Mobile Sensing for Social Interaction Monitoring and Modelling

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***Abstract*—Social interactions have been traditionally studied via questionnaires and participant observations, imposing high burden, low scalability and precision. The goal of my research is to explore novel techniques to detect and monitor social interactions in indoor settings. Through the development of a scalable research platform it would be possible to study social dynamics at a finer granularity. The collected data will inform models about people's behaviour and support architectural research.**

I. Motivation

Social interactions are fundamental in people's personal as well as working life. The importance of their study has been proven in several fields. In the workplace, team coordination, cohesiveness and productivity can be improved by allowing mixing among different groups [1]. Several architectural studies have analysed how physical spaces can potentially increase this sort of unplanned interactions. Informal and high-traffic spaces such as coffee areas and photocopiers have been proven to encourage inter-group serendipitous meetings and their location inside a building is crucial [2]. Other areas such as epidemiology have also benefited from tracking face-to-face contacts to study disease spread and infection rates [3].

Traditional techniques employed to study these phenomena, such as participant observations or self reports and surveys, may not give an objective view on human behaviour because they rely on low resolution data and are subject to biases as participants could adapt their behaviour while being observed.

Although technology has progressed significantly, the automated and accurate measurement of human interactions is still lagging behind. The main shortcomings have to do with accuracy and resolution of the captured data and with the considered aspects of social interactions. For example, many systems monitor people proximity using Bluetooth transceivers which are usually power hungry and do not offer fine spatial and temporal granularity [4], [5], [6]. Other systems, can provide better accuracy, but rely on dedicated hardware and require the instrumentation of the building which hinders their widespread adoption [7], [8], [9]. Additionally, non-verbal behaviours during social interactions (e.g. body posture, orientation and interaction distance) have been often neglected even if traditional sociology has highlighted their importance and manually studied these behaviours for decades [10], [11].

The scalability and reliability of these monitoring systems are also critical aspects. The possibility to collect longitudinal fine grained data can provide important insights on how human relations evolve over time and on how organisational structures change. Efforts need to be focused on making the technology easy to deploy and accurate in order to guarantee a large adoption and collect rich data that could serve for a better understanding of social interaction dynamics. In fact, many of the current systems require the instrumentation of the building which can raise logistic and privacy issues. Some of them also need time consuming calibration procedures in order to work accurately. The recent development of wearable devices (e.g. wrist worn fitness trackers and smart watches) offers interesting opportunities for sensing social interactions which could overcome some of the issues. These devices are becoming more and more ubiquitous, powerful and enriched with many sensors and have the advantage to be always co-located with the user. However, their scarce resources and need to complete also other tasks apart from monitoring user's interactions, represent a major challenge when devising efficient solutions to capture fine granularity data.

II. Research Path

The objective of my research is to *investigate new techniques to efficiently and accurately monitor and model social interactions using mobile devices (i.e. wearables and smartphones)*. The intent is to design and evaluate new techniques to capture human behaviour and gradually design a new mobile platform for interaction sensing. Subsequently, I expect to deploy it in a single organization repeatedly or, possibly, in different organizations. This will allow me to collect rich longitudinal data and to evaluate its performance. Finally, I will apply different geo-temporal network analysis techniques over the collected data in order to study human interaction dynamics at a fine granularity. The outcome will be the creation of accurate models of how people use indoor spaces and how the space affects their movements and interactions. The models will be then used to support architectural research. The following three broad topics will be investigated:

Research Platform for Social Interaction Monitoring. One of the goals of my research would be to explore the capabilities of commercially available mobile devices to make the face-to-face interaction monitoring efficient and as effortless as installing an app. These devices offer a broad range of sensors (multiple radios and inertial units) which have not been combined yet to improve the monitoring of social interactions. The fusion of signals from different sensors from various devices on the body could greatly improve the accuracy of such systems and provide finer grained data for analysis. With my work I intend to realise a research platform that will be used to collect richer data about social interactions.

Spatio-temporal modelling of human behaviour. In this part of my work I intend to investigate the use of the high resolution data collected with the proposed platform to create better models of how people move and interact in indoor settings. The availability of accurate information about when and where people interact and with whom, together with precise movement and flow data will allow me to model how people use the space and how it influences their behaviour.

Extension of existing frameworks to support architectural research. Architects have been using Space Syntax techniques [12] and Visibility Graphs Analysis [13] for decades to model spaces and predict patterns of human usage of space. However, in indoor settings the power of these models is limited. They do not take into consideration the location of attractors (e.g. coffee machines and photocopiers) or people and are suitable only for single floor buildings. The models I will build with the use of high resolution data will be integrated into the existing Space Syntax toolkit, in particular the Open Source software depthmapX, in order to account for the locations of attractors and people, user needs and the popularity of an amenity. The architects will use the tool to better understand how their design choices might impact on face-to-face communication before realising them in the real world, while the proposed sensing platform could be used to validate the implemented design.

III. Preliminary Results

In my PhD I have initially explored the Bluetooth Low Energy (BLE) standard to capture proximity with better accuracy than previous versions. The most common wearable platforms available, Android Wear and Tizen, have been analysed in detail. Experiments were carried out in the lab to understand which BLE parameters can be controlled on these OSs and their impact on power consumption. Then, using custom wearable devices which provide greater flexibility, I was able to evaluate BLE in a real working environment. I deployed 25 wearable devices and 17 static beacons in the company Spacelab Ltd. for a period of four weeks. Through data post-processing I was able to investigate the achievable performances if our system was to run on off-the-shelf wearable devices and understand its strengths and weaknesses.

Using the fine grained proximity data collected during the deployment I began to study the office dynamics and relate them to the organizational structure of the company. I found that different teams have a good amount of contacts with one another indicating a good level of collaboration among teams. Analysing the vertical division into hierarchical levels instead, the main pattern that emerges is that there are fewer contacts among the upper levels than among the lower levels of the hierarchy. These results point to a strongly networked type of organisation, where the way work gets done does not resemble the formal organisational hierarchy. Instead, strong lateral links emerge among the lower ranks of the hierarchy, across reporting lines and team affiliation.

Recently I have been experimenting with other wireless mediums to detect and monitor social contacts. I directed my focus towards line-of-sight technologies such as light and ultrasound in combination with inertial sensors in order to remove false positives obtained with BLE. BLE, in fact, provides information about close proximity between people but does not allow to discern if they are facing each other, as in a conversation, or if they are just next to each other (e.g., while queuing). Knowing which direction each user is facing could improve the monitoring scheme by removing unlikely interaction events. Moreover, the measurement of relative orientation and interaction distance could enable the study of non-verbal communication cues during social interactions.

Since I am interested in monitoring social interactions I cannot limit my study to proximity only. Therefore, I propose as next step to employ the microphone to understand if the user is actually talking and with whom. The combination of these sensors should allow to accurately monitor social interactions up to the level of knowing how long a person have been talking during the day and with whom.

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