
Experience in deploying wearable devices for office analytics

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Abstract

In this paper, we discuss our experience with the deployment of a wrist-worn wearable device to study proximity patterns and social dynamics in the offices of an architecture and design focussed firm. We present the challenges we faced and the adopted solutions. Through an online survey and in-person interviews we gather participants' feedback regarding their experience with the device. Although the device has been in general well received, our participants pointed out some areas of improvement. Our analysis of the deployment together with the feedback from our participants provides insights that we believe might be useful for other researchers in the same area.

Author Keywords

Mobile Sensing; Wearables; Office Analytics; Deployment; Bluetooth Low Energy.

ACM Classification Keywords

H.4 [Information Systems Applications]: Miscellaneous

Introduction

Research has shown that in-person social interactions play a significant role in different contexts. In the workplace, serendipitous interactions between members of different groups have been demonstrated to be a key factor for team coordination, cohesiveness and productivity [6, 8]. Archi-

tects and epidemiologists have also studied how work interactions can influence the design of physical spaces [3] or help in developing an understanding of disease spreading [12]. These phenomena have been mainly studied so far using ethnographic research techniques which involve participant observations or self reports and surveys. However, observations are not cost effective because they require long hours of monitoring and cannot be applied for long sessions. Surveys scale better, yet generally result in data with a lower resolution as people are not good at remembering the interactions they had during the day [10].

In recent years, several sensing systems have been proposed to capture such interactions automatically in a scalable fashion. These systems vary in terms of the hardware platform, sensing modality and the granularity with which they capture these interactions. For example, some systems leverage modern smartphones with Bluetooth to detect proximity [11, 12] while others rely on custom built devices to sense face-to-face interactions [4, 3] or fine-grained range measurements between users [5]. Standard Bluetooth based systems are usually power hungry and do not offer fine spatial resolution because they scan for nearby devices every few minutes. Infrared and ultrasound technologies can provide fine spatial granularity but require dedicated hardware that makes widespread adoption of these systems harder. In order to increase participation, Mathur et al. adopted a mixed approach, where data is collected either passively from people's smartphones or in a participatory self-reporting manner [7].

On the other hand, there has been a strong interest in wearable devices [9] with wrist-worn fitness trackers and smart watches recently gaining popularity. These wearable devices offer exciting opportunities for sensing interactions. Unlike a smartphone, that can be left on a desk or in

a bag while the user is in an indoor environment like an office, a wearable device is almost always co-located with the user. Moreover, wrist-worn devices are in contact with the skin allowing to sense physiological signals, such as skin conductance and heart rate, that are impossible to gather by a phone in the pocket. Additionally, all currently available wearable devices are equipped with Bluetooth Low Energy [2] (BLE) radios which can be employed for fine-grained interaction sensing by periodically transmitting and listening for beacons. We, therefore, envision an interaction sensing system that can be easily installed on a wearable device like a smart watch thus extending its functionality to interaction sensing and offering widespread adoption. This system will be able to gather data about social interactions for both offline and on the fly analysis to provide workers with recommendations or temporal statistics.

In this paper, we present our experience with the deployment of a wrist-worn device to collect proximity traces and movement dynamics in an office environment. We recently deployed 52 Bluetooth Low Energy devices in an architecture company in London which employs more than 35 people. We discuss the main problems we faced during this relatively large deployment and how we addressed them. For the first time in this research area, we also examine how the devices were perceived by our participants and how their suggestions might be used to improve the current version. This work aims at stimulating a conversation about opportunities and challenges encountered when adopting wearable devices in the workplace.

Wearable Platform

With the aim of studying social dynamics inside an office, we developed a prototype wearable platform, the main purpose of which was to detect proximity between people and coarse grained location inside the building. We used Blue-



Figure 1: Electronic components enclosed in 3D printed box. The dimensions of the box are 3x4x1.5cm.



Figure 2: Complete prototype attached to velcro wristband.

tooth Low Energy for this task because it is integrated in all current wearable devices. By alternating between transmission and scanning, each device is able to detect other devices (which could be other wearable devices or stationary ones for localisation) and be detected by them.

The prototype uses the Nordic's nRF51822 BLE SoC that includes a 32bit ARM Cortex M0 CPU and a 2.4GHz radio transceiver. We use a developer board from Mbienlab¹ that contains the main SoC along with the associated circuitry, a Freescale MMA8452Q 3-Axis Accelerometer, an RGB LED, a push-button switch and a vibrator motor. We also attach an SD card socket to the SoC using the Serial Peripheral Interface (SPI) in order to log data about nearby BLE devices. The prototype is powered by a single 100mAh 3.7V lithium battery rechargeable with a micro USB cable. Figure 1 shows the electronic components enclosed in a 3D printed box designed by us. Figure 2 shows the velcro strap attached to the box. This allows a participant to wear the device on his or her wrist.

Data Collection

Each device collects several pieces of information about other nearby BLE devices and about the participant wearing the device every day on a different file. For each device in the vicinity (wearable devices or static beacons), it logs the MAC address, Received Signal Strength (RSS) and the channel on which a packet from the other device has been received (37, 38, 39). The information is timestamped with the current time. Using the accelerometer, it detects whether the user wearing the device is stationary or walking with step detection [13]. It also records the moment the user starts to walk, when he or she stops and the number of steps taken during the walk. The information about the user motion is included in the broadcast BLE packets so

each device also logs the motion status of the other wearable devices in the proximity.

Deployment Overview

The deployment took place in an architecture company in London (Spacelab Ltd.²). The company employs more than 35 people of which we recruited 25 participants for a period of four weeks. The building consists of two large open spaces on two floors. The employees do not have assigned desks, they can choose the desk they prefer every day.

We asked the participants to wear our prototype platform on the wrist only when inside the office. A charging station was provided to recharge the devices and to host some spare devices in case of failures (in total 35 wearable devices were deployed). To minimise the possibility of data loss due to device malfunctions we also deployed an Android phone that collected all the data and transferred it to a server in the University of Cambridge every night.

Seventeen BLE static beacons supplied by CSR Ltd.³ were deployed in the building to obtain participants' coarse grained location. We covered each desk of the building with a separate beacon or two if the desk was large. Beacons were also placed in break out areas and in the small kitchen.

At the end of the deployment, we asked our participants to complete a Big-5 personality test in order to capture their personality traits. This data will be used during the subsequent phase of analysis (see the Conclusion for details).

Deployment Challenges

In this section, we briefly discuss the three main challenges we tried to address while designing the wearable device and the deployment. These are related to the form factor

¹<http://www.mbienlab.com>

²<http://www.spacelab.co.uk/>

³<http://www.csr.com>

of the device and the measures we took to guarantee its correct operation.

Wearability and Comfort

One of the main challenges faced by this kind of deployments is participation. After an initial period of excitement, participants tend to stop wearing the device, especially if it is obtrusive. To address this issue we tried to make our device as comfortable as possible. Our objective was to keep it small and discreet in order to maximise participation. However, this limited the size of the battery we could use and therefore the maximum achievable battery life. We tuned the BLE parameters to obtain an expected battery life of around 20 hours. Although this decision required to recharge the device every day, it allowed us to gather fine grained proximity and location data, which will be useful in the subsequent study of social dynamics in the office.

Timekeeping

In order to timestamp all the data logged on the SD card, the device maintains an internal clock. The devices were programmed to maintain the current real time with a resolution of 250ms. The correct time was provided by two Android phones twice a day in order to compensate for drifts in the devices' internal clock. Additionally, every time a device resets, it advertises that it does not have the correct time (see next section for more details). On receiving these advertisements, the phones send a synchronization beacon to allow the device to timestamp the data correctly. When post-processing the data after the deployment, the synchronization beacons received from the phones were used to compensate for the inevitable drifts and re-align the timestamps to the correct real times.

Device Diagnostic

To make sure all the devices worked properly, we implemented two simple diagnostic features in our devices. In the

BLE advertisement packets transmitted by the wearable devices, we included one bit to signal problems with the time keeping and one bit for problems regarding the SD card. These bits were checked by two Android phones (the same ones responsible to send time synchronization beacons) that scanned continuously to detect these anomalies.

The first bit is set to 1 when the device does not have the correct real time. This happens every time a device resets, in case for example of an internal error or when the battery is completely drained and then re-charged. In this case, the Android phones re-transmit a time synchronization beacon.

The second bit is used to inform that the device is not able to write data to the SD card. This can happen due to errors in the code or because the SD card is faulty or it has been pulled out of its socket. We discovered that for simple errors a reset of the device would solve the problem. Therefore, we implemented a way to remotely reset each device. The Android phone that detects the problem connects to the wearable device and resets it by writing a value into a Bluetooth GATT characteristic. If the same device reports a problem with the SD card more than 10 times, it is an indication of a major problem with the SD card or with the wearable device itself. When this happens, the Android phone reports it to the researchers by sending an e-mail in order for them to replace the device.

Participant's Feedback

We asked our participants to complete an online survey with closed and open-ended questions. We received 16 responses to this survey. We also interviewed seven participants who were asked to comment freely on their experience with the device and the deployment. In total we received feedback from 20 different participants.

P5: "After the first two weeks I saw someone not wearing it, so I said why should I bother."

P7: "People are busy, in and out of the office, have lots to do... Don't always remember to pick it up because you are busy."

P3: "Maybe some incentive during the deployment would be better, something to keep the interest high."

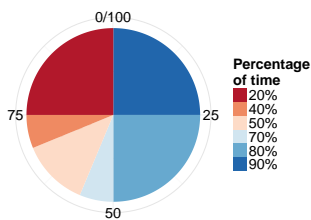


Figure 3: Percentage of time the participants wore our device.

Duration of the Deployment

The majority of the responses (68.8%) indicated the device was in use for half of the intended period (four weeks) or more (Figure 3). We discovered that the devices did not correctly record 54 files (10.8%) over a total of 500 files ($20days \times 25devices = 500files$), and they were not in use 150 times in total (30%). One possible cause of this could be the fact that the working style in the office is very dynamic and people do not have a fixed schedule (e.g. eight hours per day 5 days a week in the office) but are often outside to visit construction sites. However, in 62.5% of the responses and during most of the interviews has been declared that the deployment duration was too long. In the side bar are reported some quotes from the participants. Most of the participants felt that a period of one or two weeks would be more suitable and some of them asked for some sort of incentive to remember to wear the device (e.g. gamification).

Wearable Device

The wearable device was not perceived as completely comfortable. In fact, when we asked the participants to rate their agreement with the statement "The device was comfortable to wear all day" from 1 (Strongly Disagree) to 5 (Strongly Agree) the average of reported responses was 3.13 ($\sigma = 0.96$). Figure 4 reports detailed data for each level. The most common complaint regarded the plastic box that contained the electronic components. In fact, it was detaching from the velcro band quite often and this caused discomfort for the participants. Two devices were lost due to this. Additionally the devices were not equipped with a status LED so the participants were not sure if the device was working or charging correctly. Some of the participants ($n = 6$) reported that the velcro band was not comfortable and thought it should be softer (e.g. rubber band).

In general, the participants were not bothered by the fact that the device needed to be recharged every day but some of them ($n = 3$) asked for the possibility of using the device without the need to re-charge it for one or two weeks.

Privacy

From a privacy point of view, our participants did not appear to be concerned with the data collected by our device. We asked them to rate their level of agreement with the statement "I am concerned that the device can threaten my privacy" in a scale from 1 (Strongly Disagree) to 5 (Strongly Agree) and the average of the reported responses is 2.06 ($\sigma = 1$). Detailed data is reported in Figure 5. When we asked which one of the three kinds of data collected makes them more concerned (i.e. proximity, location or activity), only two responses reported concern, one with the activity detection and the other one with the location detection. The other responses reported no concern.

Although this study did not raise any particular concern in the participants, it is known from past research that privacy concerns in the workplace are also related to the working environment [1]. This suggests the integration in our device of privacy protection techniques, such as the possibility for the participants to stop the data collection at any time.

Conclusion and Future Work

This paper presents some of the challenges faced when deploying wearable technologies in an office, together with the feedback received from the participants. We hope this paper can foster a discussion about two main topics: (1) methods to improve the deployment of this kind of systems in real scenarios and (2) how the collected data might support organisational workflows and employees.

The natural future direction of this work is to analyse the collected data to study social dynamics inside the office.

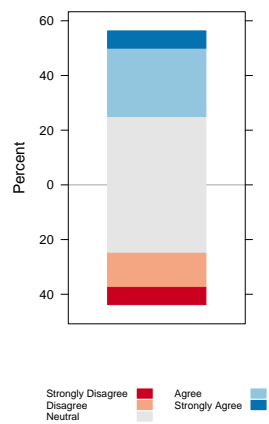


Figure 4: The extent to which participants thought the device was comfortable to wear.

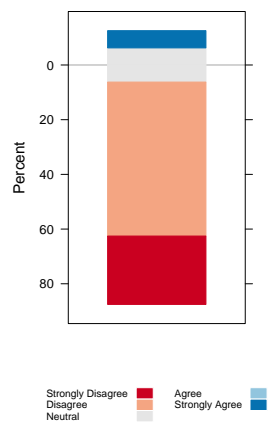


Figure 5: The extent to which participants thought the device could threaten their privacy.

We plan to focus our analysis on the participant's proximity patterns and on their movement flows. Additionally, we envision the possibility to use this data in a more dynamic way by providing user with feedback and recommendation while the device is being used. Using the personality data we collected at the end of the deployment we would like to study if and how the personality affects how people move inside the building and their interactions with other people. Moreover, given that the participants in our deployment did not have allocated desks (they could choose the one they prefer each day) we want to analyse if sitting close to attractors (e.g. coffee machine or break-out spaces) or in different areas of the building (e.g. more central locations vs. more private ones or first floor vs. basement) alters the proximity and movement patterns of a person.

Additionally, we plan to perform further deployments which will provide us with data that we can use to compare different organizational structures (e.g. rigid vs. flat hierarchy) and different building layouts to understand how these factors affect interactions and movements indoor.

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