August 2020

Dynamic Audio Level Adjustment in Wearable Audio Devices

Jonathan D. Hurwitz

Dynamic Audio Level Adjustment in Wearable Audio Devices

ABSTRACT

Ambient sound levels in environments where wearable audio devices are utilized can vary substantially. Such variation can cause responses provided via such devices to be inaudible or too loud in certain situations. This disclosure describes techniques for dynamic adjustment of wearable device audio output levels based on measured ambient sounds levels. Per techniques of this disclosure, with user permission, sound pressure levels (dB SPL) of a user's ambient environment are measured and stored in a buffer. The audio output level for the user device is set such that audio output from the wearable device exceeds an average measured dB SPL level by a predetermined threshold. When an on-board speaker on the wearable device is to be utilized, a moving average of dB SPL levels is computed that is representative of an ambient noise level of an immediately preceding time period. Based on the computed average dB SPL level, the output speaker volume is selected, e.g., set to about 6 dB above the computed average dB SPL level.

KEYWORDS

- Sound Pressure Level (SPL)
- Smartwatch
- Fitness band
- Microelectromechanical (MEMS) microphone
- Wearable device
- Speaker audibility
- Background noise
- Volume level
- Voice assistant

BACKGROUND

Wearable devices such as smartwatches are used in many different environments, e.g. while playing sports, doing errands, during workouts, while asleep, etc. Each type of environment has different sound profiles, which can also dynamically change with time. For

example, the average sound level inside a home is about 50 dB, but inside the same home with a vacuum cleaner operating at a distance of 1m, the average sound level is about 70 dB.

Based on these scenarios, device features that rely on audibility, e.g., a voice assistant response to a query, etc. may be affected by background noise levels. Typically, the device hardware and/or audio applications are configured to provide audio output at a volume level that's set to a fixed value or is set to the last user selected value. If the setting is not suitable for the user's current environment and ambient noise level, user experience can be compromised. For example, the volume setting can be too low relative to the noise floor, whereby the user is unable to hear the device audio output, or can be too high and disruptive to the user.

DESCRIPTION

This disclosure describes techniques for automatic dynamic adjustment of wearable device audio output level based on measured ambient sound levels. Per techniques of this disclosure, with user permission, sounds pressure levels (dB SPL) of a user's ambient environment are measured and stored. The audio output level for the user device is set such that audio output from the wearable device exceeds an average measured dB SPL level by a predetermined threshold.

Smartwatches and other portable electronic devices commonly include micro electro-mechanical (MEMS) microphones due to their small package size and low power consumption. MEMS microphones include a mechanical diaphragm that flexes in response to changes in air pressure caused by sound waves received at the microphone. Flexure of the diaphragm changes the capacitance between the diaphragm and a fixed plate of the device, which is translated into an electrical signal, e.g., voltage level, corresponding to a received sound pressure level.

The electrical signal generated by the microphone is responsive to received sound pressure levels up to the microphone's acoustic overload point (AOP), and is utilized by the device for audio processing.

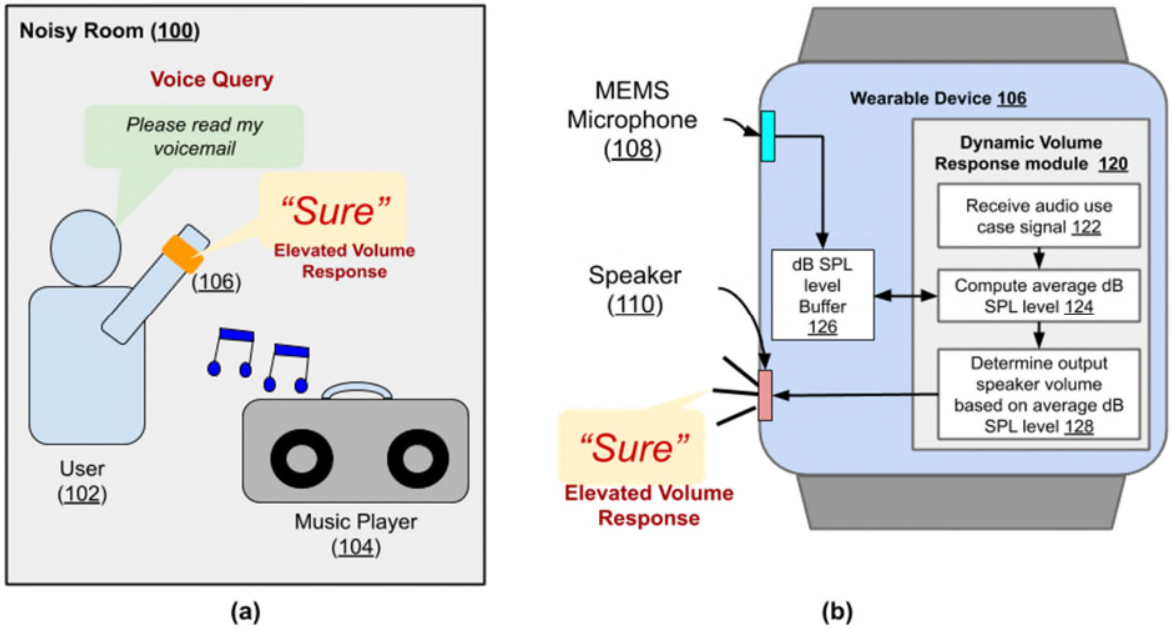

Fig. 1: Dynamic adjustment of output audio level based on ambient sound level

Fig. 1 illustrates an example of dynamic adjustment of wearable device audio output levels based on measured ambient sounds levels. In this illustrative example, Fig. 1(a) depicts a user (102) in a noisy room (100) that includes a music player in operation (104). The user poses a voice query ("Please read my voicemail") to their wearable device/smartwatch (106).

Fig. 1(b) depicts the wearable device (106) that includes a MEMS microphone (108) for receiving audio input at the device and an on-board speaker (110) for providing audio output from the device. As can be seen in Fig. 1, based on a low ambient sound level, the output ("Sure") is provided at an elevated volume level, indicated by the larger font size.

Measuring and Storing the dB SPL Level

The wearable device includes a dB SPL buffer (126) that is utilized to store (record) instantaneous dB SPL levels of sound received at the wearable device microphone over a predetermined time period. The predetermined time period can be configured based on the specific wearable device, and can be adjusted based on ambient environmental conditions and/or user settings. For example, a value between about 5s and about 10s can be utilized as a time window over which received dB SPL levels are measured and logged.

Per techniques of this disclosure, dB SPL levels at the microphone are sampled at a predetermined rate, e.g., nearly instantaneously sampled if accuracy is to be prioritized, sampled over longer periods if power savings are to be prioritized, etc., and are stored in the dB SPL buffer.

A size of the dB SPL buffer to be utilized can be calculated by the formula:

Buffer Size = S * sr * bd;

where S = number of seconds of buffered dB SPL data (e.g. 5 for 5s); sr = sampling rate of the microphone; and bd = bit depth.

As new samples are received, if this buffer is full, the oldest entry (e.g., earliest received sample) is removed and the newly received sample is added to the buffer. With user permission, the measurement and storage of received dB SPL levels is performed in the background, even when no audio-related applications on the wearable device are in active use.

Using the dB SPL level to adjust output audio level

When an application is initiated on the wearable device that requires audio output from an on-board speaker associated with the wearable device, e.g., a voice query is posed by the user

that requires an audio response from the wearable device, a dynamic volume response module (120) is utilized to determine a suitable output audio level.

As depicted in Fig. 1(b), an audio use case signal is received (122). The average dB SPL level is computed (124). For example, a moving average of dB SPL levels is computed that is representative of an ambient (environmental) noise level of an immediately preceding time period. The duration of the preceding time period is configurable based on the specific audio application and may be tailored to a desired user experience. While the instantaneous dB SPL level value determined just before any audio output is usually the most accurate value, averaging is performed to smoothen out possible variance from environmental variations and measurement error.

Based on the computed average dB SPL level, the output speaker volume is determined (128). For a sound to be audible above background noise, it generally has to be about 6dB higher than the noise floor (around four times the power). Accordingly, an audio volume level output of the device is set to about 6dB above the computed average dB SPL level, up to the maximum volume level of the on-board speaker. For example, if the computed average dB SPL level is 61dB, the output audio level at the on-board speaker is set to about 67dB.

In this illustrative example, the volume level of the on-board wearable device speaker is adjusted to an elevated level to account for the increased ambient noise level due to the music player in the room. The on-board speaker is utilized to provide an audio response to the user (“Sure”) at the elevated volume level such that the response is audible to the user above the sound level of the music player, without being too loud or uncomfortable.

In some scenarios, the computed output audio volume value based on the computation can be higher than what the speaker is capable of outputting. For example, a smartwatch speaker

may have an audio output range between about 65dB and about 80 dB. A large diesel truck about 10m away from a user would lead to about 90dB of noise. Therefore, an output audio level of about 96dB from the smartwatch speaker may be needed for the output to be audible to the user. In such a scenario, the speaker is operated at its maximum volume level - no attempt is made to overdrive it beyond its design limits. Alternatively, an indication may be provided to the user (e.g., via haptic feedback) that the response may be played back later (e.g., after the truck has passed), or the same response may be provided an additional time, e.g., after the ambient sound level drops.

Dynamic adjustment of wearable device audio output levels, per techniques of this disclosure can be utilized in many audio applications for improved speaker audibility and improved user experience. For example, the described techniques can be utilized in use cases such as a voice assistant responding to a voice query, playback of an audio message, music playback on the device, having a voice assistant read out a text or notification, reading out of turn by turn directions for navigation, etc. The techniques can be implemented as part of the operating system of a wearable device.

CONCLUSION

This disclosure describes techniques for dynamic adjustment of wearable device audio output levels based on measured ambient sounds levels. Per techniques of this disclosure, with user permission, sound pressure levels (dB SPL) of a user's ambient environment are measured and stored in a buffer. The audio output level for the user device is set such that audio output from the wearable device exceeds an average measured dB SPL level by a predetermined threshold. When an on-board speaker on the wearable device is to be utilized, a moving average of dB SPL levels is computed that is representative of an ambient noise level of an immediately

preceding time period. Based on the computed average dB SPL level, the output speaker volume is selected, e.g., set to about 6 dB above the computed average dB SPL level.

REFERENCES

1. Wilder, John, and Alessandro Morcelli. "Basic Principles of MEMS Microphones." EDN, April 9, 2020. https://www.edn.com/basic-principles-of-mems-microphones/, accessed on 26 July 2020.
2. What is an AOP Microphone?, accessed on 26 July 2020.
3. Decibel Table, accessed on 26 July 2020.
4. Digital Audio Basics: Sample Rate and Bit Depth, accessed on 26 July 2020.
5. Calculating Bit Rate and Buffer Window Values for Arbitrary Streams - Win32 apps, accessed on 26 July 2020.