REFLECTIONS: AN EMODULE FOR ECHOLOCATION EDUCATION

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ABSTRACT

An Android-based eModule app has been designed and developed for science, technology, engineering, and mathematics (STEM) education. The eModule consists of: (1) an Android demonstration of echolocation; (2) a set of notes describing the functionality of the app, the basics of echolocation, and its application to advanced signal processing systems such as RADAR, LIDAR, and SONAR; (3) quizzes to test the concepts introduced by the demonstration and the notes; and (4) companion videos. The eModule is, therefore, a holistic teaching and learning app that can be used across various grade levels including K-12, undergraduate signals and systems, and graduate DSP education.

The app, "Reflections", provides students a means to determine distances to objects while allowing them the ability to manipulate signal envelopes, signal shapes, signal types, and frequency constraints. The intuitive graphical user interface, combined with notes, videos and quizzes, creates a rich educational environment to help educate users with the fundamental concepts of signals, systems, and digital signal processing.

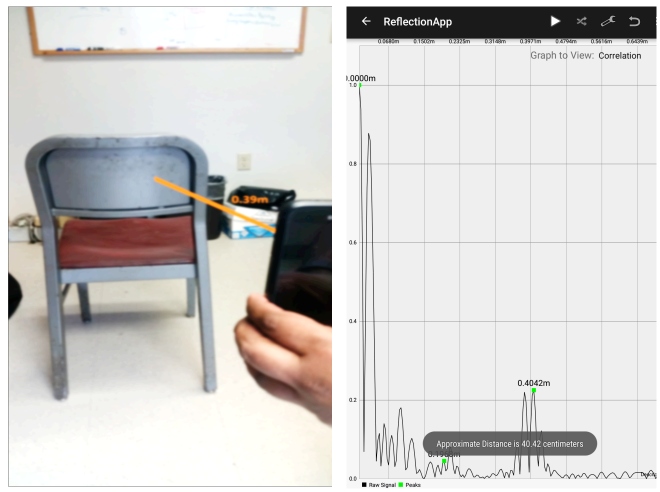
In addition to its role in STEM education, the app has potential use in low-visibility environments and for spatial acoustic analysis.

Preliminary assessments strongly support the effectiveness of the eModule as an education tool signals and systems and DSP classes.

***Index Terms*—** Android, DSP, Mobile Education, Signal Processing, eModule

1. INTRODUCTION

Studies carried out to determine students' interest in using technology in the classroom and its effectiveness suggest [1, 2, 18, 20] that students are not only open to technology in the classroom but prefer it. One study in particular, showed that students taught with the use of technology gained knowledge and developed a more positive attitude towards the subject's content, when compared to students taught by a traditional method [3].



(a) The speaker and microphone of the phone is pointed towards an object 0.39m away.

(b) The output on the app shows the return, and an object detected at approximately 0.4m.

Figure 1. Android app for echolocation being used to estimate the distance to a chair.

Mobile applications (apps) are being developed specifically to customize the classroom learning experiences of a diverse population of students [4, 5].

Mobile smart devices that run on Android, Windows Mobile and iOS platforms are usually equipped with large memory, processing power and a large number of sensors and devices such as accelerometers, gyroscopes, GPS receivers, microphones, cameras, and speakers [15]. These capabilities enable the development of apps, which can assist in classroom education. In the systems and signal processing areas, these include mobile versions of established desktop programs such as NI LabVIEW Mobile Module for handheld devices [6], iJDSP [7], AJDSP [8], Octave [9], WolframAlpha app [10], MATLAB Mobile [11], and JDSP [22,23].

In this paper, we present our work on eModule apps for STEM education, with a focus on the "Reflections" app [17] for concepts in echolocation. The eModule app comprises the following components: (a) notes covering concepts in signals, systems, and echolocation; (b) accompanying

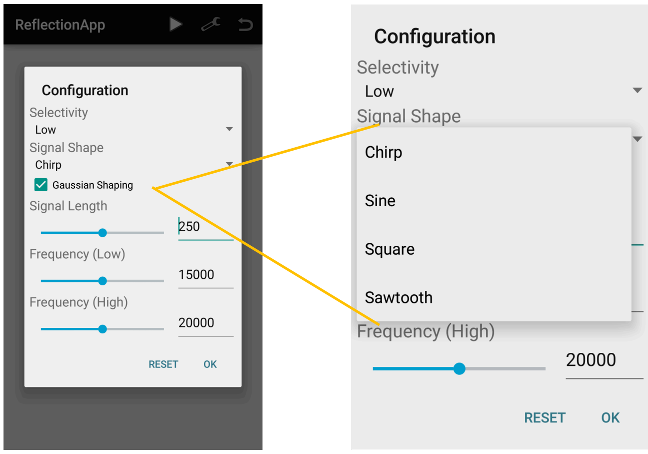


Figure 2. Configuration window (left) showing the adjustable parameters; signal shape options (right).

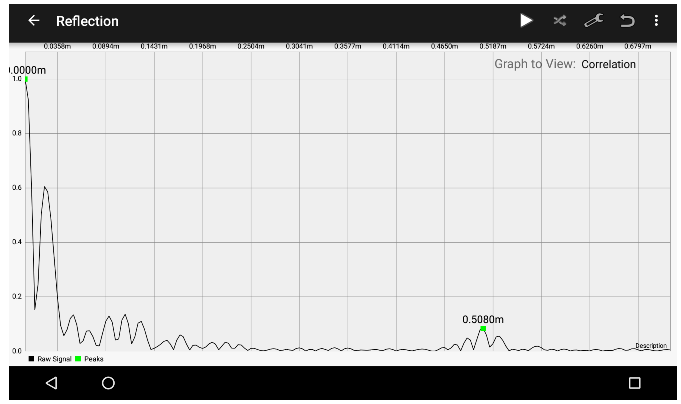


Figure 3. Cross-correlation of the return signal with the transmitted signal. An object was present at approximately half a meter from the Android device.

videos that explain concepts, as well as app demonstrations; (c) quizzes to help users assess their skill levels; and (d) echolocation demonstrations built around an Android acoustic ranging app [12,13]. The app is audio-based and utilizes echolocation to perform ranging. A signal is generated and transmitted through the speaker of the Android device. The signal travels through the environment, strikes objects, and reflects back towards the device. The sent and received signals are used to calculate the time needed for the signal to be sent and received [14], and a distance estimate is calculated. An example of the app being used and the return with the detected object are shown in Figure 1.

The rest of this paper is organized as follows. Section 2 develops a basic understanding of the app as a tool for ranging. In Section 3, the other components of the eModule, including notes, quizzes, and videos, are described. In Section 4, we discuss the educational value of the eModule concept, as well as how the app can be applied to other fields and concepts. Finally, in Section 5, future work is discussed and in Section 6, concluding remarks are presented.

2. ECHOLOCATION DEMONSTRATION

In this section, the Android-based echolocation demonstration is described.

Using a configuration interface as shown in Figure 2, a user-defined signal is generated. The signal is then transmitted from the speaker of the Android device. Reflections from objects in the area will be received by the device. Using these returns and the original signal, a cross-correlation is performed. To allow fast computation of the cross correlation, the fast Fourier transform (FFT) is utilized [12, 14, 19]. Round-trip time from the device to objects and from the objects back to the device can be estimated using the locations of the peaks in the cross-correlation and the speed of propagation of sound.

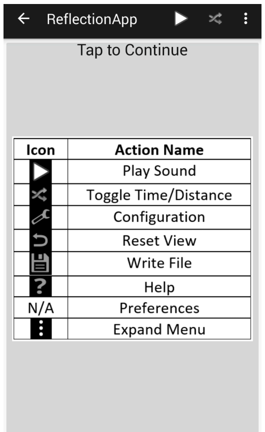
The app presents the results to the user by plotting these distance estimates on the cross correlation graph. A peak detection algorithm identifies and marks the values of all the peaks in the cross-correlation of the return. The locations of the peaks can be labeled either with the round-trip time in seconds, or the distance to the object causing the reflection in meters. An example of the resulting plot with a distance estimate is shown in Figure 3. If a distance of interest is not identified by the peak detection algorithm, a user-defined cursor has been implemented to find the distances to any points of interest on the cross-correlation signal. The zoom and pan features also allow users to view data outside the main view, as well as to look at closely spaced points.

3. COMPANION COMPONENTS

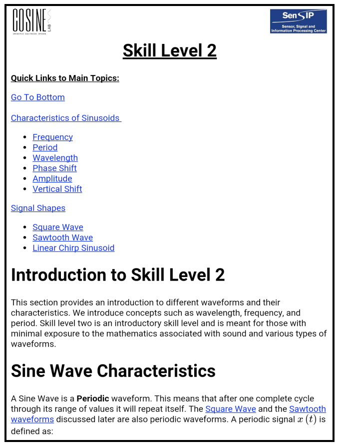
In this section, we describe the companion education tools embedded in the Android eModule app.

3.1. Supporting Notes, Exercises, and Quizzes for use in DSP classes

One of the components of the eModule app that will allow widespread use is the set of notes included within the app. These notes can be accessed from within the app, as well as the companion website [16]. These include detailed background notes at multiple skill levels, including material suitable for students at middle school, high school, undergraduate, graduate, and professional levels. An example of the notes embedded in the app is shown in Figure 4, where the relationship between the speed of sound and the distance to objects is described. In addition to a description and equations, a set of practice problems is provided to help users better understand the material. When users want to test their knowledge in the areas covered in the app, quizzes are provided at each skill level. The quiz interface allows users to optionally provide their information, and further provides complete feedback



(a) A quick start user guide that describes the features of the app.



(b) A screenshot of the high school skill level notes embedded in the app.

Figure 4. Companion notes to the app. These include user guides, as well as notes for users at multiple skill levels.

including solutions and references back to the notes for further study.

3.2. Companion Videos

Two types of videos are included in the app. One set of videos describes concepts. These include snippets of public domain videos, as well as lecture videos specifically recorded to accompany the app. Also included in the app are demonstration videos. These show features of the app, as well as simple examples that showcase useful features of the app and how the app can be used for achieving specific learning objectives. In addition to being embedded into the app, these videos are available on the companion website [16] and on YouTube.

4. EDUCATIONAL VALUE

The default signal generated by the app is a sinusoidal chirp with a Gaussian envelope. However, users can modify the signal type and the signal shape using the menu shown in Figure 2 (right). The display screen, in addition to the cross-correlation of the return, displays the transmitted and received signals.

The choice of signals can be seen on the app display once selected. This will help users to visualize different signals and the effects of parameters such as frequency and envelope shape. For example, selecting a linear chirp with a start frequency of 1000 Hz and ending at 1500 Hz is shown in Figure 5. The signal, with a Gaussian envelope applied, is shown in Figure 6.

Allowing students to select different signals will also allow users to better understand the effect of signal shapes and signal types on cross-correlation and related operations

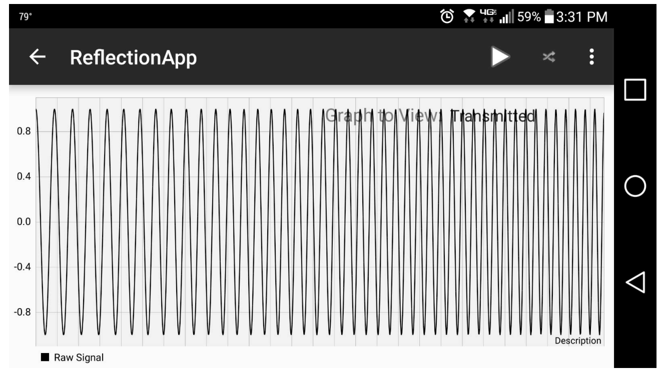


Figure 5. A linear sinusoidal chirp displayed by the Reflections app. The chirp has a start frequency of 1000Hz and an end frequency of 1500Hz.

such as convolution. For example, the chirp shown in Figure 5 generates a peaky cross-correlation. However, the selectivity of the correlation improves when the signal is shaped with a Gaussian envelope.

5. FUTURE WORK

In this section, we discuss planned future work including undergraduate workshops and the use of the app for spatial analysis assistance in low visibility situations.

5.1. Planned Undergraduate Workshops

Workshops are currently planned for the fall semester of 2016 at Clarkson University's junior-level EE 321 Systems and Signal Processing class.

A pre-quiz will first be administered to measure the current skill level of the students before the app is used. Questions will cover concepts such as the relationship between correlation and convolution, the FFT compared to the DTFT, and the effects of signal type, envelope shaping, and the effects of frequency on correlation. The quizzes that will be administered will be embedded in the app as described in Section 3.1 and shown in Figure 7.

After completing the pre-quiz, a short presentation describing the use of the app will be made to the students. Following this, students will be asked to perform a series of exercises. These exercises are described below. After the hands-on exercises, students will be provided with a post-quiz to assess what they have learned, and a survey to obtain subjective information about the app and the user experience.

The first exercise will introduce the app to the students. Students will perform ranging on various items in the classroom to see that the distance estimation is fairly accurate. The students will learn how to use the app and navigate from the home screen to various windows in the app.

The echolocation demonstrations of the app will be

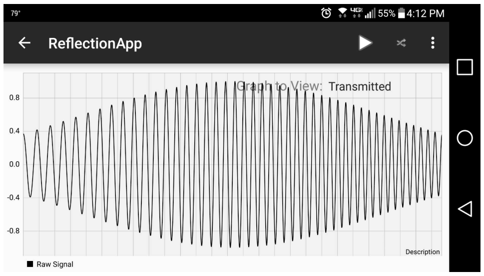


Figure 6. A linear sinusoidal chirp displayed by the Reflections app. The chirp has a start frequency of 1000Hz and an end frequency of 1500Hz, and a Gaussian envelope is applied.

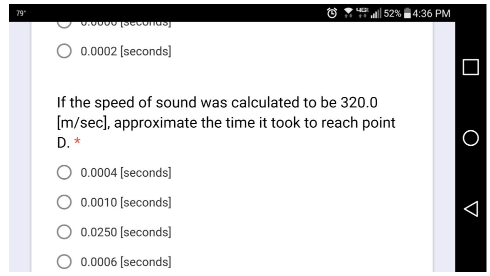


Figure 7. A quiz embedded into the app. This can be used for class workshops as well as by users to test their knowledge.

connected to concepts covered in class and will relate abstract concepts to applications that can be visualized.

Further exercises will have students vary signal and app parameters. The effects of the different signals, signal types, and signal shapes on the correlation output can be seen. The characteristics of signals that result in "good" correlation will be discussed. The concepts of correlation peaks and their widths as they relate to object location and resolution will also be presented. The correlation outputs of the app will demonstrate these ideas, and help solidify these concepts for the students.

Following the exercises, a post-quiz and survey will be administered. The post-quiz will cover the same concepts as the pre quiz. The survey will provide us with feedback concerning the performance and usability of the app. This information can help us improve the functionality and appearance of the app to better suit the needs of the students. Questions regarding the perceived helpfulness of the app to teach in-class concepts will also be included.

The results from the workshop will help us analyze the improvement on individual concepts, and will be an indicator of the effectiveness of the app in an educational setting. Student feedback will be implemented as feasible, and additional workshops will be conducted [21]. Results from the workshops will be presented at the conference.

5.2. Additions to the Reflection app

In addition to the signals already available in the app (Figure 2, right), other signals such as a square wave, a pulse width modulated (PWM) signal, as well as pseudorandom noise-like signals will be implemented. Pre-recorded signals such as bat-chirps will also be stored and used. In addition, options of different types of envelopes will be provided.

5.3. Other Applications of the Reflections app

In addition to the educational aspects, the signal return data can be analyzed to estimate the reflective properties of a given space. Data collection is being conducted and statistical and machine learning approaches can be taken to categorize each room by its reflective properties. In future editions of the app, these functions will be incorporated to add both in terms of functionality and education demonstrations.

Another potential application is the determination of the characteristics of the object encountered by the transmitted signal. By analyzing the reflected signal characteristics, determination whether an object is hard or soft can be made.

These applications can see educational benefits in areas as varied as mathematics and statistics, power engineering, and materials science.

6. CONCLUSIONS

The eModule concept and the app presented in this paper have great potential when used in the classroom to improve the quality of STEM education. These eModules can be used for students at various education levels such as middle schools, high schools, undergraduate, and graduate studies. Additionally, the eModules with multiple components including demonstrations, notes, quizzes, and videos, allow the app to be self-contained and ideal for use in education of the population at-large in less formal learning environments.

The applications to undergraduate signal processing education include topics such as correlation, convolution, FFT for fast computation, and a close look at the effects of many different parameters on the cross correlation of many different signal types. The app also shows promise in lending itself to mathematics and statistics education, presenting applied statistical methods in a clear and relatable way.

In addition to the educational applications, the practical applications of this app are relevant to many fields of study. The spatial acoustic analysis provides an efficient and cost effective way to test room characteristics, and the limited visibility application provides a way for estimating the properties of objects encountered by the transmitted signals.

7. ACKNOWLEGEMENTS

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