Interaction Technique Using Acoustic Sensing for Different Squeak Sounds Caused by Number of Rubbing Fingers

Ryosuke Kawakatsu
Division of Frontier Informatics, Graduate School of Kyoto Sangyo University
i1658038@cc.kyoto-su.ac.jp

Shigeyuki Hirai
Faculty of Computer Science and Engineering, Kyoto Sangyo University
hirai@cse.kyoto-su.ac.jp

ABSTRACT

We propose a novel interaction technique that utilizes squeak sounds caused by rubbing fingers on a smooth wet surface. The technique can be used for obtaining some inputs by the number of rubbing fingers in wet environments. This paper describes a method and its performance for identifying the number of rubbing fingers from the squeak sounds by using spectrum models such as the Gaussian mixture model. Furthermore, we describe some applications by using this interaction technique.

Author Keywords

Squeak Sound, Frequency Analysis, Harmonics, Gaussian Mixture Model, Acoustic Sensing,

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION

Various studies have been conducted for developing interaction techniques in a smart house. Some of our previous studies [1,2]focused on bathrooms and we converted an existing normal bathtub system into a user interface by using embedded sensors. A system called Bathcratch [2] detects squeak sounds by rubbing on a bathtub edge. To generate squeaks, it requires some conditions to cause the Stick-slip phenomenon. A bathtub has a smooth surface, and water can cause the phenomenon with human skins. Bathcratch uses it as an interaction technique to play DJ-scratching. Here, we extended the interaction technique using squeaks to recognize rubbing states, rubbing events including sequence, and the difference between squeaks caused by the number of fingers. This can be used in various wet environments including kitchen, washbowls in a restroom, swimming pool, and spa. This paper describes the method and its performance for identifying the number of rubbing fingers by using frequency analysis. In addition, we illustrate some smart home applications by using the proposed technique.

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IDENTIFICATION PROCESS USING MODELS OF SQUEAK SOUNDS

We can hear and notice a pitch from a squeak caused by rubbing a smooth surface, implying that a squeak sound has a fundamental frequency (F0) and a harmonic structure. Therefore, squeak sounds caused by rubbing with multiple fingers have frequency components with multiple F0s and harmonic structures corresponding to each finger. Figure 1 shows spectrograms of practical squeak sounds caused by rubbing of one finger and multiple fingers. In this paper, we propose a method for identifying the number of rubbing fingers. The proposed method focuses on the feature of frequency components and utilizes the result as an interaction technique.

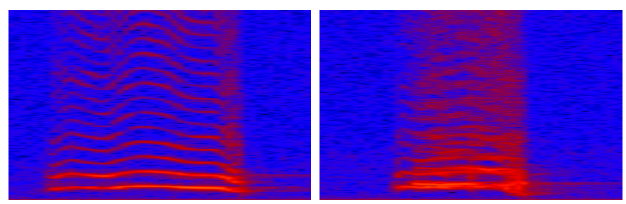

Figure 1. Spectrograms of squeak sounds; Left: one-finger, Right: multifingers.

Modeling squeaks for the number of rubbing fingers

We adopted the Gaussian mixture model (GMM) to identify the number of rubbing fingers. At present, the training data of GMMs are generated through power spectrums normalized by each area and F0s. To train their GMM parameters, we use the expectation-maximization algorithm. Figure 2 illustrates plots of GMMs with one, two, and three fingers.

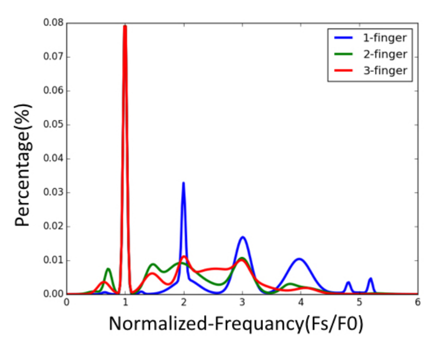

Figure 2. Gaussian mixture models for each squeak caused by rubbing fingers.

Identification Process

A piezoelectric sensor is attached to an object with a smooth surface to measure vibrations as acoustic signals. Further, the input signal is processed sequentially for each analysis frame with a frame period of 1.16 [ms] (512 [samples], SR: 44,100 [Hz]). First, a root-mean square (RMS) value of a frame is calculated. If the RMS value exceeds the threshold, the following identification method is performed.

1. Power spectrum: Calculate a power spectrum using the fast Fourier transform process.
2. Normalization: Normalize a power spectrum by its area and F0.
3. Product–Sum Operation: Perform a product–sum operation using a normalized power spectrum and each precalculated GMM.
4. Select a Model: Select a model with a maximum value of calculated results of the product–sum operation.
5. Next frame: Get input signal of frame length.

This process is repeated until the RMS value reduces more than the threshold. An identification result is the most selected model in a sequence of processed frames.

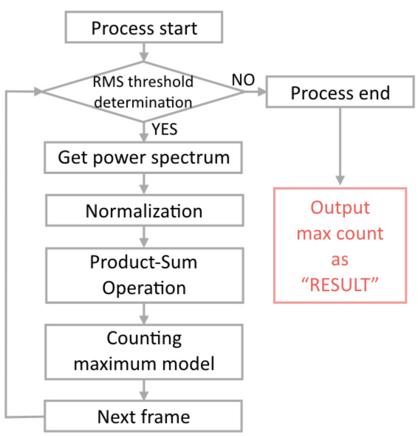

Figure 3. Block diagram for identification process.

PERFORMANCE EVALUATION

This section describes the performance evaluation for the aforementioned identification method with the top of a smooth-surfaced bathtub edge. In addition, we confirmed similar results using the tabletop of a kitchen counter. In this study, we verified the performance due to the change in two parameters: normalized frequency ranges for calculation and GMM components. This paper describes the result of evaluation for normalized frequency ranges for calculation.

Performance Evaluation of Calculation Frequency Range

The normalized frequency range for calculation affects the identification of the number of fingers. A large frequency component (e.g., F0) biases the result. Moreover, higher frequency components (e.g., over 10 kHz) do not affect the identification but affect the loads for calculations. Therefore, to obtain better identification results, an appropriate frequency range should be used. Figure 4 shows the verification results.

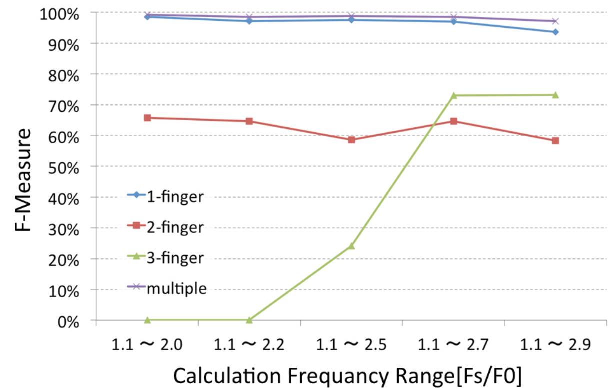

Figure 4. Relationship between F-measure and Frequency Range for Calculation.

The maximum accuracy obtained for identifying one finger is more than 95%, and the accuracies for identifying two and three fingers are more than 60%. However, if two and three fingers are regarded as multifingers, the maximum accuracy is more than 95%.

EXAMPLE APPLICATIONS

In this section, we illustrate a few applications utilizing the different squeak sounds caused by the number of rubbing fingers. Bathcratch+ is an advanced version of Bathcratch, an entertainment system of DJ scratching that functions by rubbing on a bathtub edge. This advanced version can be played by switching scratching sounds with a number of rubbing fingers. iRubBook is a book reader application that controls paging with different squeak sounds. This app can switch books through squeak-sequence patterns. iRubRemote is a remote controller for home appliances that are operated using IR remotes that utilize squeak sounds and their sequence patterns.

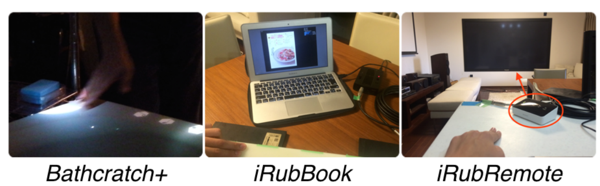

Figure 5. Example applications using squeaks by finger-rubbing.

CONCLUSION AND FUTURE WORK

In this paper, we proposed a novel interaction technique utilizing squeak sounds by rubbing a smooth wet surface. This technique can identify the difference between a squeak made by one-finger and by multifingers. In addition, we illustrated a few applications using this interaction technique. At present, the identification method uses the GMM for modeling frequency components. Its identification performance is more than 95%. In contrast to the accuracies of one finger and multifingers, the accuracy of identifying two and three fingers is not high. In the future, we plan to improve this accuracy by using other signal-processing techniques such as machine learning and frequency analysis. In addition, we plan to verify the usefulness of this interaction technique by using some applications in specific situations.

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