Performance evaluation of smartphone-based vibration meter application software

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Abstract. Modern smartphones have been equipped with MEMS sensors allowing them to be used for advanced purposes. A MEMS accelerometer is embedded in the smartphone to sense motion and vibration. Recently, many smartphone-based vibration-meter applications software employed the embedded accelerometer and used them for vibration monitoring and field measurement. However, the accuracy of this kind of vibration meter has not known yet. In this paper, we discuss about the evaluation of smartphone-based vibration meter using the standard method for vibration meter calibration described in the ISO 16063-21. A vibration measurement by the smartphone-based vibration meter is compared to the reading of the reference accelerometer type B&K 8305. The evaluation was conducted in a frequency range of 10 Hz to 50 Hz with the amplitude of 0.1 G to 1 G. This study showed that the accuracy of the smartphone-based vibration meter is decreased in the higher frequency range.

1. Introduction

In recent years, smartphones have been integrated with specific features and applications to satisfy users’ advanced purposes. Some of these advanced applications are utilizing microelectromechanical systems (MEMS) sensors embedded in the smartphones. The MEMS accelerometer is embedded in the smartphone to sense motion and vibration. Many smartphone-based vibration meters applications software employed the embedded accelerometer and used them for vibration monitoring and field measurement.

Some studies focused on adopting the embedded accelerometer in smartphones as the vibration sensor have been published. Ginart et al. developed an application in which capturing acceleration data and converting them to the velocity level to monitor machinery health conditions [1]. Meanwhile, two testbeds were carried out, realizing a real-world vibration measurement using smartphones. The result showed that the performance of the embedded accelerometer in the smartphones was good at the low frequency [2]. In addition, more practical applications were conducted investigating a pedestrian, a road and a railway bridge using a self-develop app. Despite the smartphones limited resolution, the developed application was able to determine the vibration amplitudes, natural frequencies and damping values [3].

Other research also revealed the use of the embedded accelerometer in the smartphones. A comparison along smartphone accelerometer applications was conducted to assess the accuracy of the apps when used for structural vibration monitoring [4]. Whereas, two free applications for noise and
vibration measurements have been used to examine shock noise and vibration induced by gym activities [5]. Furthermore, some studies determined the use of the embedded accelerometer in smartphones for transportation safety measurements [6-8]. Many studies concerned on the high potential of the embedded accelerometer in the smartphone for the vibration field measurement, however very few discussed the performance of these vibration meters. Therefore, this study is aimed to evaluate the accuracy of the smartphone-based vibration-meter application software.

2. Method
The measurements were conducted at the laboratory of National Measurement Standards (SNSU) for Acoustics and Vibration – BSN Indonesia. The SNSU for acoustics and vibration laboratory is responsible for the maintenance of national traceability of acoustics and vibration standard instruments in Indonesia [9]. The evaluation of smartphone-based vibration meter was carried out using the standard method for vibration meter calibration explained in the ISO 16063-21 [10, 11]. The equipment used for this method is including a signal generator, a power amplifier, an exciter, a reference accelerometer, a conditioning amplifier, a digital voltmeter and a vibration meter as the unit under test. For this study, the reference accelerometer used is B&K 8305 with 2696 type of charge amplifier. Whereas, an instrument called B&K PULSE System is acted as the signal generator, the digital voltmeter and the data acquisition software. The scheme of the measurement is shown in Figure 1.

![Figure 1. Measurement Setup](image)

An electrical signal produced by the generator is amplified with the power amplifier and turned into a mechanical acceleration by the vibration exciter. The acceleration generated by the exciter is measured by the unit under test and the reference accelerometer simultaneously. Output from the reference accelerometer is connected to the conditioning amplifier before it is sent to the B&K PULSE System for further processes. Meanwhile, the acceleration reading of the unit under test is displayed in its screen. This method is known as back-to-back method since the reference accelerometer and the unit under test are positioned inline on the top of the exciter [12].

3. Experiments
Two vibration monitoring apps, namely “Accelerometer” and “G-filed Recorder” had been selected in this study. These apps were installed in the iPhone 6 with IOS 12 version platform. The “Accelerometer” had been developed by DreamArc. It offers three axes measurement for acceleration range from -20 G to 20 G. It comes with the realtime charts as well as maximum and minimum values of acceleration. The sampling frequency can be diverse from 1 to 30 Hz. All recorded data can be exported for further analysis. The second app, G-field Recorder, had been developed by Stratos Perception, LLC. It allows
measuring acceleration in three axes with sampling frequency from 0.001 Hz up to 100 Hz. All of the captured data can be logged, plotted and exported. More features can be obtained in-app purchase version; however, all used apps for this study are in a free version. The measurements were conducted at the laboratory of National Measurement Standards (SNSU) for Acoustics and Vibration – BSN Indonesia.

To perform the measurement based on the ISO 16063-21, the smartphone is played as the vibration meter under test. The configuration of the measurement is depicted in Figure 2.

![Figure 2. Experiment set-up](image)

The measurements were carried out in a frequency range from 10 Hz to 50 Hz for the amplitude of 0.1 G to 1 G. The vibration produced by the shaker is measured by the reference accelerometer as well as the smartphone synchronously. The measured acceleration captured by the apps is shown in Figure 3.

![Figure 3 (a). “Accelerometer” by DreamArc (b). “G-field Recorder” by Stratos Perception, LLC](image)
4. Result and Discussion
To avoid the effect of the cellular phone mounting on the exciter system to the acceleration measurement, the experiments were conducted on the low-frequency range from the frequency of 10 Hz to 50 Hz with the step of 5 Hz. The reference accelerometer B&K 8305 was used to measure the acceleration generated by the exciter with the unit of G (1 G = 9.806 ms\(^{-2}\)). The acceleration value measured by the B&K 8305 was used as the reference value for the comparison. The generated acceleration was increased for each frequency with the step of 0.1 G. The measured acceleration value by each vibration meter apps was reported as the correction value to the reference. These correction values were used as the indicator to evaluate the performance of each vibration meter apps. The experiment result is summarized in Table 1.

| Frequency (Hz) | Acceleration (G) | Correction (G) |
|---------------|------------------|----------------|
|               | Reference Accelerometer | Accelerometer | G-field Recorder |
| 10            | 0.100            | -0.043         | -0.019          |
| 15            | 0.200            | -0.091         | -0.087          |
| 20            | 0.300            | -0.152         | -0.151          |
| 25            | 0.400            | -0.216         | -0.204          |
| 30            | 0.500            | -0.287         | -0.246          |
| 35            | 0.600            | -0.403         | -0.305          |
| 40            | 0.700            | -0.439         | -0.338          |
| 45            | 0.800            | -0.342         | -0.339          |
| 50            | 0.900            | -0.390         | -0.368          |
| 50            | 1.000            | -0.426         | -0.424          |

In general, the apps are able to detect acceleration for all frequency range and given level. At frequency 10 Hz, the correction is small for both apps, where the second app provides better accuracy than the first app. In the frequency range of 25 Hz to 30 Hz, both applications showed a similar performance with the correction of about -0.2 G. However, starting from frequency 35 Hz to 50 Hz, the second app provides better accuracy. Even both apps use the same accelerometer device, the experiment result shows that the reading acceleration value has a different result. This difference is caused by the different data processing techniques used by each application. For example, the sampling period or data averaging length implemented in the software.

5. Conclusions
An evaluation of the smartphone-based vibration meter application based on ISO 16063-21 has been performed in the frequency range of 10 Hz to 50 Hz with the acceleration level of 0.1 G to 1 G. The measured acceleration by the application was corrected against the reference value to evaluate the performance of the applications. It is obtained from the experiment that each application has different accuracy. For future work, the method of mounting of the smartphone to the exciter shall be evaluated to increase the testing frequency range.

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Contribution statement
The authors of this paper stated that all authors are the main contributors to the writing of this paper.
References

[1] Ginart A, Ali I N, Barlas I, Ginart A A, Sheldon J S, Kalgren P W and Roemer M J 2011 IEEE Conf. on Aerospace pp 1–7

[2] De Dominicis C M, Depari A, Flammini A, Sisinni E, Fasanotti L and Tomasini M 2014 IEEE Int. Instrumentation and Measurement Technology Conf. Proc. pp 1617–22

[3] Another reference Feldbusch A, Sadegh-Azar H and Agne P 2017 X Int. Conf. on Structural Dynamics (Procedia Engineering vol 199) pp 2790-2795

[4] Cahill P, Quirk L, Dewan P and Pakrashi V 2019 Advances in Computational Design 4 001

[5] Kaewunruen S and Lei C 2020 Smartphone sensing and identification of shock noise and vibration induced by gym activities Acoustics Australia

[6] Fazeen M, Gozick B, Dantu R, Bhukhiya M and González M C 2012 IEEE Transactions on Intelligent Transportation Systems 13 1462

[7] Vaiana R, Iuele T, Astarita V, Caruso M V, Tassitani A, Zaffino C and Giofre VP 2014 Modern Applied Science 8 88

[8] Grimberg E, Botzer A and Musicant O 2020 Safety Science 131 104917

[9] Rusjadi D, Putri C C, Palupi M R, Dwisetyo B, Utomo F B, Prasasti N R 2020 J. Phys. Conf. Ser. 1568 012009

[10] International Organization for Standardization 2003 ISO 16063-21:2003 Methods for the calibration of vibration and shock transducers – Part 21: Vibration calibration by comparison to a reference accelerometer (Switzerland:ISO)

[11] Julianni F, Barros E de and Mathias M H 2013 C. R. Mecanique 341 687-696

[12] Hermawanto D, Palupi M R, Rusjadi D, Prasasti N R, Dwisetyo B Putri C C and Akil H A 2018 J. Phys. Conf. Ser. 1075 012052