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

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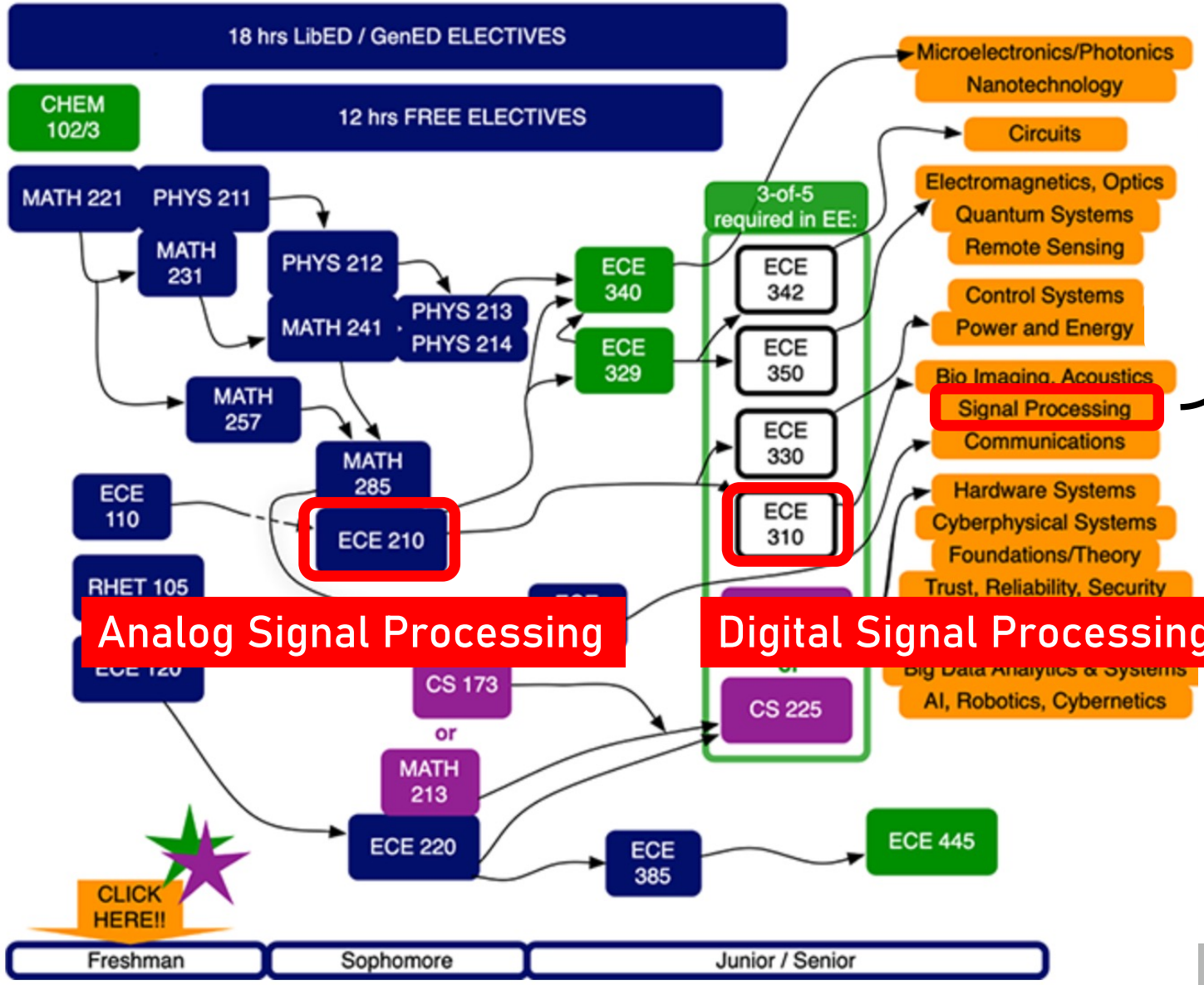
# Motivation – *where?*




Electives

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

...

# Motivation – *what?*

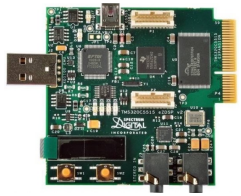
What do we want to deliver in “Embedded DSP course”?

- DSP is everywhere and COOL!
  (Bridge the 200/300 Level Signal Processing knowlegde and real life application.)
- But, how does it actually work in HARDWARE?
  (Practical challenges in implementation.)

# Choosing Hardware Platform

"Conventional"
DSP Education Kit

Texas Instruments



STM

ARM

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

But:

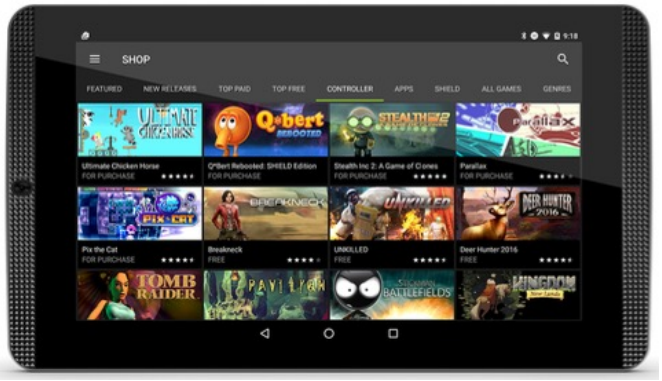
- Steep learning curve due to bottom-up approach
- Lose interest before main DSP topics
- Less mobile

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 transer & 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)**

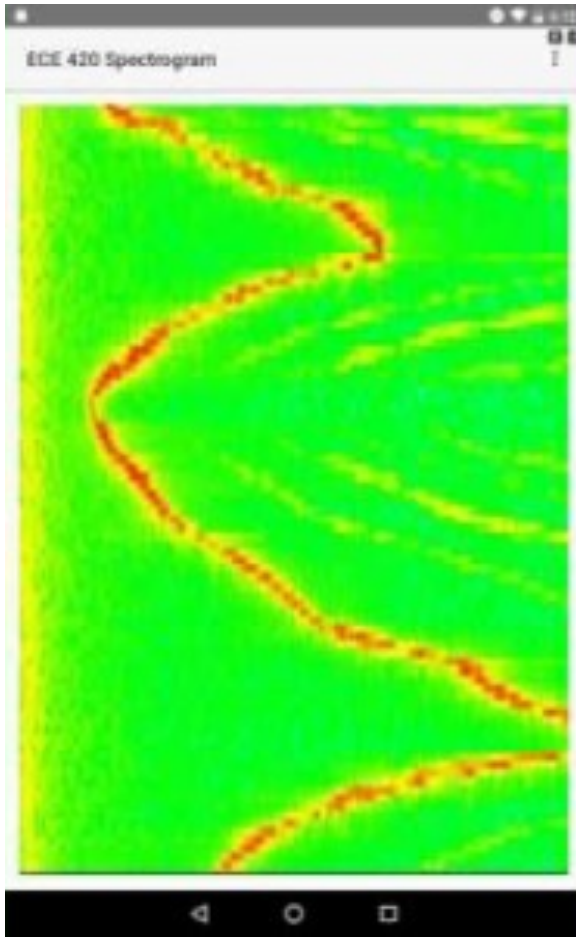
- Free topic or ~30 recommended papers
- Assigned Project Lab (=Pre-lab, simulation)
- Final Project: Android

# Structured Labs – Topics

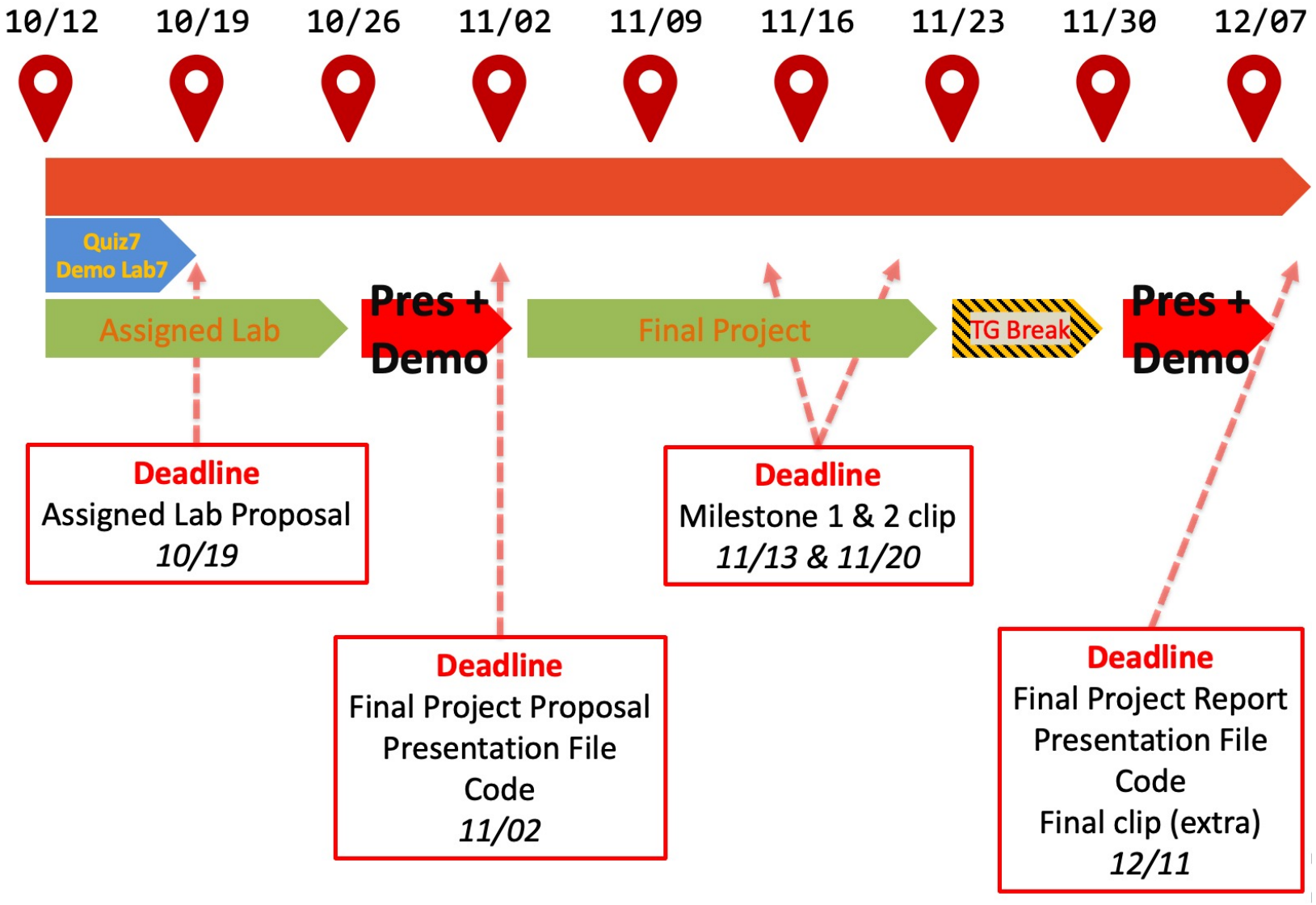
| Lab Number | Topic |
|---|---|
| Lab1 | IMU, peak detection |
| Lab2 | Real-time audio filtering (FIR) |
| Lab3 | Spectrogram |
| Lab4 | Pitch detection |
| Lab5 | Pitch synthesis |
| Lab6 | Image processing<br>(2D filtering, histogram EQ) |
| Lab7 | Video processing (KCF tracking) |

# Structured Lab Example – Lab3

```
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 ************************ //
```



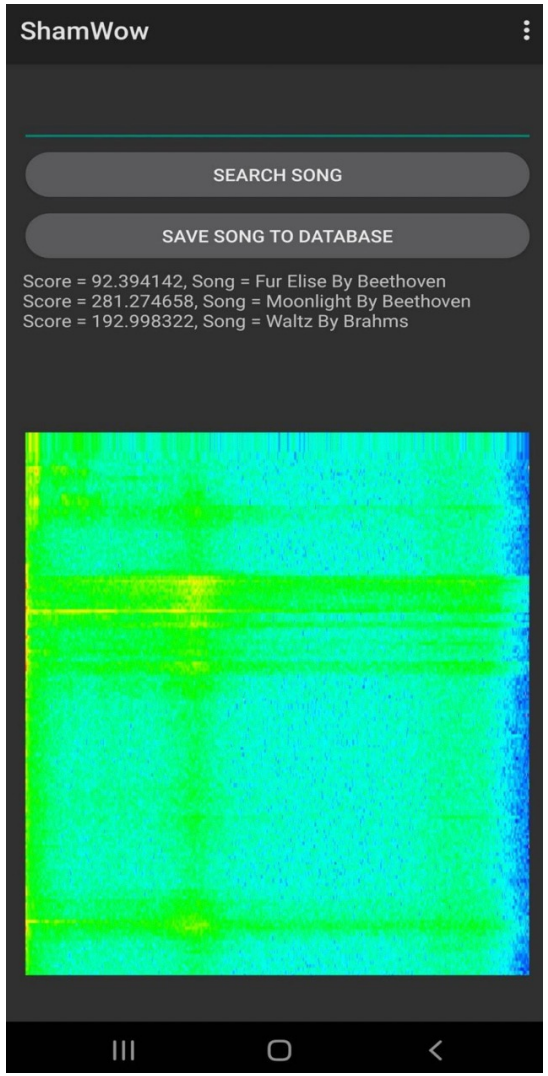
# Project Schedule (Fall 2020)



# Group Projects – Examples

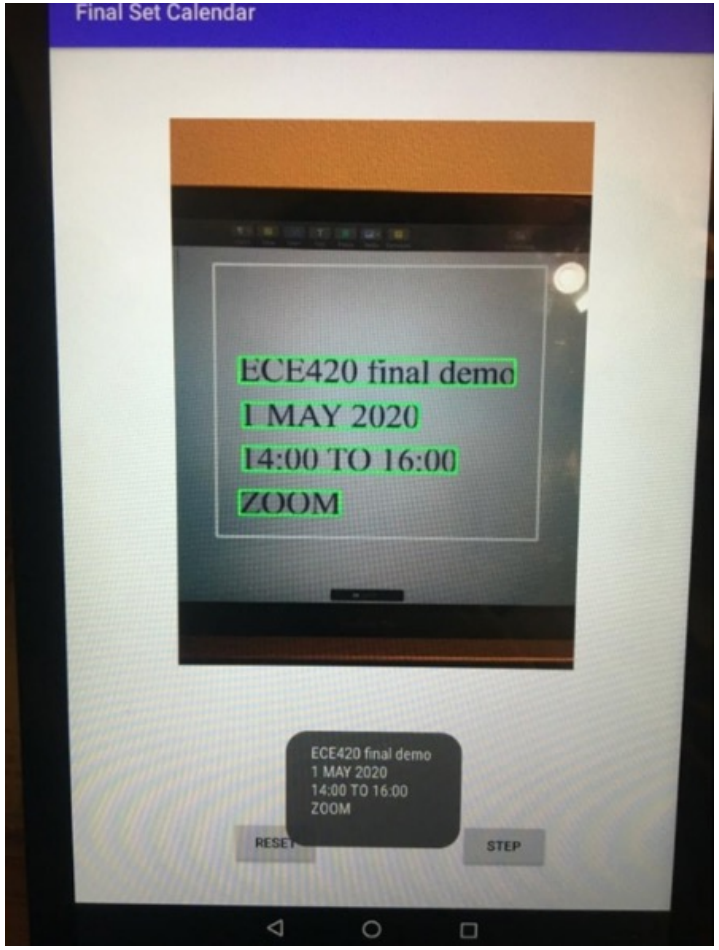
## Musical Instrument Synthesizer

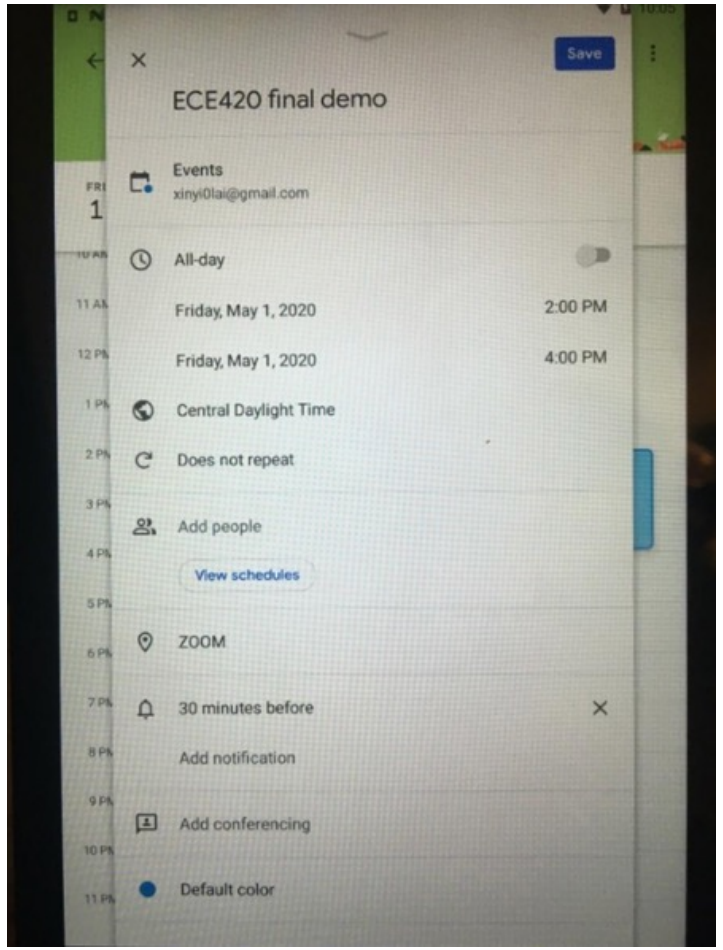

## Music Search



# Group Projects – Examples

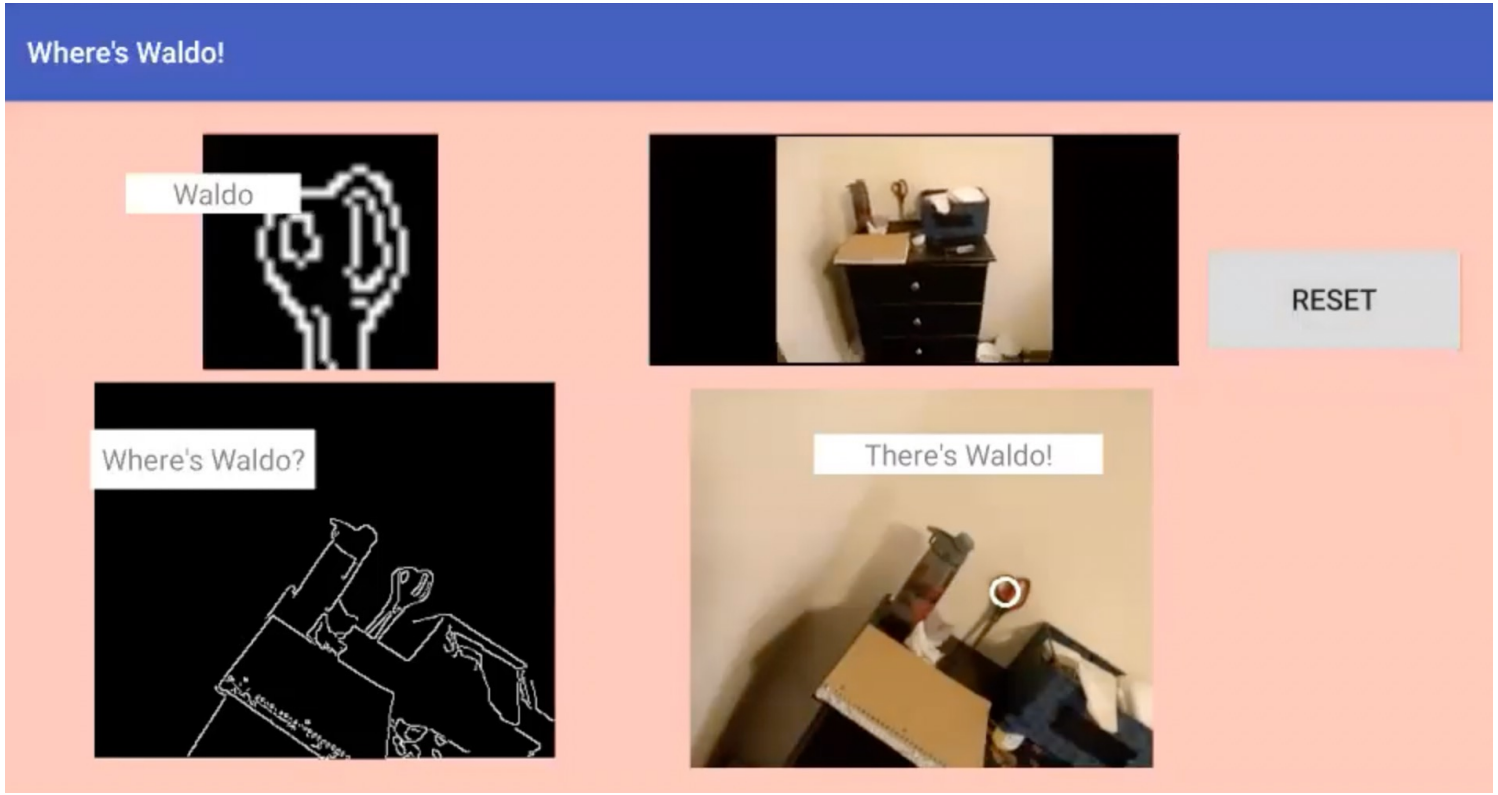
## “Calendar” Recognition



# Group Projects – Examples

**“Where’s Waldo?”**




**Foreground Removal**

# Group Projects – Topics

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

- 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

| Questions | Spring 2020 | | Fall 2020 | |
|---|---|---|---|---|
| | Mean | STD | Mean | STD |
| Q1 | 4.25 | 1.16 | 4.00 | 1.22 |
| Q2 | 3.88 | 1.13 | 4.22 | 0.97 |
| Q3 | 4.00 | 1.07 | 4.11 | 1.27 |
| Q4 | 4.00 | 0.76 | 4.00 | 1.12 |
| Q5 | 3.88 | 1.13 | 4.00 | 1.12 |

- 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

| | Spring 2020 | Fall 2020 |
|---|---|---|
| Fully implemented | 9 | 6 |
| Partially implemented | 3 | 3 |
| Failed to implement | 0 | 1 |

← 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?

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**Thank You**
**Questions?**

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