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Sleep Mode Activation Based on Detecting Laptop Lid State via Ultrasonic Ping Signal

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ABSTRACT

Sleep mode conserves laptop battery when the device is not in active use. A quick mechanism to put a laptop in sleep mode is simply to close the lid. Most laptops include a Hall Effect magnetic sensor to detect whether the laptop lid is closed. This imposes additional costs and can increase thickness. This disclosure describes the use of existing speakers and microphones of a laptop to detect lid state. An inaudible ultrasonic ping is emitted via built-in speakers and reflection of the ping is captured using the built-in microphone(s). The sound signature is analyzed to determine lid state. Distinct Doppler spectrogram signatures can be associated with the state of the laptop lid, as closing an open lid results in a blueshift with a dip toward higher frequencies while opening the lid causes a redshift with a rise toward lower frequencies. The Doppler spectrograms are input to a suitably trained binary classifier that generates an indication of whether the laptop lid is closed. The indication can be used by the device operating system to activate sleep mode.

KEYWORDS

- Sleep mode
- Laptop lid
- Lid state detection
- Closed laptop
- Hall effect magnetic sensor
- Doppler effect
- Ultrasonic ping

BACKGROUND

Laptops are configured with a sleep mode that conserves battery when the device is not in active use. Sleep mode conserves battery while avoiding the time and effort required in shutting down and restarting the laptop each time the device is not in active use.

Apart from explicit user action to invoke sleep mode, a quick mechanism to put a laptop in sleep mode is simply to close the lid. Most laptops include a Hall Effect magnetic sensor to detect whether the laptop lid is closed. When the sensor indicates that the lid is closed, the laptop is automatically put in sleep mode. Conversely, when the sensor indicates that the laptop lid is open, the laptop is taken out of sleep mode such that the user can resume use of the laptop.

The use of magnetic sensors to detect the state of the laptop lid imposes additional costs and can potentially increase the thickness of the device. On the other hand, laptops that lack such a sensor cannot be automatically put in sleep mode by closing the lid, thus requiring the user to remember and take explicit action to put the laptop in sleep mode prior to closing the lid. If the user forgets to activate sleep mode prior to closing the lid of a laptop that lacks a sensor to detect lid closure, battery drain can occur even when the laptop is not in active use.

DESCRIPTION

This disclosure describes techniques to detect whether a laptop lid is closed by using existing speakers and microphone(s) in the laptop. An ultrasonic ping signal inaudible to the human ear is emitted via the on-board laptop speakers. The ping signal is reflected back by any nearby objects. The reflected signal is captured by the microphone(s).

When the lid is open, the reflected signal is close to null since the lid is not in the path of the ping signal. In contrast, the ping signal is reflected strongly and immediately when the lid is closed. Moreover, reflection of sound waves by a nearby moving object, such as the lid in the

case of the laptop, exhibits the Doppler effect, with the pitch increasing as the object moves closer (blueshift) and decreasing when the object moves away (redshift). Therefore, the reflected signal captured by the laptop microphone can indicate a blueshift when the lid is being closed and a redshift when it is being opened.

If $s(t) = \cos(2f_{tone}t)$ is the ping signal at the ultrasonic frequency f_{tone}, then the reflected signal can be expressed as $r(t) = A \cos(2 [f_{tone} + v / c] t)$ where A is the signal attenuation scalar, v is the velocity of lid, and c is the speed of sound. The velocity is positive when the lid is being closed and moving toward the speaker (blue shifting) and negative when the lid is being opened and moving away from the speaker (red shifting).

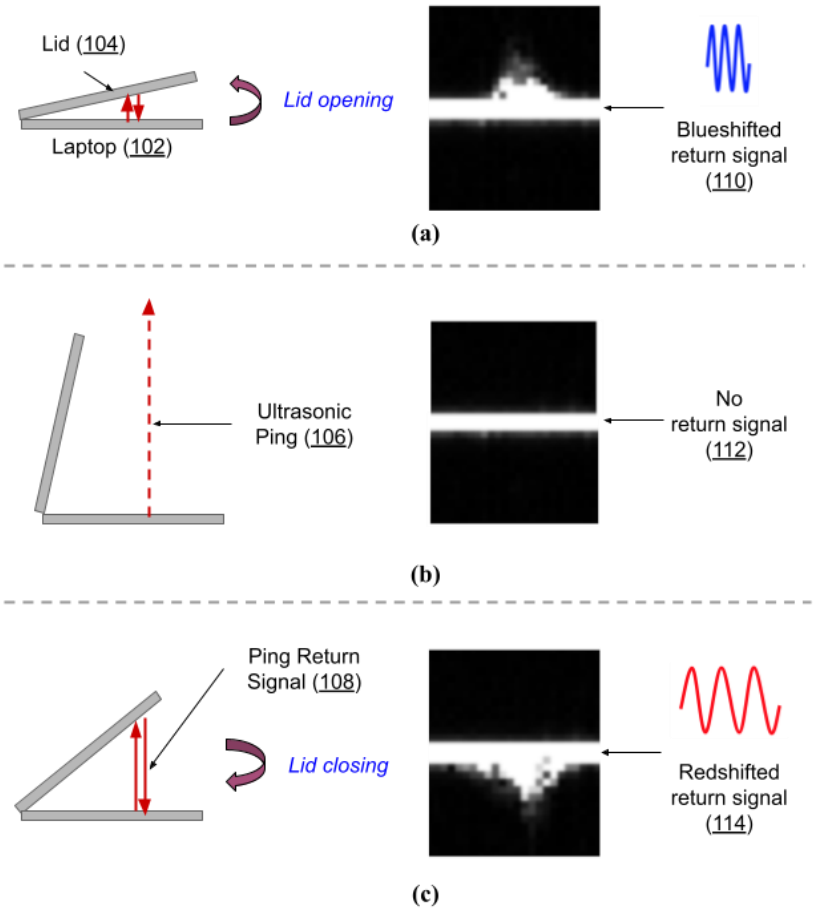

Fig. 1: Detecting the state of a laptop lid using an ultrasonic ping signal

Fig. 1 shows an operational implementation of the techniques described in this disclosure. An ultrasonic ping signal (106) is emitted via the speakers of a laptop (102). When the laptop lid (104) is open, it does not obstruct the signal (Fig. 1b), thus no return signal (112) is generated via reflection of the original signal. When the lid is being opened (Fig 1a) or closed (Fig 1c), the lid is present in the path of the ping signal, thus reflecting it. The reflected return signal is captured by the device microphone(s). A return signal that is blueshifted (110) in comparison to the original ping indicates that the lid is being opened (Fig 1a) while a redshifted return signal (114) indicates that the lid is being closed (114).

The reflected signal received by the microphone can be processed using a digital Doppler processing block to yield Doppler spectrogram signatures that can be input to a simple binary classifier that indicates whether the lid is closed. The Doppler processing includes:

1. **Mixing** (optional): Ultrasonic signal mixing can isolate the Doppler frequency s(t) * r(t), i.e., the difference frequency between the ping source and reflection. Operationally, it generates two frequency components: the desired Doppler component and a high-frequency ghost component. The high-frequency component can be removed easily using a simple low pass filter (LPF).
2. **Windowing**: This windowing operation is performed to suppress side lobes in frequency to increase the Doppler spectral peak resolution that intersects with the peak of the direct current (DC) signal. The operation can use a typical window such as Hann.
3. **Transforming**: A Fast Fourier Transform (FFT) can be applied to convert the Doppler signal into frequency domain. Correct application of all steps up to this point yields an almost pure tone at the frequency corresponding to the velocity of the lid moving in free air.

4. **Stacking**: To enable robust classification, stacking is employed to buffer the instantaneous events for a duration of sufficient length, such as tens of milliseconds. The buffers can be deemed as Doppler spectrograms. Distinct spectrogram signatures can be associated with the state of the laptop lid as closing an open lid results in a blueshift with a dip toward higher frequencies while opening the lid causes a redshift with a rise toward lower frequencies.

A collection of such spectrograms can be used to train a binary classifier such as a neural network with an application-specific architecture. The Doppler spectrograms generated in an operational implementation as described above are input to the trained binary classifier. The output of the classifier can indicate whether the laptop lid is open or closed. To avoid excessive power consumption, the ultrasonic ping can be generated at suitable intervals that are set by the developers and/or determined dynamically at runtime.

The techniques described in this disclosure can be used with any device that includes built-in speakers and microphone(s) and has a closable lid. The state of the lid detected using the techniques as described above can be provided to the device operating system (OS) as well as any suitable application, e.g., a web browser or other application. The OS and the applications can leverage the detected lid status for automatically performing relevant actions, such as activating sleep mode on the device when the device lid is closed.

The described techniques can detect whether the device lid is closed with high accuracy without requiring Hall effect magnetic sensors. Eliminating the need to provide a Hall effect magnetic sensor can reduce device cost and potentially enable device manufacturers to produce devices with lower thickness. In addition, the techniques can add the capability of detecting the state of the device lid to legacy devices that lack a Hall effect magnetic sensor.

CONCLUSION

This disclosure describes the use of existing speakers and microphones of a laptop to detect lid state. An inaudible ultrasonic ping is emitted via built-in speakers and reflection of the ping is captured using the built-in microphone(s). The sound signature is analyzed to determine lid state. Distinct Doppler spectrogram signatures can be associated with the state of the laptop lid, as closing an open lid results in a blueshift with a dip toward higher frequencies while opening the lid causes a redshift with a rise toward lower frequencies. The Doppler spectrograms are input to a suitably trained binary classifier that generates an indication of whether the laptop lid is closed. The indication can be used by the device operating system to activate sleep mode.