ON-LINE LABORATORIES FOR SPEECH AND IMAGE PROCESSING AND FOR COMMUNICATION SYSTEMS USING J-DSP

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ABSTRACT

J-DSP is a java-based object-oriented programming environment that was developed at Arizona State University for use in the undergraduate DSP class [1]. In this paper, we describe innovative software extensions on J-DSP to accommodate on-line laboratories for speech processing, image processing, and communications systems. Significant modifications in the object-oriented GUI of J-DSP that enable simulation of feedback systems are also presented. The speech processing functions enable on-line simulations of speech coding algorithms and include PCM and ADPCM quantization as well as more elaborate algorithms such as the LPC and the CELP. Image processing functionality includes development of 2-D signal processing capabilities including 2-D-FFT, 2-D-filter design, and 2-D graphics and picture processing. Communications functionality covers several aspects of analog and digital modulation and demodulation. On-line laboratory exercises have been developed in the aforementioned areas and posted on a web site (jdsp.asu.edu). This site also includes on-line evaluation forms for the exercises. Statistical and qualitative evaluations that assess the learning experiences of the students that use J-DSP will be presented in the full paper.

1. INTRODUCTION

At Arizona State University (ASU) DSP-related courses are well attended by distance learning students. In order to provide on-line laboratory experiences to distance learners the ASU Multidisciplinary Initiative on Distance Learning (MIDL) laboratory developed and tested successfully an exemplary laboratory prototype tool [1], called Java-DSP (J-DSP), for use in the undergraduate DSP class. This simulation environment enables students to establish and execute DSP simulations from any computer equipped with a browser. The MIDL is currently developing and evaluating significant extensions of this J-DSP prototype in other areas of undergraduate education. In this paper, we present innovative software extensions on J-DSP to accommodate on-line laboratories for speech processing, image processing, and communications systems. Significant modifications in the object-oriented GUI of J-DSP that enable simulation of feedback systems are also discussed. The extensions presented have been funded by the NSF CCLI program and involve developing and disseminating the new J-DSP functions along with a series of on-line laboratory exercises.

2. EXISTING SIGNAL PROCESSING FUNCTIONS IN J-DSP

The J-DSP editor is an object-oriented signal processing simulation environment. All functions in J-DSP appear as graphical blocks that are divided into groups according to their signal processing functionality. Existing functionality includes: filter design, FFT, plotting, periodograms, correlograms, updampling/downsampling, AR time-series, signal generation, etc. Details on these blocks are given in [1] and at http://jdsp.asu.edu. Simulations are established by linking blocks and establishing a flowgram.
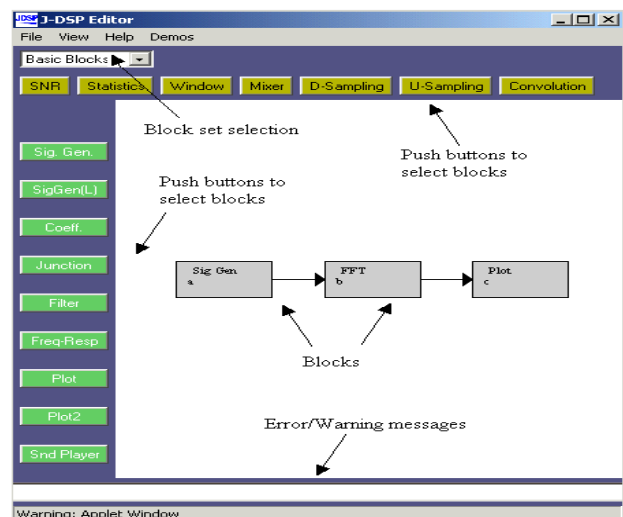

Figure. 1 J-DSP Editor Environment
(J-DSP can be accessed from http://jdsp.asu.edu)

3. NEW SPEECH PROCESSING FUNCTIONS

Several new functions have been developed to support new experiments exposing undergraduates to additional DSP-related topics such as speech analysis-synthesis and vocoders, image processing, and communications systems. Speech processing blocks now supported by J-DSP include: frame-by-frame

processing of speech, autocorrelation, filter parameter transformations, line spectrum pairs, bandwidth expansion, perceptual weighting, quantization, pitch Estimation. A sound player block is also provided to listen to the processed speech record. A typical vocoder flowgram that can be supported is shown in Fig. 2.
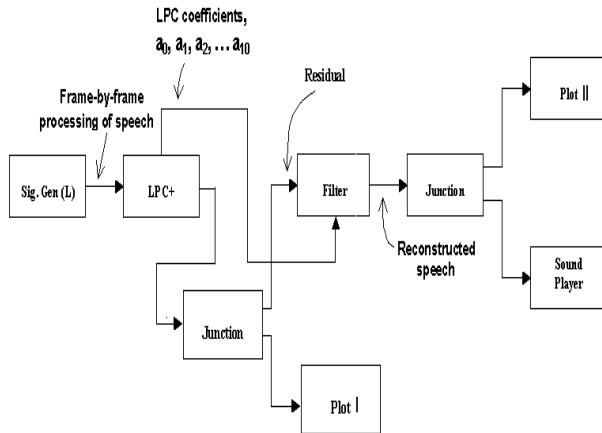

Figure. 2 LPC vocoder block diagram

In order to compute the time varying spectra of speech and other signals a 3-D spectrogram function was also developed.

4. NEW IMAGE PROCESSING FUNCTIONS IN J-DSP

New image processing functions include 2-D filter design, 2-D FFTs, 2-D plots and some picture processing capabilities. In particular J-DSP now includes signal generation of 2-D signals; 2-D filtering; 2-D convolution; 2-D FIR filter design; 2-D FFT; 2-D frequency response; 2-D transforms and select functions for image restoration and enhancement. Students can carry simulations of window-based 2-D FIR design. LPF, HPF, BPF and BSF filters can be designed using both separable and non-separable design techniques. 2-D FIR filters can be implemented using time domain convolution and FFT-based fast convolution. 2-D transforms include DFT, DCT and wavelet transforms. Row-Column (RC) decomposition using 1-D FFT has been implemented in the 2-D FFT block.

5. COMMUNICATION FUNCTIONS IN J-DSP

The J-DSP communication functions support simulations of analog and digital communication systems. Analog modulation blocks such as amplitude modulation (DSB-SC AM, SSB AM, and conventional AM) and angle modulation (FM/PM) have been developed. Demodulators supported are envelope and coherent detection using a phase locked-loop. Digital modulation schemes supported are binary pulse amplitude modulation (PAM), M-ary PAM, phase shift keying (PSK), quadrature PSK and M-ary PSK. Receiver blocks supported include the matched filter demodulator and maximum likelihood detection algorithm. A Monte Carlo simulation J-DSP block was also developed to compute bit error rate probabilities.

6. J-DSP INFRASTRUCTURE EXTENSIONS

In addition to the development of new functionality in speech and image processing ongoing work addresses the way blocks are designed and manipulated in the J-DSP editor. Changes in the Java object-oriented program and the J-DSP GUI now facilitate state-space realizations of digital filters as well as feedback systems. Perhaps the most important modification successfully implemented is the addition of feedback capability. Most of the J-DSP code supporting the GUI was re-written while at the same time blocks have been re-designed to offer additional features. J-DSP blocks can now be rotated and flipped thereby allowing the realization of feedback systems. Future J-DSP Editor versions will allow a user to create and save composite blocks, by grouping together a collection of primary blocks. New blocks have been designed to be easily adjustable with regard to the number of inputs and outputs. Each block can now have up to ten inputs or outputs on each side. Finally, in order to achieve better block and connection placement, changes have been made in order to allow a user to drag and modify a connection line as necessary.

7. ON-LINE EXERCISES USING J-DSP

Java-based laboratory exercises introduce the concepts of PCM, ADPCM, LPC vocoders, bandwidth expansion and perceptual weighting filter. Students can experiment with LPC transformations involving direct form, reflection coefficients (RC), and Line Spectrum Pairs (LSP). J-DSP provides blocks that would facilitate the implementation of simple vocoders and students can experiment with pitch detection and its effect on speech synthesis. Experiments with open- and closed-loop analysis have also been developed.. With regard to image processing several exercises have been designed including filter design, image filtering and enhancement, 2-D spectra, the DCT and its utility in JPEG, etc. Communication systems exercises include AM and FM modulators and demodulators, simulations with noise, digital modulation simulation and evaluation, and computation of bit error rates.

8. LEARNING ASSESSMENT

Electronic evaluation forms have been developed for the evaluation of the J-DSP simulator and the on-line laboratory exercises. Qualitative as well as quantitative data is collected automatically and stored on the network. General assessment includes providing feedback on the DSP functions while specific forms focus on each exercise specifically by posing questions to determine whether the student has learned a concept.

9. REMARKS

This paper presented NSF funded extensions on J-DSP. More results from all test sites will be presented at the workshop.

10. REFERENCES

[1] A. Spanias et al, "Development and Evaluation of Web-Based Signal and Speech Processing Laboratory for Distance Learning," *Proc. IEEE ICASSP-2000*, Istanbul, June 2000.