HearThat? – An App for Diagnosing Hearing Loss

Silvia Figueira, Kevin Nguyen, Shweta Panditrao
Computer Engineering Department
Santa Clara University
Santa Clara, CA 95053
{sfigueira,ktnguyen,spanditrao}@scu.edu

***Abstract*— Hearing loss is a problem that affects people of all ages all over the world. However, because it is not a life-threatening problem, and resources in emerging markets are scarce, audiometric devices for hearing-loss diagnostics are not typically available in underserved communities. Considering this scenario, we have implemented an app for hearing-loss pre-screening. Our app can execute in a broad range of phones, which are available everywhere, providing individuals in underserved communities with access to hearing-loss diagnostics.**

Keywords—Hearing Loss Diagnostics, Mobile Audiometry, Humanitarian Apps, Mobile Apps for Underserved Communities

I. Introduction

The audiometric hearing test is a thorough assessment conducted by an audiologist to determine the hearing capacity of a patient. The patient wears earphones and sounds at various pitches and volumes are projected into his/her ear. Diagnostic information collected from this test and the analysis of the patient's medical history can assist audiologists in determining the cause of the patient's hearing loss. Additional hearing tests may be necessary to evaluate the type of hearing loss though.

Currently, an audiometer is used in the initial screening for hearing loss detection. Audiometric tests are typically conducted by doctors, and results are generally assessed using a desktop-based software application. This solution has some problems in emerging markets: audiometers are expensive, and specialists are not available. Since hearing loss is not a life-threatening problem, and resources are limited, it is not very common for clinics in underserved communities to provide audiometric tests.

Inspired by Solar Ear [6], a social enterprise that has been bringing inexpensive hearing-aid solutions to underserved communities in emerging markets, we have developed a mobile solution for hearing loss diagnostics. Our solution is based on phones that are already available in these communities, and it has a simple interface to enable its usage for a pre-screening test without a specialist.

Note that apps for audiometric tests have been developed for iPhones [3] and Android [2] phones, but they do not execute on simpler phones, which are prevalent in emerging markets and underserved communities. Our app was developed using jQuery Mobile [4] and PhoneGap [5], which enable it to be ported to a variety of phones, including feature phones. Also, to enable it to run on simpler phones, the app was developed with a very simple interface.

The mobile audiometric-test application has the potential to contribute to efforts for healthcare accessibility. While the app cannot fully eliminate the need for testing conducted by professionals, it can provide an initial screening for individuals. It also provides individuals with a tool to track their hearing regress over time, removing the need for frequent visits to a professional unless potential hearing loss is detected. This is also a practical solution for individuals, for whom visits to a medical clinic are expensive and time consuming.

II. Developing Humanitarian Apps

A. Platforms

Feature phones are the most prominent devices in emerging markets and underserved communities. However, Android phones are starting to make a presence. Therefore, when developing for these communities, one should not assume a specific platform.

After determining the requirements and use cases that our project had to fulfill, various implementation strategies were considered to determine the preferred design choice for implementation of the system. Designs that were considered included a web application, a native Android mobile application, and a PhoneGap mobile application. After analyzing these design choices, we decided that the PhoneGap mobile application was the best option to fulfill the system's needs.

Web applications can be advantageous since they are not platform specific. Any smartphone or tablet with an Internet connection is able to view web applications. However, with the use of PhoneGap, mobile applications can also be made for each platform with no extra effort from the developer. Additionally, web applications require a constant connection to the Internet, using either WiFi or data, whereas mobile applications need only be downloaded once over an Internet connection and then operate without one. Moreover, web applications give rise to browser compatibility issues that the developer must resolve. PhoneGap eliminates these issues since the tool automatically takes care of translating developer code so that it is compatible with a variety of platforms. This gives mobile applications a significant advantage over web applications.

Through evaluating multiple design options, the benefits of using PhoneGap to create a mobile application became apparent, since this technology provides benefits in terms of offline application usage and cross-platform compatibility.

B. *Technologies Used*

PhoneGap, HTML5, CSS3, JavaScript, and jQuery are the main technologies used. A description of each of these technologies is provided below:

- PhoneGap is an open-source software application that is able to translate applications written for the web (HTML5, CSS3, JavaScript, jQuery) into native mobile code for various platforms. PhoneGap currently supports two of the major smartphone operating systems, Android and iOS, but also supports a variety of simpler phones.
- HTML5 and CSS enable the creation of the front-end interface for the application.
- Javascript and jQuery enabled the development of the backend system including functions, storage, and dynamic content manipulation necessary for the application.

C. *System Architecture*

As in any app, the user starts at the home screen. From there, the user can choose to take a test, view/share his or her test history, or view the FAQ page.

Taking a test prompts the user to calibrate the device and either create a new profile, which would prompt the user to enter the username and password of the new profile, or use an already existing profile, which would prompt the user to input the password for the profile. After taking the test, the result is displayed. The user can then decide whether to save the results to the profile or return to the home screen.

If the user decides to view or share his or her history, the user selects a created user profile. The user cannot create a new profile if this option is selected. After selecting a profile and inputting the password for that profile, the user can view all the saved test results in that profile.

III. THE HEARING TEST

A. *Calibration*

The system asks the user to calibrate their device before beginning a hearing test. Calibration is necessary to ensure that results are accurate and precise. In order to calibrate, a point of reference is necessary. While audiometers in a clinic use sophisticated technology to calibrate, our app needed to use a common point of reference accessible to the largest number of users. The point of reference used for this system is the sound that one's hands make when they are rubbed together. Studies have shown that this sound is, universally, about 65 decibels (dB). Therefore, in order to calibrate, the system plays a sound at 65 dB and prompt the user to adjust their phone's volume so that the sound their phone is making matches the sound their own hands produced when rubbed together. By following this methodology, the user can successfully calibrate their device.

B. *Profiles*

Before taking the hearing test, the system prompts the user to create or select an existing profile. Profiles are a method for organizing data with each profile essentially acting as a folder under which test results can be saved. Profiles and the test results under those profiles are saved using the phone's local storage. Profiles can be created when the user takes a test. A new profile is only stored if the user creates a new profile while taking a test and then saves the results of that test. Once saved, the user can select that profile when he or she takes the test again or select that profile when deciding to view history.

C. *Scope of the Test*

An important part of designing this project was determining how the actual test would be administered. The test replicates a simplified version of an audiometric test performed in a clinic, as this application's main purpose is to be a screening tool. Similarly to a clinical test, this application projects tones at various frequencies; these frequencies falls in the range of 250 Hertz (Hz) to 8,000 Hertz, as this is the practical scope of frequencies that encompasses the range of human speech. In addition to dividing this range into frequency intervals, each frequency is played at various decibel levels to determine the boundary hearing capabilities of the user. The decibel range is from 0 to 80 decibels hearing level (dB HL), as this is a large enough range to gauge whether a user presents hearing loss or not.

The test plays six different frequencies: 250, 500, 1000, 2000, 4000, and 8000 Hz. The decibel hearing levels that can be played for each frequency of sound are 0, 5, 10, 15, 20, 30, 40, 50, 60, 70, and 80 dB HL.

D. Decibels Hearing Level (dB HL)

Decibel hearing level is a special decibel scale that has its point of reference around what doctors consider to be the normal hearing level. Audiometers in a clinic play back their tones using this scale in order to compare the tones a person can hear from the tones a person with normal hearing can hear.

E. Tones

This test will be administered using only warble tones, which means that each sound file is a tone whose frequency varies periodically several times per second over a small range. This is used to improve accuracy in the detection of hearing loss, by preventing standing-wave patterns from forming in reverberation chambers. Other options that the audiometric test may include are frequency modded tones, in which multiple frequencies are combined to create a desired pitch through interference or amplification, or narrow band noises, which involves only a narrow band of frequencies per tone.

F. Up-10-Down-5 Method

The application uses a mechanism called the up-10-down-5 method to let the system know what sound it should play back to the user based on the user's responses. For each frequency, the first tone played is at 0 decibels. The user is asked to answer "yes" or "no" if he or she can hear the tone. If the user answers "no", the same frequency is played with a tone that is 10 decibels higher than the previous tone. If the user answers "yes", a tone of the same frequency is played that is 5 decibels lower than the previous tone.

This method only uses the 0 to 80 dB HL range for each frequency because the sound files available only offer tones with a 5 dB HL differential within this range. While within this range, if the user answers "no", a tone in the same frequency but 10 dB HL higher is played back to the user. When the user answers "yes" a tone that is the same frequency but 5 dB HL lower is played back to the user, and the next answer from the user determines the saved result, which will determine the hearing range. If the user answers "yes" again, then the sound currently playing is saved, and if the user answers "no", then the sound before the 5 dB HL decrease is saved instead. The combination of dB HL level and frequency is saved for later processing.

If the user answers "no" enough times that the sound played reaches 30 dB HL, then the up-10-down-5 method is no longer in use. Instead, the dB HL level continues to increase by 10 each time the user answers "no", and when the user answers "yes", the current dB HL level and frequency is saved.

Special cases to the test:

- If the user answers "yes" at 0 dB HL, the frequency and 0 dB HL is saved.
- If the user answers "no" at 80 dB HL, the frequency and 80 dB HL is saved.

G. Test Results

From the hearing test, pairs of frequency and dB HL level are gathered from the user's responses. These results are displayed in a graph with frequencies on the x-axis and dB HL on the y-axis. In addition, the user is provided with a hearing loss scale that indicates normal hearing or hearing loss, in which case at what frequency and severity.

Table 1: Hearing Loss Levels

Decibels Hearing Level Range (dB HL)	Hearing Loss
0 to 20	None
30 to 40	Mild
50 to 70	Moderate
80	Severe

H. Interpreting Results

A hearing loss scale is given to the user. Levels of hearing loss include: none, mild, moderate, and severe. These levels of hearing loss are delineated by different colors, which are projected on the graph. By looking at the color under which the peaks of the graph for each frequency fall, the user can determine his or her level of hearing loss for that particular frequency. Table 1 outlines the levels of hearing loss in relation to dB HL ranges, and Fig. 1 shows examples of sounds at different levels.

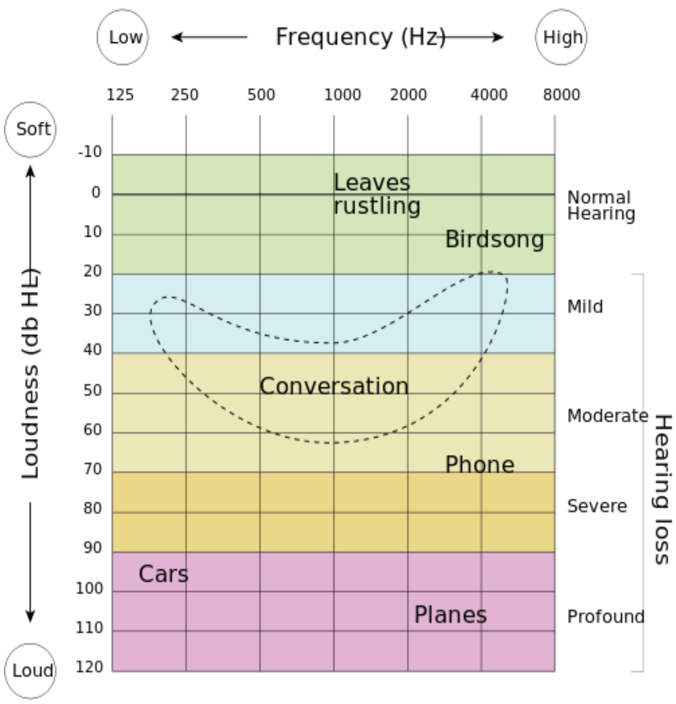

Fig. 1: Decibel ranges for different sounds.

Figures 2 and 3 show examples of hearing ranges, given by the curve, at different levels. In Fig. 2, the user can hear very low decibels, indicating no hearing problem. In Fig. 3, the user can only hear high decibel levels, indicating moderate hearing loss.

I. Saving Results

On the page displaying the test results, the user should have the option to save the test results. If this option is selected, the results should be saved under the profile that was chosen earlier, before the test.

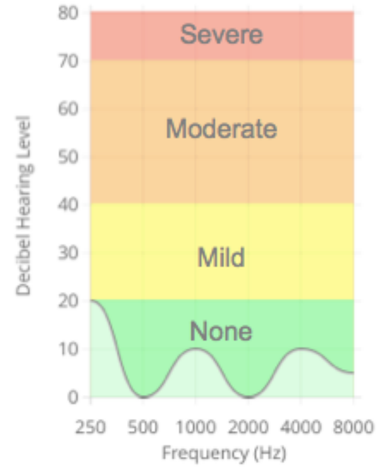

Fig. 2: Normal hearing range.

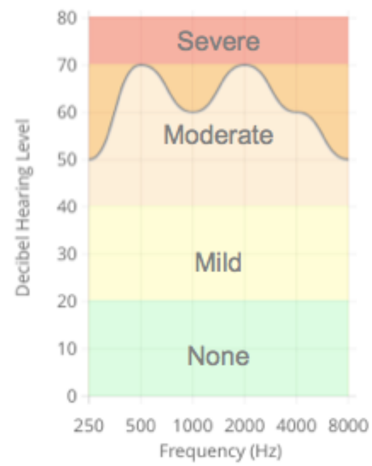

Fig. 3: Hearing range showing moderate loss.

J. Accuracy

In order for the hearing test to be a reliable tool, the sound files need to be accurate and comparable to the sound files used in a clinic. Currently, the sound files used were provided Dr. Stéphane Pigeon [1], an audiologist and signal-processing engineer. Dr. Pigeon is a specialist in audiology and has created these sound files for use on his own website, which has an online hearing test. According to Dr. Pigeon, these sound files have been calibrated against an actual audiometer. The sound files used in this application are as accurate as the sound files generated by Dr. Pigeon.

K. Viewing History

Test results should be saved under a profile and available for viewing at any time. Users should be able to scroll through past test results.

IV. The App

The Home Screen, shown in Fig. 4, is the initial screen that the user sees when he or she starts the application. It directs the user to tap the menu bar on the top right of the screen for more options, which leads to the screen shown in Fig. 5.

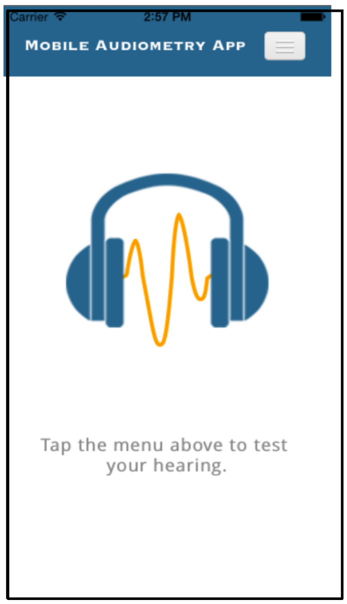

Fig. 4: Home Screen.

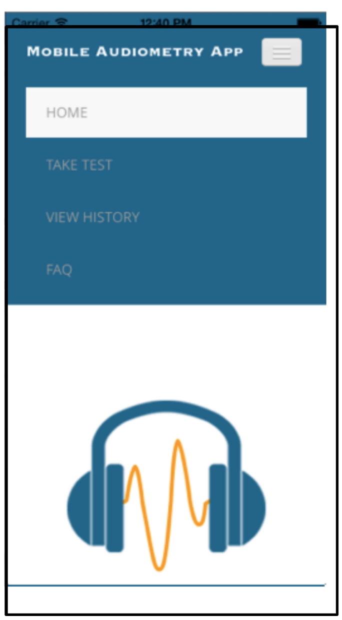

Fig. 5: Menu.

As shown by the screen in Fig. 5, the user may take a test, view history, or check the FAQ screen.

When the user chooses to take a test, before starting the test, the user is asked to calibrate the device, as shown in the screen in Figures 6, 7, and 8, which scroll down.

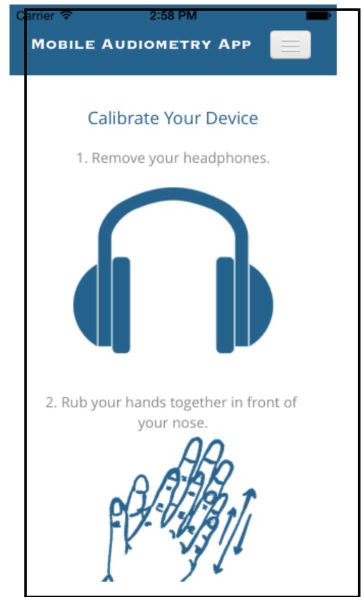

Fig. 6: Initial instructions.

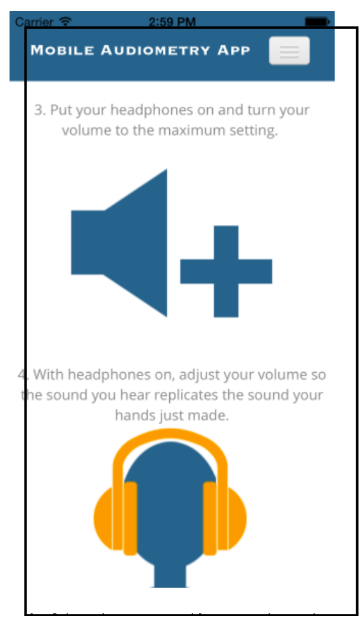

Fig. 7: Continuing the instructions.

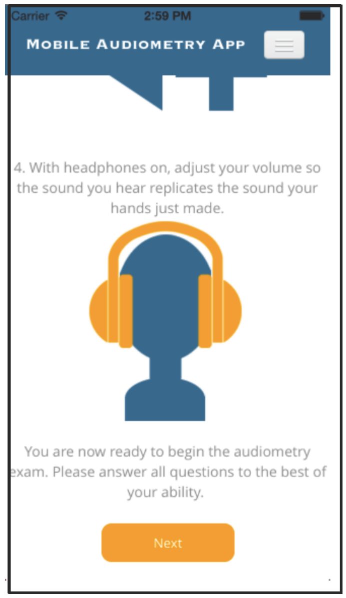

Fig. 8: Final instructions.

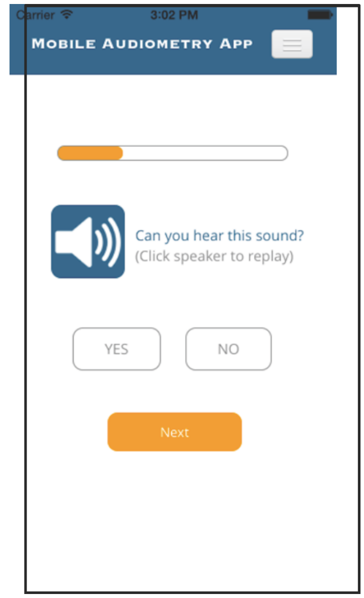

Fig. 10: Taking the test.

Also, before a test can begin, the user must create a new profile or select an existing profile under which the test results will be saved, as shown in Fig. 9.

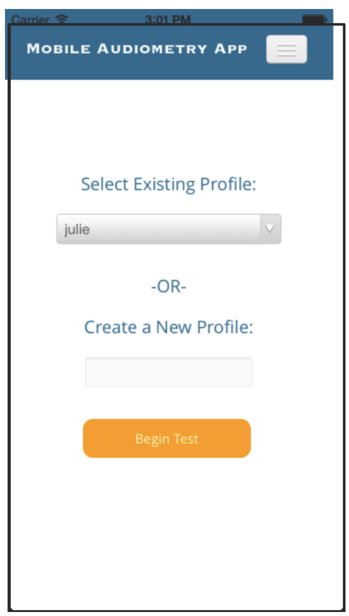

Fig. 9: Selecting or creating a profile.

As shown in Fig. 10, during the test, the user will listen to sounds and click "yes" or "no", if he or she can or cannot hear each of them respectively. The user may replay each sound, if necessary. The orange bar at the top of the screen shows the user his or her progress.

As shown in Fig. 11, at the end of the test, the user will see a graph showing his or her hearing level. The green portion of the graph represents the lower decibel levels, and the red portion at the top represents the higher ones. The curve shows the hearing range, which in this case is normal, since the user could hear the lower decibel sounds. After checking the result, the user has the chance to save the results, which can be seen later, by choosing to view history in the menu screen, shown in Fig. 5.

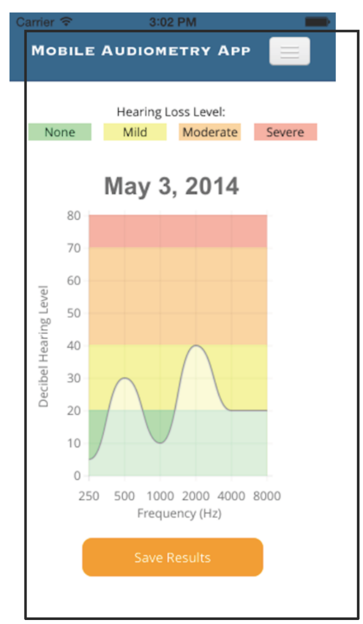

Fig. 11: Test result.

When the user chooses to view history, in the menu screen (Fig. 5), the app will show the screen presented in Fig. 12, in which the user may scroll through all the results obtained under the same profile, most recent results first.

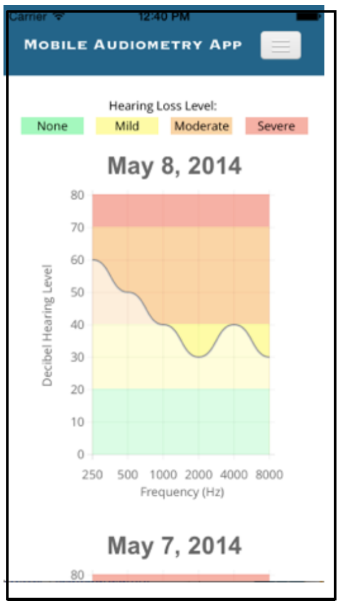

Fig. 12: History.

V. Conclusion

Mobile apps are helping underserved communities by enabling them to benefit from technology in different ways. These apps are enabling several communities to take advantage of their phones. Our project focuses on using the phones that are already present to provide individuals with access to audiometric tests for hearing loss pre-screening.

We have not compared the results obtained by the app with the results obtained from an audiometer, and we plan to do that before making the app available. Also, currently, the app maintains all the results locally. A future version of the app will enable the user to email results to a specialist.

Acknowledgments

We would like to thank Dr. Stéphane Pigeon for his guidance and for sharing the audio files used in the app.

References

[1] Dr. Stéphane Pigeon, http://www.stephanepigeon.com
[2] Google Play, http://play.google.com
[3] iTunes Store, https://www.apple.com/itunes/
[4] jQueryMobile, http://jquerymobile.com
[5] PhoneGap, http://phonegap.com
[6] Solar Ear, http://solarearinternational.wordpress.com