WIP: Implement Your DSP Algorithm on Android Tablet: Real-time DSP Laboratory Course

Thomas Moon and Mihn N. Do

University of Illinois at Urbana-Champaign (USA)
Motivation – where?

Analog Signal Processing

- Introduction to Image and Video Signal Processing
- Fundamentals of Engineering Acoustics
- Biomedical Ultrasound Imaging
- Embedded DSP Laboratory...

Digital Signal Processing
What do we want to deliver in “Embedded DSP course”?

- **DSP is everywhere and COOL!**
  (Bridge the 200/300 Level Signal Processing knowledge and real life application.)

- **But, how does it actually work in HARDWARE?**
  (Practical challenges in implementation.)
Choosing Hardware Platform

“Conventional” DSP Education Kit

- Covers various topics (circuits, architecture, I/Os, etc)

But:
- Steep learning curve due to bottom-up approach
- Lose interest before main DSP topics
- Less mobile

We want to
- Focus on DSP
- Introduce more advanced topics
- Offer mobility
Our Choice

Android phones/tablets

Mobility & Wireless connectivity

- Integrated I/Os in a single package
  → More experiments with less effort
- Wireless connection to the Internet
  → Easy data transfer & Video conference (COVID-19)

Out-of-box experience

- Zero-setup time for I/Os and configuration

Developer friendly

- Support C/C++
- Android Studio
  → a unified environment for all Android devices
- Available on most OS (Windows, macOS, Linux)
**Course Structure**

**Structured Labs (7 weeks)**
- 7 Labs
- **Pre-lab**: Python Simulations
- **Lab**: Porting to Android (C++)

**Group Projects (8 weeks)**
- Free topic or ~30 recommended papers
- **Assigned Project Lab** (=Pre-lab, simulation)
- **Final Project**: Android
<table>
<thead>
<tr>
<th>Lab Number</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab1</td>
<td>IMU, peak detection</td>
</tr>
<tr>
<td>Lab2</td>
<td>Real-time audio filtering (FIR)</td>
</tr>
<tr>
<td>Lab3</td>
<td>Spectrogram</td>
</tr>
<tr>
<td>Lab4</td>
<td>Pitch detection</td>
</tr>
<tr>
<td>Lab5</td>
<td>Pitch synthesis</td>
</tr>
<tr>
<td>Lab6</td>
<td>Image processing (2D filtering, histogram EQ)</td>
</tr>
<tr>
<td>Lab7</td>
<td>Video processing (KCF tracking)</td>
</tr>
</tbody>
</table>
```c
void ece420ProcessFrame(sample_buf *dataBuf) {
    // Code mitted

    // Data is encoded in signed PCM-16, little-endian, mono channel
    float bufferIn[FRAME_SIZE];
    for (int i = 0; i < FRAME_SIZE; i++) {
        int16_t val = ((uint16_t) dataBuf->buf_[2 * i]) | ((uint16_t) dataBuf->buf_[2 * i + 1]) << 8;
        bufferIn[i] = (float) val;
    }

    // Spectrogram is just a fancy word for short time fourier transform
    // 1. Apply hamming window to the entire FRAME_SIZE
    // 2. Zero padding to FFT_SIZE = FRAME_SIZE * ZP_FACTOR
    // 3. Apply fft with KISS_FFT engine
    // 4. Scale fftOut[] to between 0 and 1 with log() and linear scaling
    // NOTE: This code block is a suggestion to get you started. You will have to
    // add/change code outside this block to implement FFT buffer overlapping (extra credit part).
    // Keep all of your code changes within java/MainActivity and cpp/ece420_*
    // ************************** START YOUR CODE HERE ************************** //

    // ************************** END YOUR CODE HERE ************************** //
```
Project Schedule (Fall 2020)

- **10/12**: Assigned Lab
- **10/19**: Quiz Demo Lab
- **10/26**: Pres + Demo
- **11/02**: Deadline Final Project Proposal Presentation File Code
- **11/09**: Deadline Milestone 1 & 2 clip
  - **11/13 & 11/20**: Final Project Proposal Presentation File Code
- **11/16**: Final Project
- **11/23**: TG Break
- **11/30**: Pres + Demo
- **12/07**: Deadline Final Project Report Presentation File Code
  - **12/11**: Final clip (extra)
Group Projects - Examples

Musical Instrument Synthesizer

Music Search
Group Projects - Examples

“Calendar” Recognition
“Where’s Waldo?”

Foreground Removal
### Group Projects - Topics

<table>
<thead>
<tr>
<th>Category</th>
<th>Topic</th>
<th>SP 2020</th>
<th>FA 2020</th>
<th>Total</th>
<th>By Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio processing</td>
<td>Audio classification [5]</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Speech synthesis [6]</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speech detection [7]</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Music synthesis [8]</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Image/Video processing</td>
<td>Shape detection [9]</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Face recognition [10]</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Text detection [11]</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Object tracking [12, 13]</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

- A weak bias toward Image/Video topics.  
  (but, we offer 4 audio labs and 2 image/video labs)
Online Delivery

- In-lab quiz converted to CBT.
- Online lecture and office-hour.
- **Lab and project demonstration:**
  Students can share the tablet screen and sound by Zoom.
Results

<table>
<thead>
<tr>
<th>Questions</th>
<th>Spring 2020</th>
<th>Fall 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>STD</td>
</tr>
<tr>
<td>Q1</td>
<td>4.25</td>
<td>1.16</td>
</tr>
<tr>
<td>Q2</td>
<td>3.88</td>
<td>1.13</td>
</tr>
<tr>
<td>Q3</td>
<td>4.00</td>
<td>1.07</td>
</tr>
<tr>
<td>Q4</td>
<td>4.00</td>
<td>0.76</td>
</tr>
<tr>
<td>Q5</td>
<td>3.88</td>
<td>1.13</td>
</tr>
</tbody>
</table>

• Q1: Rate the overall quality of this course. [1-Exceptionally Low, ..., 5-Exceptionally High]
• Q2: How much have you learned in this course? [1-Very Little, ..., 5-A Great Deal]
• Q3: Statement of objectives and purposes throughout course. [1-Never Clear, ..., 5-Consistently Clear]
• Q4: Quizzes - fairness. [1-Unfair Content, ..., 5-Very Fair Content]
• Q5: Quizzes - grading. [1-Unfairly Graded, ..., 5-Fairly Graded]

*8 responses out of 31 students in Spring 2020 and 9 out of 21 students in Fall 2020.*

• **82%** students rated the course's quality as high or exceptionally high (4 or 5 out of 5 in Q1)
• **77%** students felt they learned a good or great amount (4 or 5 out of 5 in Q2)
Future Works

<table>
<thead>
<tr>
<th></th>
<th>Spring 2020</th>
<th>Fall 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully implemented</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Partially implemented</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Failed to implement</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Is it good or bad?

- How can we improve the project completion rate? (or should we?)
- Did the coding Android overwhelm the students?
- Is Android tablet a true solution for Embedded DSP course?
WIP: Implement Your DSP Algorithm on Android Tablet: Real-time DSP Laboratory Course

Thank You
Questions?

Thomas Moon

University of Illinois at Urbana-Champaign (USA)
Contact email: tmoon@illinois.edu