TapLaptop: Expansion of the Operating Area of a Laptop by Detection Taps Using a Single Embedded Microphone

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ABSTRACT
Unique sounds are produced by tapping each area of the keyboard or palm rest on a laptop PC. These different sounds are attributable to the internal structure of the computer or the position of the microphone used to detect these sounds. Various approaches are available for enriching the input area by identifying the operating sounds produced by users, but most require an additional microphone (e.g., piezoelectric microphone) to detect the structure-borne sounds carried by the laptop structure. In this study, we propose the expansion of the operating area of a laptop by distinguishing tapping sounds using the embedded microphone. Our method does not require any external sensors, thereby maintaining the advantages of laptops in terms of mobility and low weight, and it is readily deployed on a laptop using the embedded microphone.

Author Keywords
Acoustic sensing; tapping; machine learning; finger input; embedded microphone;

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
A laptop keyboard has a limited number of keys because it is small compared with a standard external keyboard. Therefore, it may be necessary to use combinations of keys to trigger specific commands. Thus, to initiate complex or contiguous commands, it is necessary to learn the combination of keys that corresponds to each command. A possible solution to these problems is to expand the input area by attaching external sensors (e.g., piezoelectric microphone) to the laptop or table surface, which may have effects on mobility. The construction of a robust system without additional sensors would solve the problems while still maintaining mobility, but such techniques are not available at present.

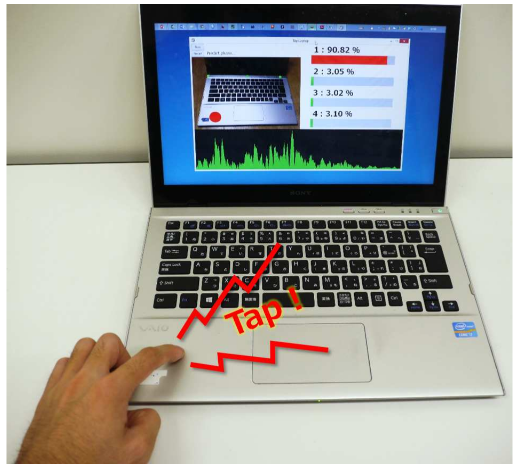

Figure 1. The system recognizes taps on the laptop keyboard.

The growth of voice chat services such as Skype means that the latest laptops contain embedded microphones around or under the keyboard where the location tends to be the ideal position for speech acquisition. These microphones are also sensitive to the sounds of typing and tapping on the keyboard or the palm rest. A previous study analyzed their positioning and characteristics [1]. In this study, we propose the expansion of the operating area of a laptop by distinguishing tapping sounds using the embedded microphone (Figure 1).

However, the embedded microphone is intended to capture speech and it is not designed to capture structure-borne sounds. Thus, we determined whether it is capable of distinguishing the tapped areas.

IMPLEMENTATION
The prototype system comprises two modules: the fast Fourier transform (FFT) analyzer samples the microphone and applies the FFT to an incoming signal to separate the component frequencies, where a support vector machine (SVM) classifier performs machine learning. The sampling rate is 44.1 kHz while recording a signal.

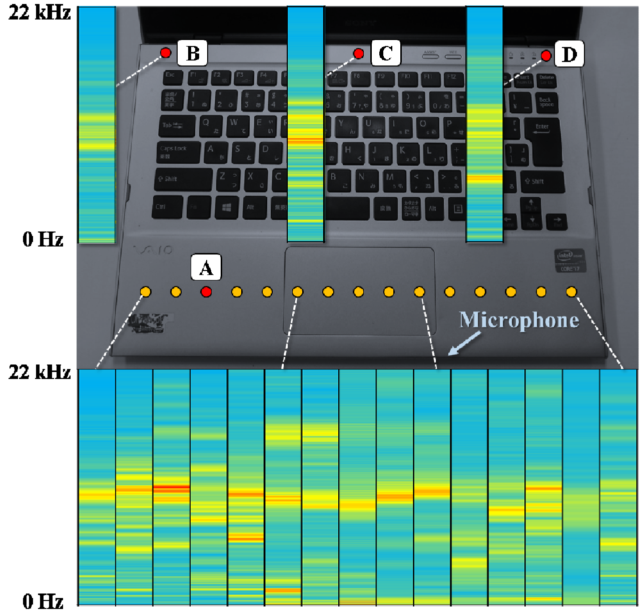

Figure 2. Frequencies at specific areas on the laptop.

The system detects a tapping input if the input tapping sound volume from the microphone exceeds a certain threshold value. The peak value of the signal is recorded but it is not possible to record the entire signal because the recording starts from this point. Therefore, we divide the input signal to allow tap detection and recording. The tap detection signal is subjected to a high-pass filter to prevent the influence of environmental noise such as voices. The system detects the volume of this signal and treats it as tapping when it exceeds the threshold. Note that we determined the threshold value experimentally. The recorded signal is always delayed for several milliseconds. Thus, it is necessary to record the whole tap sound to set an appropriate delay time, which we set as 25 ms in the present study. The length of the recorded signal comprises 2048 samples (ca. 46 ms). The system applies the FFT to the recorded signal using a 2048-point Hann window to compute 1024 points for the frequency vector.

The SVM classifier performs learning and recognition of the tap sounds using a SVM implemented in LibSVM [2]. The parameters of the kernel can be tuned using a grid search to improve the accuracy. The features extracted by the FFT analyzer are passed to this SVM classifier.

PRELIMINARY STUDY

Figure 2 shows a spectrograph of the average frequency response when tapping each position on the laptop 10 times. Note that all of the taps were produced by the tip of the forefinger. We confirmed that the spectrum structure differed among various positions, but the tap sounds were often distorted when the tapping position was too close to the microphone.

In our preliminary study, we considered four positions around the keyboard (the red points from A to D in Figure 2), which were located well away from each other, thereby allowing a user to distinguish them easily. We performed tapping in sets of 10 for each position and repeated 12 sets. Thus, we collected 480 frequency response signatures for the training set.

Using these data, we conducted a cross-validation with the entire training set, where we employed LibSVM (RBF kernel, c = 8.0, g = 0.00012). The results showed that the recognition rate was 96%.

IMPROVEMENT AND FUTURE WORK

We propose to expand the operating area of a laptop by distinguishing these tapping sounds using the embedded microphone. Our system can detect the positions tapped by users without any external sensors, but some important considerations need to be addressed to improve our current method.

Our current system cannot detect the tapped positions in a robust manner in noisy environments. We could address this problem by using a high threshold value, but noises may be misinterpreted as tapping sounds when other signals are received, such as a fricative sounds or strong pushing on the keyboard. According to Harrison et al. [3], the sound produced by finger tapping also varies when different finger parts make contact with the surface. In the current system, we assume that all of the taps are produced by the tip of the forefinger.

Embedded microphones are also present in other devices in addition to laptops. For example, a microphone is used for making calls on a general smartphone and it a web camera. Our approach could also be applied to these devices to allow tap inputs because it may be difficult to attach an external sensor to such devices.

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