Grouve: Spontaneous Proximal Group Formation with Ultrasonic Sound Waves

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ABSTRACT
In daily life, we use computers and smartphones to organize a groups activities and share documents with its members. However, creating that group in the digital domain is often performed manually. Solutions to automate the process of forming a group of physically proximate members, so far, mostly relied on Bluetooth or WiFi. In contrast to these solutions we present Grouve, an automatic ad-hoc based group formation technique running based on ultrasonic waves. As Grouve uses inaudible sounds for communication, it has the natural advantage that the sound signal stays inside a limited space, which matches most of the application contexts. In this paper we report on the design process and implementation of Grouve.

ACM Classification Keywords
H.5.3. Information Interfaces and Presentation (e.g. HCI): Group and Organization Interfaces;

Author Keywords
Ultrasound; calendar; appointment; broadcast; group formation; sharing.

INTRODUCTION
Interaction with mobile devices often includes the need to specify groups, either to share files, or to synchronize organizational details. In many cases, the members of the group are in close proximity, e.g., in the same room during a meeting. Nevertheless, transferring the knowledge about members of this group into the digital domain mostly requires manual interaction, e.g., inviting people by mail. This process is error prone and cumbersome to perform on small devices. Voice commands, as suggested to overcome this problem, require contextual knowledge to be able to fill in the correct information, which is not always available.

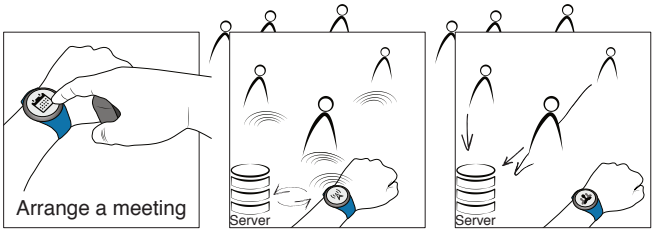

Figure 1. Grouve leverages our natural understanding of sound propagation to simplify the process of re-creating groups in the digital world. Even thin walls block ultrasound waves reliably which ensures that only members of a confined space are invited to the digital representation of the group.

As humans, we have a natural understanding of sound and its propagation, knowing where it is blocked, and where it passes through. As such, sound is an ideal carrier for the task of forming groups on the spot, as it stays within confined spaces, is easily blocked, and does not travel through walls such as radio waves. Smartwatches and smartphones are equipped with a microphone and a loudspeaker, bringing all the hardware needed. In this paper we propose Grouve, an ultrasound-based system to define groups, for example to allow synchronizing of new scheduled events or share information.

PROOF OF CONCEPT
We focused on the following scenario (cf. Figure 1): *At the end of the meeting, the participants want to schedule a follow-up event. As the attendees come from different companies and some joined on short notice, there is no digital document containing all contact information. Instead of having to collect all email addresses and ensure that they are correct, the meeting manager launches Grouve on her smartwatch and invites the other persons in the room to join. After launching our app on their device, e.g. smartwatch, smartphone, laptop, the other participants are automatically added to the group and scheduling can start in sync.* To demonstrate Grouve in a real-world scenario, we implemented a scheduling application for mobile devices similar to CalendarCast [1]. Current applications for planning with multiple agendas require to go through many steps before a date and time is set. After a time slot is appointed, all members need to accept or reject this time slot which can take a considerable amount of time as response times can be high, or people are just silently acknowledging that a meeting was scheduled. The UI of applications that

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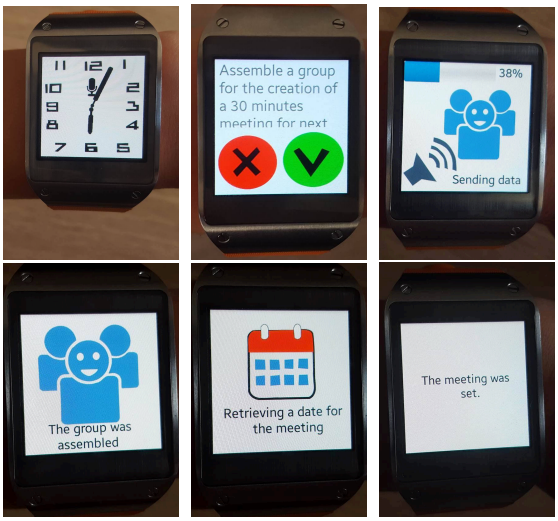

Figure 2. The program flow for the meeting creator. The task represented here is the creation of a meeting for next week with everyone present in the room.

manage several calendars often gets cluttered, even on the desktop, and even more so on mobile devices. Our concept tackles these issues and is designed to plan a meeting with nearby people in a short amount of time. One user initiates the process of finding a common timeslot, making his mobile device the master for this session (Figure 2). The other participants join the group by launching the adequate app on their smartwatch or smartphone. After the devices automatically formed a group, the master devices tries to determine a free common slot, which is then communicated to the remaining devices. The other participants finally just have to approve or reject the invitation. Before implementing this process in software, we performed a small evaluation with four users and paper prototypes, which brought us to include more detailed feedback on screen. The overall program flow was well received.

TECHNICAL CONCEPT

With Grouve we want to automatically create a group within a set boundary and user devices. The requirements are, that the device is capable of emitting and receiving sounds, and that a defined owner of the device is specified. To initiate the formation of a group, one user sets up her device to be the master device. The master device first requests a unique group ID from the central group creation server. After receiving the group ID, the master device modulates this ID into a sequence of sounds. This is done by creating a 4-letter hashed ID out of the group ID, a salt to ensure security, and a predefined alphabet that was mapped to frequencies ranging from 18600 Hz to 20400 Hz. Although not all of these frequencies are inaudible by humans, as humans can hear sound up to 20 kHz[2], most people are not able to hear above 18 kHz as hearing capabilities decreases as we age[4]. We also prepend and append the hashed ID with a *start* and *end* symbol/frequency. All the frequencies are represented as a sine waves.

Meanwhile, the other devices are constantly listening for group IDs. When a master device sends out a sound sequence that represents a group ID, the listening devices that are in its proximity pick up the corresponding signal. We buffer the incoming time-domain signal from the microphone, sample it (N = 1720), and compute the FFT of this 39 ms signal. With the results of the FFT, we search for the highest amplitude from bin 1443 to bin 1638 (18 498 to 20 999Hz). After that, we perform some other calculations since the actual frequency sent and the one received can deviate two bins up or down.

Since touching the device while listening can lead to false detections, we opted to send out each signal five times. We thus need to detect a frequency five times before it is registered as a character. Once a *start*, four characters and an *end* are detected, we decode the hashed string with the resulting integer being the group ID. After receiving a full group ID, the listening devices add themselves to the correct group on the group creation server. A specific user is identified with the device by means of a predefined user profile present on the registering device.

CONCLUSION & FUTURE WORK

We presented Grouve, an ultrasound based group formation process that works across different device classes and only requires a loudspeaker and a microphone. The use of sound as carrier makes it easy for users to understand the range of the transmission. We evaluated the Grouve technology in a scheduling application for a corporate environment, a situation where group formation is a common task. Results showed the automatic group formation to be easier which also resulted in a significantly lower mental workload.

The application of this technology is not limited to corporate environments, as it can also be used to share a group photo among the people present on that photo, right after it was taken. Location-based games also may require to repeatedly define groups when joining or splitting to solve a certain riddle [3], which becomes much simpler with Grouve.

The rather short range of our ultrasound signals (around 1.5m with the smartphone as sender) and the slightly problematic placement of the loudspeaker on the smartwatch we used means that the boundary of the group formation space does not necessarily need to be a closed space. Instead, group creation can also happen based on proximity with the members being in a 1.5m radius.

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