Audio Fingerprinting in UbiComp Environments – Performance Measurements and Applications

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***Abstract*—We propose an audio-based mechanism for device authentication. The method is feasible with low-end microphones and can be extended to further UbiComp application domains as improved location estimation of sensor nodes or arlarming. Measurement results obtained in a preparatory study demonstrate the performance of the approach.**

I. Introduction

Recent wireless pairing mechanisms have serious shortcomings as, for instance, obtrusive user feedback in Bluetooth or range-limitation with NFC. We propose the use of sampled life audio in order to provide a means of proximity restricted device pairing mechanism. In a nutshell, audio-fingerprints [1] are exchanged between devices. Audio-fingerprinting allows for the restriction of authentication to rooms in a building. A device that is willing to authenticate captures a few seconds of environmental audio, transforms it into a fingerprint and transmits this to the partner device. This second device can then decide, if the first one is in the same room with reasonably high probability.

II. Experimental Results

We captured 25 audio samples at various loudness levels and at different positions in a room. Audio is captured at 44100 kbps and is applied to a (70Hz,7kHz)-bandpass-filter to reduce the impact of noise. In our implementation we split the sample into 21 sub-sequences each of which is divided into 21 Frequency bands. Energy differences between frequency bands of concurrent sub-samples define an audio-fingerprint of 400 bits. At the receiving device, the same calculation is applied and fingerprints are compared.

Figure 1 shows the Hamming distance for fingerprints of matching and non-matching audio samples for one exemplary setting. Although the fingerprints of matching audio samples have a considerable count of bit errors, matching and non-matching audio samples can be separated. An acceptance threshold of 160 bit errors, for example, results in a false-positive ratio of 0.37% and a false-negative ratio of 33.11% over a total of 11250 different fingerprints. Consequently, when not one but several fingerprints are utilised for authentication in a j out of l procedure, the false-negative ratio can be greatly reduced with still low probability that an adversary might fool the protocol. A random bit sequence of length n has a Hamming distance of less than k bits to a target bit sequence with probability at most

$$\frac{\binom{n}{k}}{2^n} \tag{1}$$

For a fingerprint length of $n = 400$ bits and a Hamming distance of $k = 160$ bits (as in our case) this is $\frac{0.4173488724}{10^{115}}$.

III. Applications in UbiComp Scenarios

Apart from the pairing of devices, other applications in ubiquitous settings are straightforward. Consider, for example, a WSN that is supplied indoors. In order to increase accuracy of location estimation of the sensor nodes, audio fingerprinting provides means to group sensors in one room.

Furthermore, indoor location tracking by audio-fingerprinting constitutes an interesting approach. The location of an individual can be tracked on a per-room-basis with only audio sensors available. Probably, the audio-sensors of otherwise located devices might be utilised to this end, so that existing location tracking solutions can be extended in an ad-hoc manner without further infrastructure costs.

Also, alerting is possible, for example, as theft prevention or detection. An alarm might be issued as soon as a device is removed from the proximity of its owner.

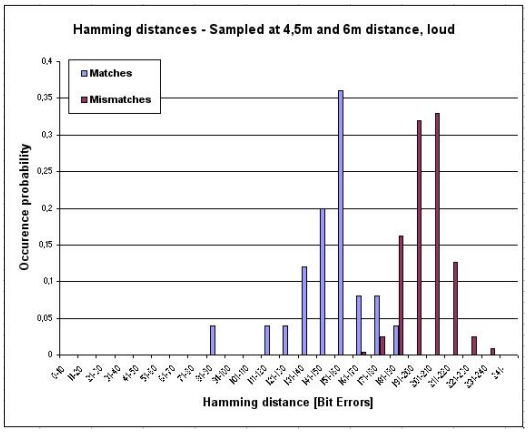

Fig. 1. Hamming distances in matching and non-matching fingerprints.

References

[1] J. Haitsma and T. Kalker, "A highly robust audio fingerprinting system," in *Proceedings of the 3rd International Conference on Music Information Retrieval*, October 2002.

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