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Use of smartphones for introductory acoustics education

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In order to propose an effective method using smartphones (including tablets) for acoustics education in introductory courses for architectural and environmental acoustics for architectural studies, the authors have examined some applications which work on smartphones. As the first step applications measuring sound level and spectrum at reasonable prices are chosen and their precisions have been verified. Results showed that the most iOS devices have somewhat reasonable precision, e.g., for SPL measurement it is similar to Class 2 sound level meter, though some Android devices give lower precision. Then the authors introduced these tools to students and encouraged them to use these tools to produce a noise map (with dB(A) only and with both dB(A) and sound spectra). Even though these are only simple tools, they allow students to understand the relationship between their sensation and physical values. As further studies, the authors also tried to use some more applications which enable students to measure more advanced physical values, such as Band Levels, Leq, Impulse Responses, Reverberation Times etc. Some examples of the measurement results of them are also presented.

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1. INTRODUCTION

This paper presents main results on the authors' project to develop an efficient method of the use of smartphones, including tablets, for introductory teaching of architectural and environmental acoustics for university students. The paper consists of two parts: The first part is the review and summary of the results which have already been published in the authors' previous papers[1-4], the second part is the overview of preliminary results of the authors' current project.

Usually the introductory teaching of architectural and environmental acoustics for university students, mainly for students of architectural departments, is started without the knowledge of basic physical background of acoustics. Therefore, the instructors often let the students listen to the sound environment surrounding them and draw their attention to the loudness, feature or how they feel to it, etc., and put them down on a map to make a so-called sound map, which is similar to soundscape. In this process they do not know the physical criteria which describe the sound quantitatively.

However, even in such an introductory teaching, knowing basic physical criteria such as sound pressure level, power spectrum, etc., should be useful for students to gain a physical insight into the acoustic environment, to understand the meaning of those physical criteria, and to gain a quantitative sense to the sound that they hear. It is expected that this will encourage a more profound discussion.

The authors consider that smartphones will be usefully employed for this purpose. There are many applications for smartphones and tablets for various acoustic measurements. Therefore, in this project, the authors first selected suitable applications for basic measurements and examined their accuracy. Secondly, we asked our students actually to do some exercises using smartphones and the examples of their output were presented. Since these results have already been published in Refs. 1 – 4, only the summary will be given in this paper. The authors continue this project for more advanced measurement with smartphones for advanced learning of architectural and environmental acoustics. Some examples of the recent on-going project will be introduced in the subsequent sections in this paper. Readers who are interested in the basic studies by the authors are suggested to refer Refs. 1-4.

2. SUMMARY OF BASIC STUDIES[1-4]

A. DEVICES AND APPLICATIONS USED IN THE PROJECT

There are two types of smartphones (hereafter, this word is used as including tablets): one is iOS devices (iPhones, iPads, etc.) and the other is Android. In many cases the same application is available for the both. Therefore, it is necessary to examine the accuracy of the both types.

Regarding the applications, simple and inexpensive applications to measure sound pressure levels (SPL) and power spectrum should be selected. The authors, after some preliminary tests, selected SPL Meter (Studio Six Digital)[5] for SPL (A- and C-weighted) and bs-spectrum (Bismark)[6] are selected to use in this project.

In order to examine the accuracy of the both these applications and devices, first the measured value of SPL by SPL Meter on iOS devices and Android were compared with one measured by Class 1 sound level meter. First, in an anechoic chamber, broadband noise was emitted from a loudspeaker, and using calibration function of SPL Meter, calibration was made to show the same level as that Class 1 sound level meter. Then, 1/1 octave band noise (125-4k

Hz) was measured by both the Class 1 sound level meter and smartphones (both with A-weighting).

As for Android devices, although the result is not presented here, the measurement values showed large errors and individual differences, as well as, non-linearity in many devices. Therefore, we had to give up using Android devices for this project because it is not expected to obtain accurate value.

On the other hand, iOS devices showed fairly good agreement with Class 1 sound level meter. An example of the comparison result (iPhone 4S) is shown in Fig. 1. Although the iOS devices give lower values at 125 Hz and levels lower than 40 dB(A), the error is within a few decibels at other frequencies. Therefore, SPL Meter on iOS devices can be as accurate as Class 2 sound level meters and can be used for the present purpose. The errors at 125 Hz of iOS devices were inferred to be due to the characteristics of the pre-amplifier of the device.

Regarding the sound power spectrum, only iOS device with bs-spectrum was tested. The same sound was measured by iOS devices with bs-spectrum and PC software, and the results were compared. Figure 2 showed an example of the result. Except for low frequencies, the results measured by iOS devices with bs-spectrum were considered to be accurate enough for the present purpose.

Also, for outdoor measurement, we examined the effect of hand-made windscreen made of a block of plastic foam, and confirmed that it does not affect measured level and is effective under the condition of wind speed less than 6 m/s.

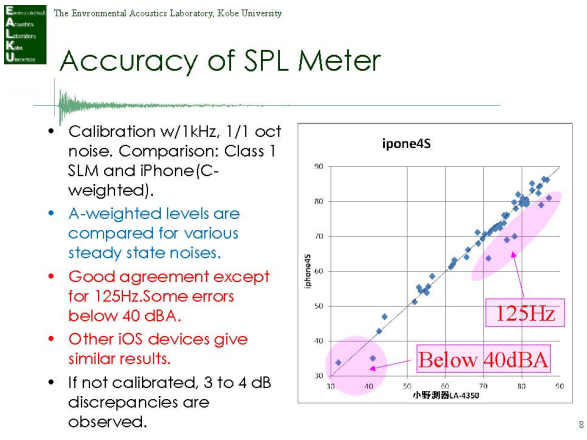

Figure 1. Accuracy of SPL Meter (iOS).

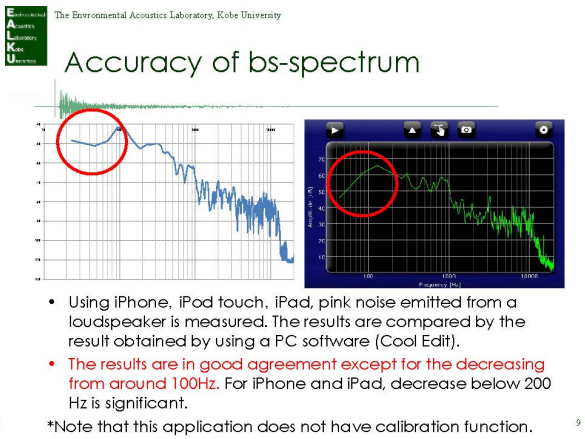

Figure 2. Accuracy of bs-spectrum (iOS).

B. EXAMPLE OF STUDENTS' OUTPUT

After the examination above, we decided to use iOS (iPhone, iPod touch, iPad mini etc.) with SPL Meter and bs-spectrum, and, as a trial, we asked students to actually carry out some measurement exercises:

- Noise map (with only noise levels)
- Noise map (with noise levels and power spectrum)
- Discussion on the sound insulation of window (by using A- and C-weighted SPL)

As the most typical example, a noise map with noise level and power spectrum is shown in Fig. 3. In this trial, measurements were made in a residential area and measurement points were taken in places of different sound environment so that students could find various features of sound spectrum. After this measurement, the students could understand very well not only the

difference of the sound environment of each point from the noise level measurement, but also that in the characteristics of various sounds from the spectrum data as well.

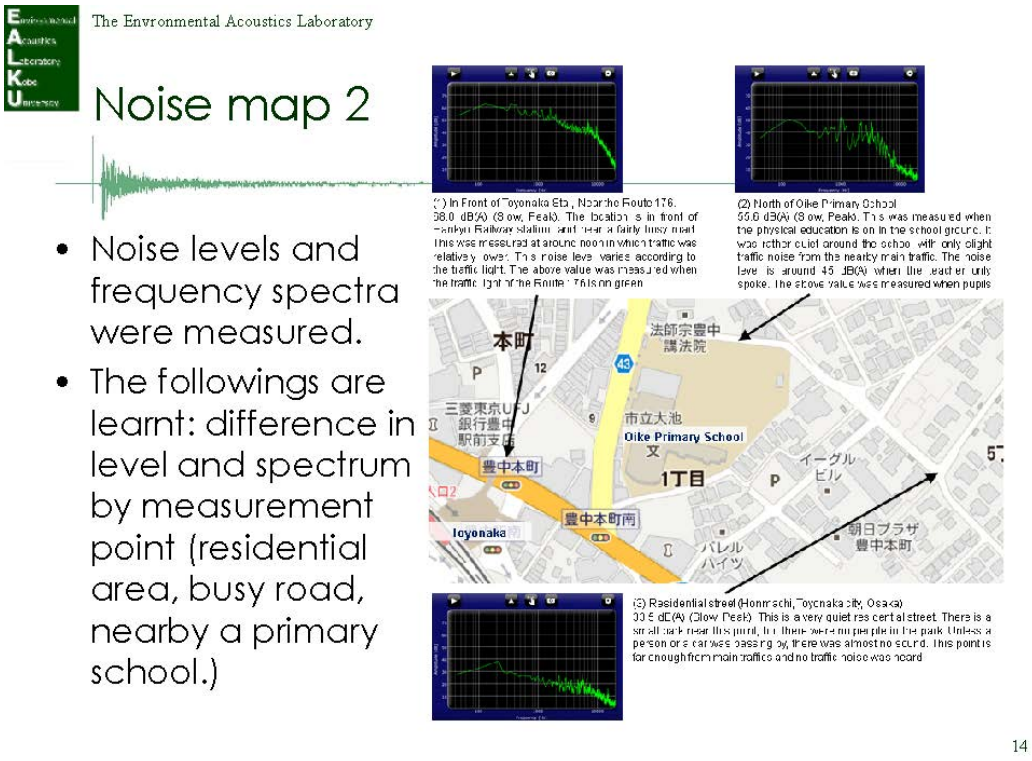

Figure 3. An example of the noise map with noise level and power spectrum.

3. CURRENT PROJECT: MORE ADVANCED MEASUREMENT

In the above the basic studies and trial tests were summarized. Thus, an introductory teaching with smartphones was confirmed to have potential effectiveness, though only SPL and power spectrum are measured. However, for more full discussion, some more advanced measurements are desirable. For example, Leq is quite important for evaluating non-steady noise such as traffic noise etc. Also, for introductory teaching of sound environment in rooms it is better if one can measure reverberation times, impulse response, and various room acoustic criteria with smartphones in simple way, though the measurement is not very precise.

In fact, there are many applications for iOS devices for room acoustics measurement. Using such an application, more advanced measurement can be used in acoustics classes. Here, we introduce the results of preliminary tests of two applications: One is Signal Scope Pro[7] (Faber Acoustics) and the other is SoundOut[8] (Australian Hearing).

A. SIGNAL SCOPE PRO

This is an multi-purpose application including various functions such as a sound level meter (A-, C- and Z- weighting, with integration function for Leq), FFT analyzer (spectrum and 1/1- and 1/3-octave levels) and an oscilloscope. So far its measurement accuracy of Leq(A) has been examined. The test was performed in the same way as was performed for SPL Meter described in the preceding section. The comparison result is shown in Fig. 4.

As long as using the "low-range" function of the application, the measured results by this application are good agreement with those by Class 1 sound level meter, and it is confirmed that this application will be reliable to use for acoustics teaching.

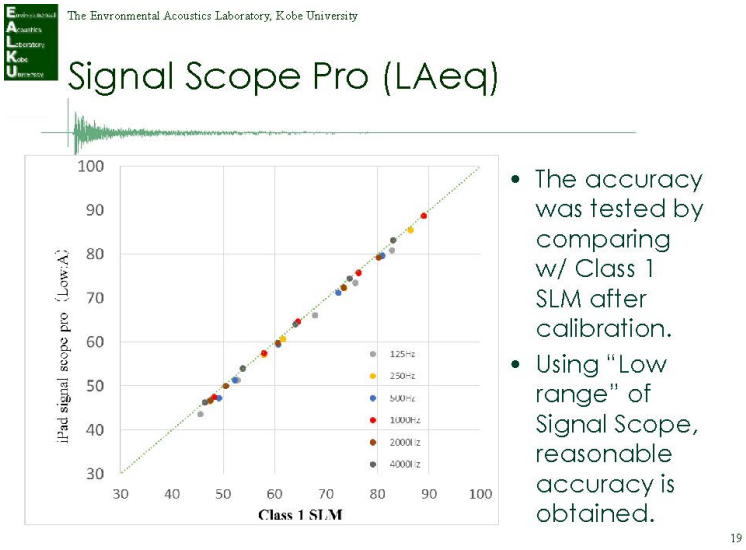

Figure 4. Accuracy of Leq(A) measurement by Signal Scope Pro (iOS).

B. SOUNDOUT

This application is only for iPad and iPad mini. This measures the reverberation as well as STI of a room. One can use this application easily by following the guidance presented on the screen: first one should measure the background noise level, then following the guidance, one makes an impulsive sound by clapping hands. By doing this, the application gives the result of the reverberation time and STI of a room. A comparison test was made in an ordinary student laboratory: the reverberation time and STI measured by this application were compared with those measured by a PC software. Figure 5 shows the screenshot of the measured results. Both the reverberation time and STI were in fairly good agreement. As this application is very simple and user-friendly, it can be effectively used in an introductory class for room acoustics.

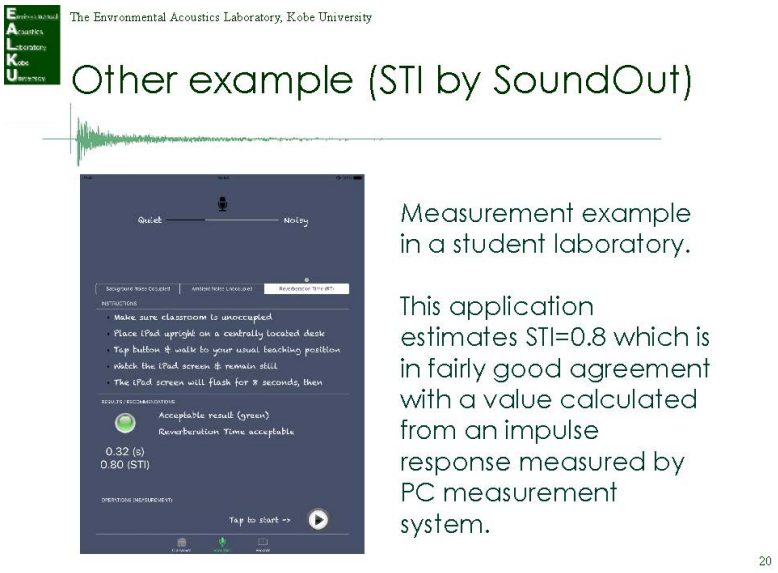

Figure 5. An example of screenshot of SoundOut (iPad mini).

4. SOME PROBLEMS

After the trial tests with students, we had a free discussion with the participants on the introductory teaching method using smartphones. From the students' opinion the most important point was the cost of the applications. Although SPL Meter and bs-spectrum are inexpensive, some students are not willing to spend money on buying the applications. One possible solution may be to prepare pre-installed devices and let students use them in classes. This problem will be more serious for more expensive applications for advanced measurements. Also there is an opinion that, for advanced acoustical criteria, preliminary guidance before measurement should be important for them to understand it fully.

5. CONCLUDING REMARKS

In this paper, the authors project on the use of smartphones (including tablets) for introductory classes of acoustics (mainly for architectural and environmental acoustics) are introduced. For the basic study parts which have already been published, the summary was given. Also, some preliminary results of current project on the use of smartphones for more advanced measurements are introduced. From this series of studies, it can be concluded that, for basic measurements, such as SPL and power spectrum, simple applications on iOS devices can be used effectively. For somewhat advanced teaching, more sophisticated applications are currently examined. However, some problems, mainly concerning the cost of applications, should be considered in practice.

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[5]http://www.studiosixdigital.com/

[6]http://www.bismark.jp/bs-spectrum-app/index.html

[7]http://www.faberacoustical.com/

[8]https://www.hearing.com.au/ (Detailed information of the application is not presented)