DSP Algorithm and Software Development on the iPad/iPhone Platform

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Outline

• Motivation
• iJDSP Background
• Design Architecture
• New iJDSP Functions
  Convolution Demo
  FIR Filter Design
  IIR Filter Design
  Hardware Interface iJDSP with WSN
• Assessments
• Future Work
Motivation

• Mobile Market

Huge growth of Smartphones and Tablet PC from 2007 to 2011

Acquired from the online source: http://i-stuff.org/will-android-and-ios-take-over-the-pc-market/
Statistic acquired at March 2011

- Apple iOS: 27%
  
  *iPhone*

- Android OS: 37%
  
  *Samsung Galaxy, LG, HTC, etc.*

- RIM BlackBerry OS: 22%

- Windows Mobile: 10%

- Web OS: 3%

- Symbian OS: 2%

Acquired from the online source:

http://blog.nielsen.com/nielsenwire/?p=27418
• **Mobile Educational Tools**
  - Star Walk
    *Astronomy*
    $2.99
  - HP 12c Financial Calculator
    *Bussiness*
    $14.99
  - Spectrogram
    *Music: Visualize frequency over time*
    $9.99
  - MATLAB Mobile
    *Computing & Simulation*
    $0.00
    *Command line only*
    *Lightweight mobile version*
    *Heavily relies on the Internet*
• Need for DSP Mobile Tool

- Standalone mobile application with intuitive graphical user interface.
- Rich user interactions stimulate students interest.
- Provide multi-touch experience to undergraduate/graduate DSP students and distance learners.
- Demonstrate signal processing concepts
- Undergraduate labs on iPhone/iPad
- Infrastructure for research in sensor networks
iJDSP Background

• **Features:**
  - Intuitive Graphic User Interface
  - Free DSP Mobile App through iTunes App Store
  - Multitouch Experience
  - Visualize DSP Functions

• **Platform:** *Compatible with iOS 3.2 or later*

• **Development Environment:** *Xcode*

• **Hybrid Programming:** *Objective C/C*
• Graphical User Interface

Navigation Bar
Main Canvas
Block Diagram
Tool Bar
Tool Bar Items
- Add button
- Delete button
- Info button
- Tips button
## User Gesture Recognition

<table>
<thead>
<tr>
<th>Gesture Recognition</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double tap on a block</td>
<td>Open a block</td>
</tr>
<tr>
<td>Long hold on a block</td>
<td>Delete the block</td>
</tr>
<tr>
<td>Single tap on a pin</td>
<td>Make a connection</td>
</tr>
<tr>
<td>Single tap on a connection</td>
<td>Delete a connection</td>
</tr>
<tr>
<td>Hold and drag on a block</td>
<td>Move blocks</td>
</tr>
<tr>
<td>Swipe down/up on main canvas</td>
<td>Hide/show tool bar</td>
</tr>
</tbody>
</table>
• DSP Functions

1. Signal Generator
2. Digital Filter
4. Frequency Response
5. PZ Computation
6. FFT
7. Plot
8. Sound Recorder/Player
9. Convolution Demo (new)
10. FIR Filter Design (new)
11. IIR Filter Design (new)
...
Design Architecture

- Model - View - Controller Paradigm\(^1\)

![Diagram of Model - View - Controller Paradigm]

1. Model
2. View
3. Controller

- User Action
- Update
- Notify
- superclass
- subclass

Model - subclass - NSObject

View - superclass - UIView

Controller - superclass - UIViewController
• View Layers
• Touch Event Handling

The Responder Chain

Canvas View

Part View

Pin View

Make a connection on canvas

Touch on a Pin

Pin View

Part View

Canvas View
New Added Functionalities in iJDSP

• Convolution Demo: Animated continuous / discrete convolution
• Filter Design: FIR / IIR filter design
• Collaborative Sensor Signal Processing Enabled by iJDSP:
  ▫ Wireless connection between sensors and iPad
  ▫ GUI for sensor motes on iPad
  ▫ Inputs from multiple sensors: photometer, microphone, thermometer and accelerometer
  ▫ Real-time plot of sensor data
  ▫ Frame-by-frame process with DSP functions in iJDSP
• Convolution Demo
• FIR Filter Design
  • Windowing Method
  • Parks-McClellan Algorithm
Window Type

- Rectangular
- Triangular
- Hamming
- Hanning
- Blackmann
- Kaiser
-Example:

Design a lowpass filter using Kaiser window method with following specifications,

\[ 0.9 \leq |H(e^{j\Omega})| \leq 1.1, \quad 0 \leq \Omega \leq 0.25\pi \]
\[ |H(e^{j\Omega})| \leq 0.056, \quad 0.5 \leq \Omega \leq \pi \]
- Verified using MATLAB Code

• PZ plot in MATLAB

• PZ plot in iJDSP
• Magnitude of Frequency Response in MATLAB

• Magnitude of Frequency Response in iJDSP

• Linear Phase Constraint in MATLAB

• Linear Phase Constraint in iJDSP
• IIR Filter Design

<table>
<thead>
<tr>
<th>Analog Approximation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butterworth</td>
</tr>
<tr>
<td>Chebyshev I</td>
</tr>
<tr>
<td>Chebyshev II</td>
</tr>
<tr>
<td>Elliptic</td>
</tr>
</tbody>
</table>
-Example:

**Design a lowpass Elliptic IIR filter with following specifications,**

- **Passband Cutoff frequency:** $0.4\pi$ ; **Stopband Cutoff frequency:** $0.6\pi$
- **Tolerance in passband:** $1\text{dB}$; **Tolerance in stopband:** $45\text{dB}$

(a) Set up for IIR Filter Design

(b) Main Menu of IIR Filter Design
- Verified using MATLAB Code

* **PZ plot in MATLAB**

* **PZ plot in iJDSP**
- **Magnitude of Frequency Response in MATLAB**

- **Magnitude of Frequency Response in iJDSP**

- **Nonlinear Phase in MATLAB**

- **Nonlinear Phase in iJDSP**
- Comparison between four types IIR

Use same filter parameters

- **Butterworth** \(\text{(Order} = 10)\)

- **Chebyshev I** \(\text{(Order} = 6)\)

- **Chebyshev II** \(\text{(Order} = 6)\)

- **Elliptic** \(\text{(Order} = 4)\)
MIB600 Ethernet Interface Board

MTS310CA Sensor Board

MICAz Mote

- Microphone
- Sounder (4.5kHz)
- RF transceiver
- Microprocessor (2.4GHz)
- LED
- Temperature sensor
- Honeywell HMC1002 Magnetometer
- Analog Devices ADXL202JE Accelerometer
Targeted Applications:
- Environmental Monitoring\textsuperscript{[2]}
- Security\textsuperscript{[3]}
- Gesture Recognition\textsuperscript{[4]}
- Tracking\textsuperscript{[5]}
- Localization
- New graphical user interface for WSN

- Buffering panel
- Control panel
- Real-time plot area
- Workflow Chart
- DSP Functions with Sensor Data

Frame-by-frame processing with DSP functions in iJDSP

![Diagram of Sensor 0, FFT 1, and Plot 2 process flow]
Assessments

- 34 students including 19 undergraduates from EEE407 class and 15 graduates from SenSIP Center participated.
- Over 75% students would recommend this application to their friends.
The pedagogy adopted in iJDSP workshop includes:

(a) Lecture on the pertinent signal processing concepts
(b) A pre-lab on the concepts involved in the laboratory exercise
(c) A simulation exercise using iJDSP
(d) A Post-lab to test student understanding of the concepts
(e) Assessments involve students in the evaluation of the exercises and the software.
### Evaluation Questions and Responses

<table>
<thead>
<tr>
<th>Evaluation Questions</th>
<th>Strongly Agree (%)</th>
<th>Agree (%)</th>
<th>Neutral (%)</th>
<th>Disagree (%)</th>
<th>Strongly Disagree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Performing this exercise, you learned the concept of cascaded and parallel</td>
<td>21.1%</td>
<td>31.6%</td>
<td>31.6%</td>
<td>15.7%</td>
<td></td>
</tr>
<tr>
<td>configuration of systems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Do you now understand more clearly the relationship of the frequency response with</td>
<td>89.5%</td>
<td>10.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the poles and zeros?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The contents of this exercise helped you understand the concepts of FIR and IIR</td>
<td>36.9%</td>
<td>52.6%</td>
<td>10.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>filter design.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• After the lab, you know which of the IIR filters have ripple characteristic in both</td>
<td>47.4%</td>
<td>31.6%</td>
<td>15.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stopband and passband.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Concept of pole and zero was improved by using iJDSP.**
- **89.5% students felt iJDSP helped them to understand FIR and IIR filter design.**
Statistics Based on the Assessment from Undergraduates from EEE407.
Total Number of Students = 19.

<table>
<thead>
<tr>
<th>Evaluation Questions</th>
<th>Strongly Agree (%)</th>
<th>Agree (%)</th>
<th>Neutral (%)</th>
<th>Disagree (%)</th>
<th>Strongly Disagree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• How long did it take to get used to the simulation environment on iJDSP?</td>
<td>$(t&lt;5\text{min})$</td>
<td>$(5\text{min}&lt;t&lt;10\text{min})$</td>
<td>$(10\text{min}&lt;t&lt;20\text{min})$</td>
<td>$(20\text{min}&lt;t&lt;30\text{min})$</td>
<td>$(t&gt;30\text{min})$</td>
</tr>
<tr>
<td></td>
<td>73.7%</td>
<td>21.1%</td>
<td>5.2%</td>
<td>5.2%</td>
<td></td>
</tr>
<tr>
<td>• Does the graphic user interface of iJDSP appeal to you?</td>
<td>26.4%</td>
<td>63.2%</td>
<td>5.2%</td>
<td>5.2%</td>
<td></td>
</tr>
<tr>
<td>• It is easy to set up the lab simulations.</td>
<td>68.4%</td>
<td>31.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• You feel comfortable performing simulations with the size of the screen.</td>
<td>31.6%</td>
<td>36.8%</td>
<td>10.5%</td>
<td>21.1%</td>
<td></td>
</tr>
<tr>
<td>• Did you feel comfortable with the processing speed of the device for all the exercises?</td>
<td>73.7%</td>
<td>26.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

✓ 95% students got used to the environment within 10 min.
✓ 89.6% students liked user interface of iJDSP.
Statistics Based on the Assessment from Graduates from SenSIP Center.  
Total Number of Students = 15.

<table>
<thead>
<tr>
<th>Evaluation Questions</th>
<th>Strongly Agree (%)</th>
<th>Agree (%)</th>
<th>Neutral (%)</th>
<th>Disagree (%)</th>
<th>Strongly Disagree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Performing this exercise, you learned the concept of cascaded and parallel configuration of systems.</td>
<td>53.4%</td>
<td>33.3%</td>
<td>13.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Do you now understand more clearly the relationship of the frequency response with the poles and zeros?</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The contents of this exercise helped you understand the concepts of FIR and IIR filter design.</td>
<td>40.0%</td>
<td>46.7%</td>
<td>13.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• After the lab, you know which of the IIR filters have ripple characteristic in both stopband and passband.</td>
<td>46.7%</td>
<td>46.7%</td>
<td>6.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The contents of this exercise helped you understand the introductory spectral analysis concepts of the Fast Fourier Transform.</td>
<td>46.7%</td>
<td>40.0%</td>
<td>13.3%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

✓ Concept of pole and zero was improved by using iJDSP.
✓ 93.4% students felt iJDSP helped them to understand concept of filter design.
✓ 86.7% students understood FFT better after exercises.
Statistics Based on the Assessment from Graduates from SenSIP Center.
Total Number of Students = 15.

<table>
<thead>
<tr>
<th>Evaluation Questions</th>
<th>Strongly Agree (%)</th>
<th>Agree (%)</th>
<th>Neutral (%)</th>
<th>Disagree (%)</th>
<th>Strongly Disagree (%)</th>
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<tr>
<td>• How long did it take to get used to the simulation environment on iJDSP?</td>
<td>((t&lt;5\text{min}))</td>
<td>((5\text{min}&lt;t&lt;10\text{min}))</td>
<td>((10\text{min}&lt;t&lt;20\text{min}))</td>
<td>((20\text{min}&lt;t&lt;30\text{min}))</td>
<td>((t&gt;30\text{min}))</td>
</tr>
<tr>
<td></td>
<td>60.0%</td>
<td>20.0%</td>
<td>6.7%</td>
<td>6.7%</td>
<td>6.7%</td>
</tr>
<tr>
<td>• Does the graphic user interface of iJDSP appeal to you?</td>
<td>40.0%</td>
<td>53.3%</td>
<td>6.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• It is easy to set up the lab simulations.</td>
<td>53.3%</td>
<td>46.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• You feel comfortable performing simulations with the size of the screen.</td>
<td>40.0%</td>
<td>40.0%</td>
<td>13.3%</td>
<td>6.7%</td>
<td></td>
</tr>
<tr>
<td>• Did you feel comfortable with the processing speed of the device for all the exercises?</td>
<td>80.0%</td>
<td>20.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 80.0% graduates get used to iJDSP within 10min.
- 93.3% students felt GUI of iJDSP appeal to them.
- Users liked larger screen size
- iJDSP users preferred to perform simulation on iPad.
Publications


References


