

## **AC 2007-1131: USING J-DSP AND LABVIEW TO PERFORM UNDERGRADUATE LABS**

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# USING J-DSP AND LABVIEW TO PERFORM UNDERGRADUATE LABS

## 1. Introduction

Java-DSP (J-DSP) is a universally accessible online tool primarily intended for studying concepts in signal processing<sup>1</sup>. Extensions to communications<sup>2</sup>, image processing<sup>3</sup>, speech processing<sup>4</sup>, and controls<sup>5</sup> have also been previously produced under an NSF EMD program. In addition, J-DSP modules for demos of technology to high schools have also been generated<sup>6</sup> and interfaces to hardware for real-time DSP have been produced<sup>7</sup>. The software is currently being tested in six different universities<sup>8</sup> including Arizona State University, University of Texas-Dallas, University of Washington-Bothell, University of Rhode Island, University of Central Florida, and the University of Cyprus. The scripting capabilities embedded in the software enable generation of HTML code<sup>9</sup> and MATLAB scripts<sup>10</sup>.

A new interface has been developed to allow students and users to move between Java-DSP and the National Instruments LabVIEW tool. This interface is made possible using J-DSP Mathscript capabilities and provides an effective way to utilize several functionalities across both visual environments. The motivation for providing this feature is to enable students to access important LabVIEW modules and functions and particularly tap on powerful real-time capabilities of LabVIEW that allow to acquire and process real-time signals. This interface has been tested by students in the Digital Signal Processing laboratory.

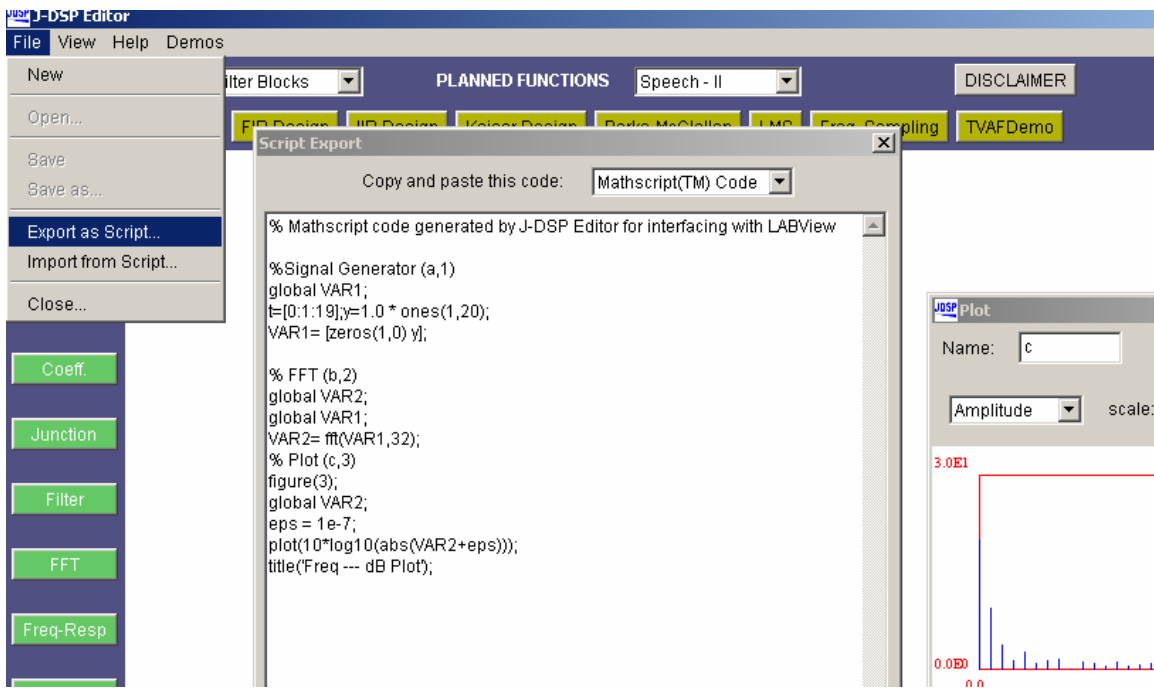
## 2. Generating Mathscript Code from J-DSP Simulation

Mathscript is a text-based scripting language available in LabVIEW that can be executed in the Mathscript window by the LabVIEW runtime engine. A native LabVIEW function, Mathscript node, can be used as well to form and execute a program in block diagram mode. As such most or all J-DSP simulations can be translated to Mathscript code, modularly developed for block execution. Figure 1 illustrates the generation of Mathscript code for a certain J-DSP simulation. The generated code can be obtained by selecting “Export script” feature under the

file menu. The code is then copied and saved as a file and can be subsequently loaded by LabVIEW. Running J-DSP as a signed applet can also eliminate the cut-and-paste process and make this code export seamless. The details of the interface are provided in the next section.

### 3. Interface between J-DSP and LabVIEW

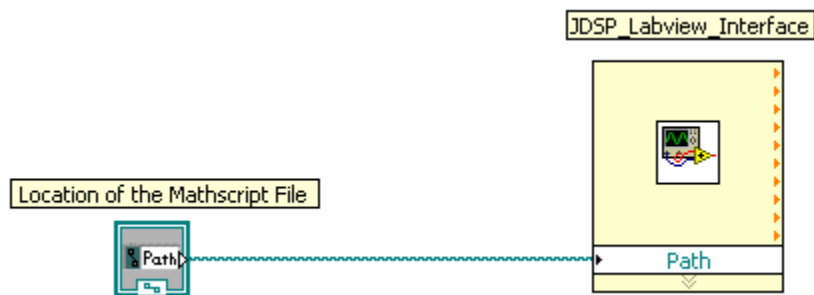
The interface developed is a LabVIEW model (*JDSP\_Labview\_Interface .vi*) that takes the Mathscript code generated by J-DSP and simulates the functionality of the original block diagram as designed in J-DSP.



**Figure 1. Generating Mathscript code from J-DSP**

In addition the interface also generates a pictorial layout of the block diagram in the LabVIEW front panel. This enables the user to visualize the logical flow of the simulation as expressed by J-DSP and allows the user to handle the outputs of intermediate blocks using the native LabVIEW VIs. This has a great advantage in that it enables the user to combine the functionalities of both J-DSP and LabVIEW.

The Mathscript code generated by J-DSP is modular in the sense that it contains the code generated for each block in a sequential manner. This allows the *JDSP\_Labview\_Interface* to interpret the code by splitting the code and using a subvi (*JDSP\_Block.vi*) corresponding to each J-DSP block. This prototype interface hence provides a way to use the intermediate outputs of the block diagram to extend the design. The *JDSP\_Block* consists of a Mathscript node which executes the code associated to the block. As illustrated in Figure 2, the *JDSP\_Labview\_Interface* can be used as a subvi in the model that the user develops, by providing as input, the path of the Mathscript file generated by J-DSP, saved in the local computer. The outputs of each block are available as output terminals of the *JDSP\_Labview\_Interface*. The design can be extended by using the outputs with native LabVIEW blocks thereby effectively interfacing the features of both applications.



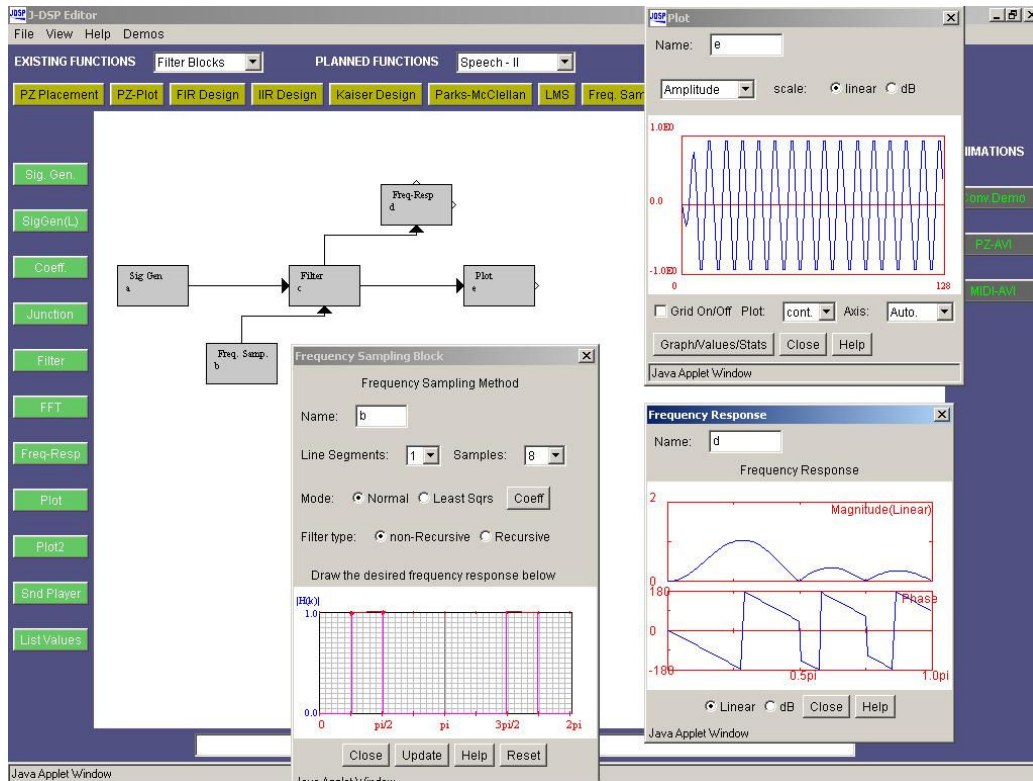
**Figure 2. A simple model demonstrating the JDSP\_Labview\_Interface**

Once the model shown in Figure 2 is executed in the LabVIEW environment the simulation is executed. Also by double clicking the *JDSP\_Labview\_Interface* block, the front panel of the subvi appears where the pictorial layout of the J-DSP block diagram can be seen. The total number of blocks is also displayed in the front panel. An example demonstrating the interface and steps to be followed are explained in the next section.

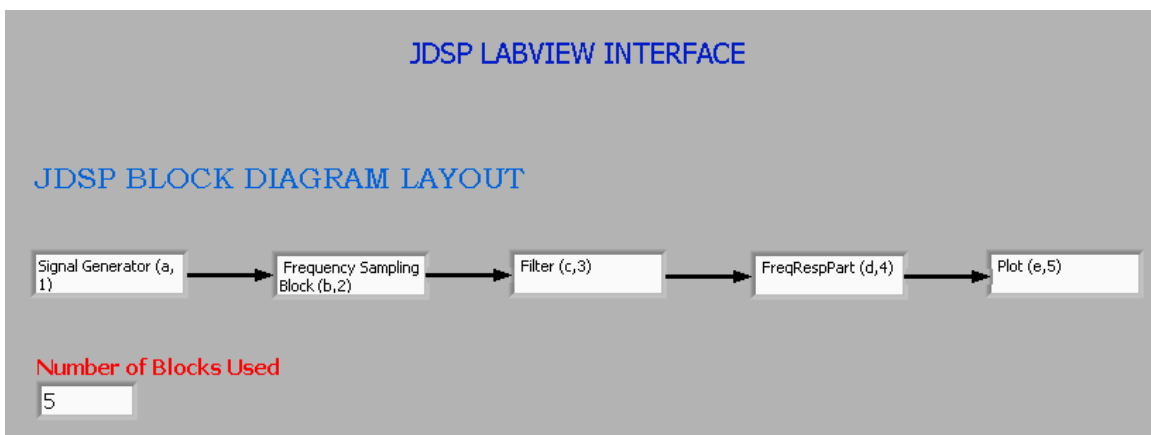
#### **4. Example of a J-DSP Simulation Interfaced with LabVIEW**

A bandpass filter is designed using frequency sampling method in J-DSP. The Mathscript code generated corresponding to this simulation is used with the developed interface. This design is extended in LabVIEW by designing a filter with similar specifications using window method

with native LabVIEW blocks. The input to this extension is taken from output terminals of the *JDSP\_Labview\_Interface* block. Figure 3 illustrates the creation of a block diagram in J-DSP and Figure 4 shows the pictorial layout generated by the *JDSP\_Labview\_Interface* block in LabVIEW.



**Figure 3. Filter Design using Frequency Sampling in J-DSP**



**Figure 4. Pictorial Layout Generated by LabVIEW Interface using Mathscript Code**

## 5. Example with Real-time signals

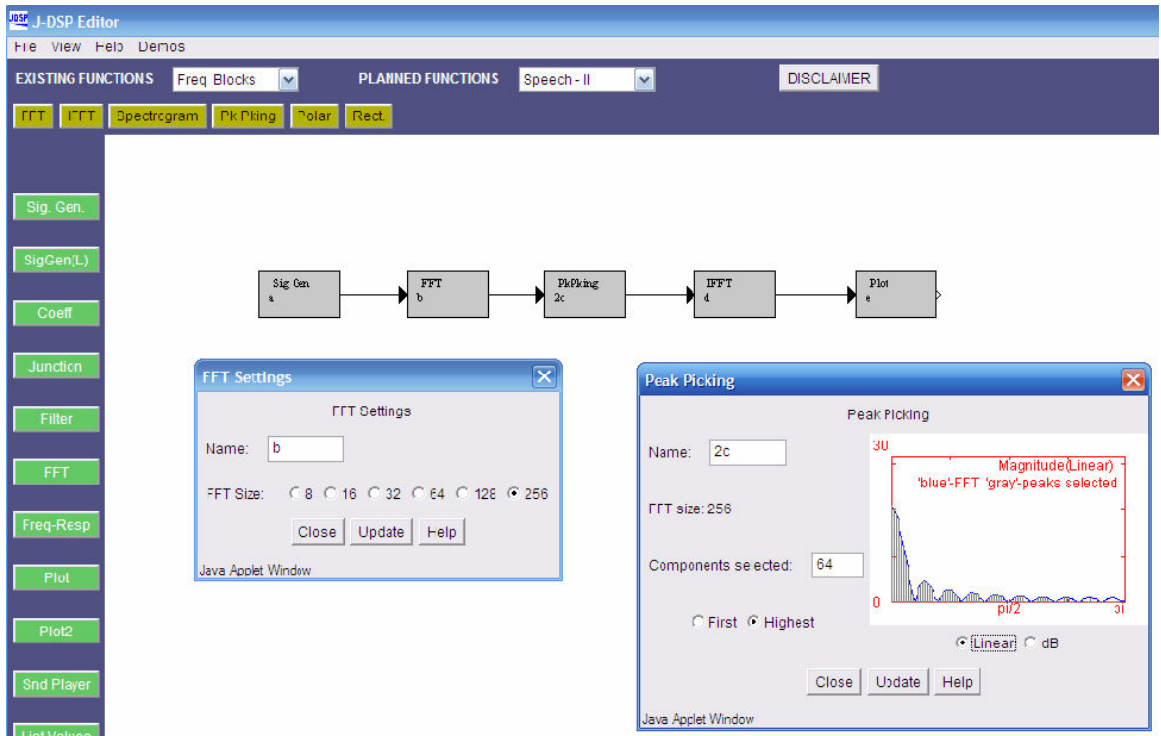
In addition to enabling the user to extend the design in LabVIEW, the interface allows to exploit the real-time processing capabilities of LabVIEW. Real-time inputs can be acquired into LabVIEW and processed by the Mathscript code generated by J-DSP using the interface. Figure 6 (in the next section) illustrates this by using real-time audio inputs with the ‘FFT based compression’ experiment. The user can provide the real-time speech input through the microphone. This experiment can be extended to varied range of real-time signals that LabVIEW supports.

## 6. Utility in DSP Courses

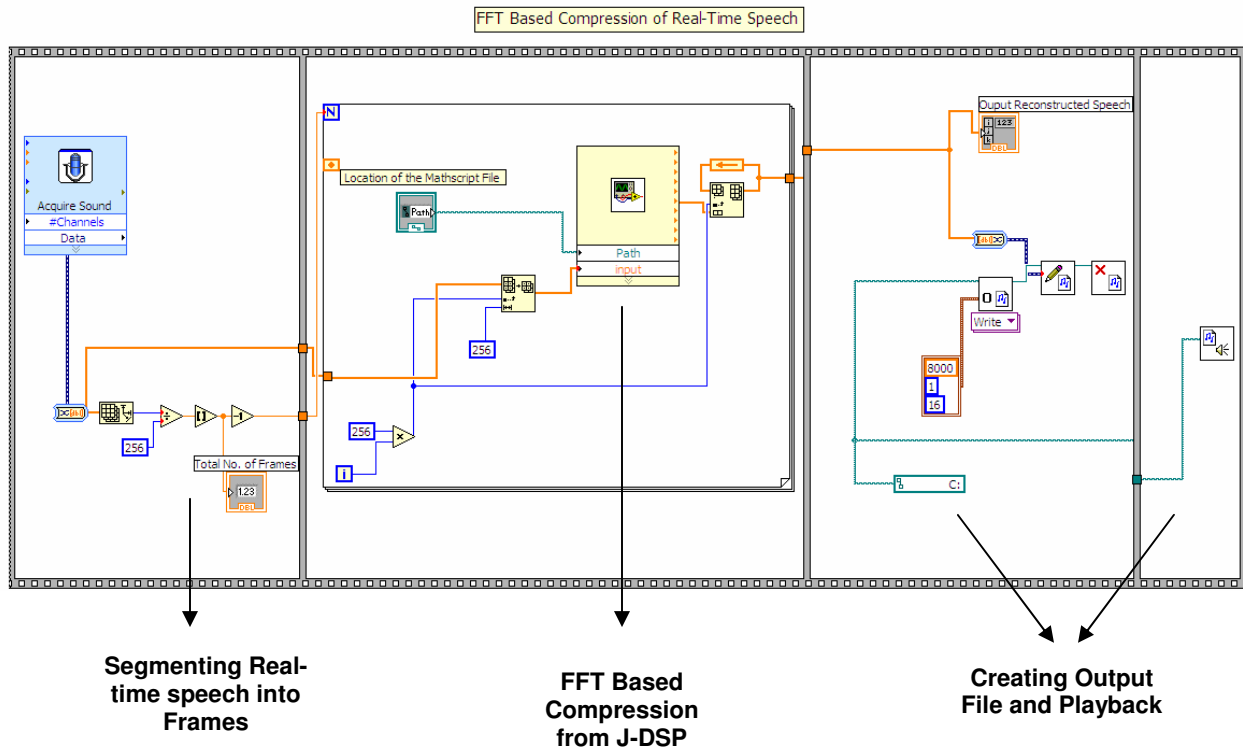
The interface to LabVIEW was used to demonstrate a real-time signal acquisition, processing, and playback by establishing the program in the J-DSP environment on the Internet and then porting it to LabVIEW that supports real-time signal acquisition. An FFT-based speech compression simulation that helps show the utility of Parseval’s theorem was demonstrated. Other pedagogical byproducts of these experiments across the two platforms include exposition of students to several programming and data flow structures through examples with J-DSP scripts, Mathscript, and LabVIEW VIs.

## 7. Assessment

FFT based speech compression involves processing the speech signal frame by frame and then transforming it using the FFT. A reduced number of DFT components is then used to reconstruct the signal. In this last “data compression” step, only a specific number of FFT magnitude peaks are selected and used for signal reconstruction. The peak picking implies that maximum signal to noise ratio is maintained which can be shown using the Parseval’s theorem. This experiment combines the functions of both J-DSP and LabVIEW by modularly splitting it across the two environments. Information on FFT-based compressions schemes, such as this simple one, are described in text books<sup>11,12</sup>.



**Figure 6. FFT Compression – Basic Block Diagram in J-DSP**



**Figure 7. FFT Compression – LabVIEW Model with Real-Time Input and Playback**



This experiment uses LabVIEW to acquire real-time speech and split the signal into frames of size 256 samples. The frames are then processed by the *JDSP\_Labview\_Interface* block, which executes the Mathscript code generated by J-DSP for the design shown in Figure 5. The processing uses the Peak Picking block in J-DSP, which selects the highest components or first few components from the DFT coefficients based on the choice made. The reconstructed frames after peak picking can then be handled in LabVIEW to create output files with playback features. The model created in LabVIEW is illustrated in Figure 6.

An assessment quiz was administered before (pre-quiz) and after (post-quiz) the hands-on laboratory exercise. Some of the questions posed are itemized below:

1.  $\mathbf{S}$  is the frequency domain vector representation of the speech signal vector  $s$ . If  $\mathbf{S}$  consists of  $N$  components, which one of the following approaches, would result in better speech quality ( $n < N$ )
  - a) Picking the  $n$  largest components of  $\mathbf{S}$
  - b) Picking the first  $n$  components of  $\mathbf{S}$
2. In question 1, if  $\mathbf{S}$  contained 256 FFT components, which one of the following would result in best speech quality
  - a) Selecting the first 16 components
  - b) Selecting the highest 16 components
  - c) Selecting the highest 64 components
  - d) Selecting the first 64 components
3. The FFT Peak-picking analysis-synthesis process can be used to compress speech signals
  - a) True
  - b) False
4. The magnitude of the  $N$ -point FFT of the speech signal is defined as  $S(0), \dots, S(N-1)$ . It can be shown that the magnitude spectrum is
  - a) Even-Symmetric about the point  $N/2$
  - b) Odd-symmetric about the point  $N/2$
  - c) Even-symmetric about the point  $N/2+1$
  - d) Odd-symmetric about the point  $N/2+1$
5.  $\mathbf{S}$  is the  $N$ -point FFT of the signal vector  $s$ . Which of the two maximizes the SNR of the reconstructed signal ?
  - a) Selecting the first  $n$  components of  $\mathbf{S}$
  - b) Selecting the highest  $n$  components of  $\mathbf{S}$
6. Which of the two methods for selecting the reduced set of FFT components of the signal produces a low pass filtering effect?

- a) Selecting the highest n components
- b) Selecting the first n components

7. SNR maximization in FFT component selection for speech analysis-synthesis can be shown using the Parseval's theorem

- a) True
- b) False

In addition to the above questions an interview was carried with the participating students.

We conducted a preliminary assessment using a small group of undergraduate and graduate students. Students were given the quiz before and after working with these two environments. There was evidence of improvement in the understanding of this FFT application after forming the simulation on J-DSP and conducting the real time experiment on LabVIEW. When students were interviewed they noted on the average that combining features of J-DSP and LabVIEW was useful in terms of utilizing the real time capability of LabVIEW and the simplicity of organizing the DSP simulation on J-DSP. Our assessment above was preliminary with only a few students. We will be conducting additional assessment in the DSP class in the spring and fall semesters of 2007 and will have additional detailed quantitative assessment at the conference presentation.

## 8. Conclusion

A J-DSP interface to LabVIEW was described. The interface uses the LabVIEW Mathscript code and the J-DSP scripting capability. The scripting functionality of J-DSP provides an intuitive way to combine the features of J-DSP with advanced real time processing capabilities of LabVIEW. A preliminary assessment was conducted using pre- and post-quizzes and student interviews. Students noted that combining features of J-DSP and LabVIEW was useful in terms of utilizing the real time capability of LabVIEW and the simplicity of organizing the DSP simulation with J-DSP. More detailed assessment results will be reported at the conference.

## Acknowledgement

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