Virtual Uniforms: Using Sound Frequencies for Grouping Individuals

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Abstract
In this paper, we present the concept of grouping individuals and detecting their proximity by emitting/receiving inaudible tones using their mobile phones. The inspiration stems from wearing uniforms of different colors to group subjects based on the roles, occupations or teams. The goal is to get an insight into the social context and social interaction patterns.

Author Keywords
Mobile phone sensing; Social context analysis; Proximity detection;

ACM Classification Keywords
H.5.3 Group and organization interfaces; H.5.5. Sound and music computing;

Introduction
Understanding social context in an automatic fashion is considered to be an important aspect in ubiquitous computing. Its importance spans from allowing a mobile phone to know when to vibrate and when to ring depending on the surrounding, to bringing new insights about the problems of industry and government such as logistics and resource management, transportation, and public health [1]. In particular, it has been demonstrated that IT-supported data collection related to social interaction patterns and social contexts can reveal critical predictors of productivity, creativity and job satisfaction [1], improve the management of healthcare staff [2] or to uncover flows of patients, healthcare staff, visitors and tutors [3] for a better internal organization and logistics. For such analysis of interaction/flow patterns and social contexts, an IT tool is mainly expected to be continuously delivering information about the proximity between individuals and their identification (such as to identify if an

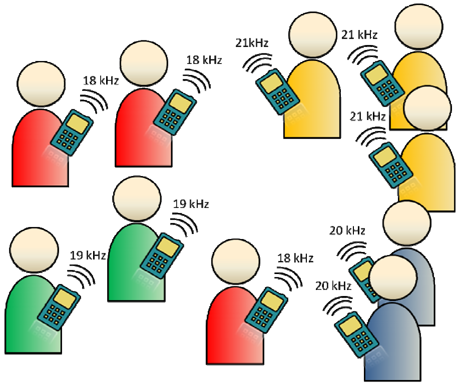

Figure 1.The concept of Virtual Uniforms

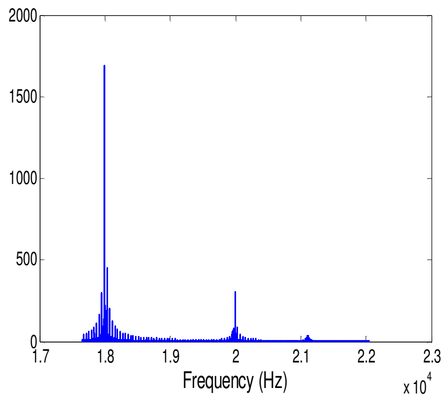

Figure 2. Frequency spectra in proximity of three groups of users

individual is a doctor or nurse, or which department in the company he/she belongs to).

Our approach for differentiating individuals and detecting their proximity is based on using mobile phones that are emitting/receiving sounds of different frequencies which are associated to different individuals' profiles. The inspiration for this concept stems from the uniforms (or jerseys) of different colors that are grouping individuals by roles, occupations, or teams. In the same manner in which a color corresponds to the frequency of the emitted light, sound frequencies emitted by mobile phones are used in our approach to group individuals that are carrying mobile phones (Fig.1). We selected the sound frequency range of 18-22 kHz which belongs to the intersection between hearing range of humans and ultrasound spectrum, however typically inaudible to adults. We calibrated the volume of the emitting sound in such a way to be recievable only by the phones in the proximity up to 2m (which, according to the proxemics study, belongs to social space). In this way, we detect proximity between individuals while grouping them according to the defined profiles (e.g. roles in the company, department, occupation, or interests).The proposed setup requires only the basic hardware, namely a speaker and a microphone embedded in mobile phones.

Our approach

Selected Frequency Range

The sampling frequency of 44.1 kHz represents de facto standard that majority of mobile phone microphones support; according to the Nyquist-Shannon sampling theorem 22 kHz represents the upper boundary frequency component which can be detected. On the other hand, the upper hearing frequency in humans is considered to be 20 kHz, however in practice this depends on a number of factors including age, gender, ambient noise, sound volume, and so on. Typically, the frequencies of18 kHz and higher cannot be heard in every day conditions by the majority of individuals, even younger ones [4] (which was witnessed also in our experiments when we used mobile phones emitting sounds of 18 kHz and higher). For the above reasons, we selected the frequency range of 18 – 22 kHz for the tones sequentially emitted and received by the mobile phones in order to group the users according to the selected criteria in a certain application scenario.

Sound analysis

In our experiments, we used Android based mobile phones (*HTC Desire S* and *Samsung Galaxy Mini 2*) which were emitting tones of frequencies of 18, 20 and 21 kHz and which were carried by the individuals from three different departments, the IT support, research group, and finance respectively. The difference between the selected frequencies can be set to a level lower than 1 kHz, however one may note that in specific scenarios the number of groups of users can exceed the number of distinguishable discreet frequency levels in the selected range; in such case, the issue can be resolved by using unique signal patterns at the emitter's side. To analyze the received signal frequency spectrum we used Fast Fourier Transformation (FFT). In order to tackle the problem of noise, a simple noise cancelling strategy [5] was applied which consists of summing frequency spectra in time. This strategy is based on the assumption that the signal components are always focused in the same frequency range in contrast to noise that is more random. Figure 2 shows the frequency spectra for 18, 20 and 21 kHz (associated with the abovementioned three groups of users) captured at a distance of 1 m, 2 m and 3 m between the emitting and receiving phones. It should be mentioned that the frequencies were distinguishable also in the presence of voice, music and ambient noise. Yet, we leave a deeper analysis of the experiments to future publications.

The mobile phone application

In addition to identifying profiles of surrounding individuals, our mobile phone application infers social situations; this feature is described in the following.

Although the previous studies demonstrated a high accuracy in estimating distance between two phones based on the time of arrival of sent/received acoustic signals [6], in our implementation a simplified approach sufficed to detect distances relevant to face-to-face social interactions (thus avoiding demanding tasks for mobile phones). Namely, we calibrated the volume of the emitting sound for indoor environments to indicate the presence of mobile phones that are at the distances lower or equal to 2m[1]. For privacy reasons, we were applying permutation and stretching methods on the received audio signal for each voice occurrence. It should be mentioned that this algorithm did not impact the frequency spectrum of the audio signal thus not interfering with the detection of nearby mobile phones that are emitting sounds in the range of 18 – 22 kHz.

[1] The size of social space as defined by proxemics can change with a number of factors such as culture or gender. However, the distance calibration can be easily adjusted to different applications and scenarios.

Once the proximity of two or more mobile phones is detected (at distance ≤ 2 m as previously explained) and the presence of voice is recognized, we assumed that a social interaction has taken place, otherwise individuals are considered to be in proximity but not interacting. By analyzing the received signal frequency spectrum, each mobile phone becomes aware of the corresponding profiles/groups of users involved in an ongoing social interaction.

Electromagnetic vs Audio Signals for Proximity Detection and Grouping Individuals

In the current literature the prevalent approach for detecting proximity using mobile phones has relied on Bluetooth scanning to sense nearby mobile phones [7]. Since the Bluetooth scanning indicates devices in the proximity of approx. ten meters, the alternative approach of estimating distances between phones (i.e. interpersonal distances) is based on RSSI analysis either of Bluetooth or Wi-Fi [8] signals. Although not specifically addressed, identifying/grouping individuals can be performed through setting Bluetooth or Wi-Fi identifiers (SSID – Service Set IDentifier). However, in practice, the obstacle for providing a ready-to-use application intended for detecting proximity and profiles of users relates to the technical constraints (especially in Android phones) of keeping Bluetooth always visible and turning on Wi-Fi access point/scanning modes simultaneously or alternating between the two modes (which is possible only when the mobile phone firmware was changed).

The alternative approaches for detecting proximity between mobile phones are based on the similarity analysis of the received ambient sounds [9]. Identifying and grouping nearby individuals requires the access to all phones since processing data from only one phone cannot provide the information about the surrounding individuals. The analysis of the sound emitted from one and received from the other phone provided a highly accurate distance estimation in the system called BeepBeep [6]. This system requires exchanging the time duration with its peer thus calculating two-way time of flight. Overall, the shortcomings of sound-based methods are related to the type of environments and the position where the phone is carried (such as a pocket or a bag) which can impact the system's accuracy.

The choice between Bluetooth/Wi-Fi and sound-based approaches strongly depends on the application and technical constraints, requiring one to make a trade-off between the indicated advantages and disadvantages of the two approaches.

Conclusion

This paper presented the concept of assigning inaudible frequencies of sound emitted by mobile phones to different profiles of users thus allowing for their differentiation when they are in proximity. Our goal was to provide a solution which is easy to deploy and ready-to-use upon the application installation, without the need for technical knowledge. We believe that our application provides a tool which can allow insights into the contexts of individuals' interactions thus supporting the research in the processes and social network structures in companies and other organizations.

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