive ISA. This enables remote user interaction with the hardware during the conduction of a particular experiment. The developed laboratories as detailed in sections 4 will avail students and researchers at the Faculty of Technology, Makerere University a relevant laboratory experience, even though they are not in physical contact with experimentation hardware.

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