CitySense
Pervasive Sensing in Urban Scenarios

Paulo Mendes
SITI, COPELABS, University Lusófona
paulo.mendes@ulusofona.pt

***Abstract*— The advances in the areas of microelectronics and telecommunications are helping to materialize the vision of a pervasive computing model through the incorporation of sensors and communication interfaces into objects of everyday life. Recent research efforts aim to make large-scale sensing a reality by leveraging the increasing sensing capabilities found in personal devices such as cell phones. This paper describes the CitySense project, which aims to develop a pervasive non-intrusive sensing system able to infer about individual behaviour as well as collective behaviour.**

Keywords—Non-intrusive sensing; Group sensing; Behaviour inference.

I. Introduction

Pervasive computing has been mostly used to build systems encompassing a small number of devices that interact with single users or small groups. As technology becomes truly pervasive, low-cost sensing systems may be built and easily deployed based on diverse sensing devices, such as mobile phones, which are carried by a large number of people, as well as embedded systems that can be integrated into self-propelled sensing devices. Large-scale sensing systems may support a diverse set of applications, mostly related to urban scenarios, from predicting traffic jams and modeling human activities, social interactions and mobility patterns, to community health tracking and city environmental monitoring.

Recent research efforts aim to make large-scale sensing a reality by leveraging the increasing sensing capabilities found in personal devices, such as cell phones. Architectural challenges include methods for accurate sensing, context extraction, inference and sharing data, as well as protecting the privacy of involved people. Placing people at the center of the sensing system implies, first or all that owners of personal sensing devices should keep the desirable level of user experience. Therefore, sensing systems should ensure that owners of sensorial devices are agnostic of any sensing activity, to ensure the desirable adoption rate.

Opportunistic sensing ensures that the owner of sensorial devices remain agnostic of any sensorial activity: the device is activated whenever its state matches the requirements of a sensing application, and the latter does not have an impact on user experience. However, opportunistic sensing occurs without user intervention and may be required to infer about complex activities. Hence, a major challenge is the correlation of contextual conditions and personal characteristics (e.g. age and lifestyle) encountered in large-scale mobile sensing systems, as well as the integration of multiple data representing the same real-world activity into a consistent, accurate, and useful representation.

Current approaches to opportunistic sensing focus on the usage of personal sensing devices, such as smart phones, to infer about individual activities. However, the major impact of large-scale sensing systems is expected to be in the inference about group, communities or swarm behaviour. For instance, the automatic recognition of the density of human gathering and the direction of movement of is relevant for many applications.

The CitySense project aims to develop a pervasive non-intrusive sensing system able to detect human activities (physical activity, social proximity, relative location, voice patterns), which will be used to infer about individual behaviour (e.g. social context and isolation; anxiety detection), as well as collective behaviour (e.g. crowd control, detection of human swarms, emotional contagion, community health tracking), as shown in figure 1.

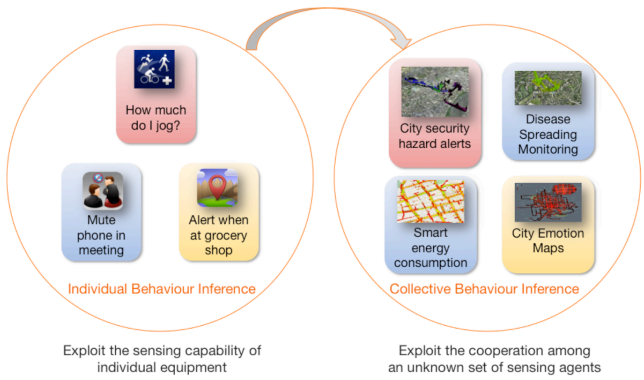

Fig. 1. Pervasive Sensing

The scientific focus of the project is the investigation of accurate systems for the inference of complex personal activities over a diverse set of contexts, as well as the self-organized properties of large-scale sensing systems. Self-organization can be used to ensure the scalable operation of pervasive sensing systems by allowing the decentralized operation of a large set of simple sensing agents, which can be implemented in personal mobile systems (e.g. smartphones), in embedded systems (e.g. wearable devices), or carried by self-propelled systems (e.g. drones). Such self-organization property aims to align the operation of the sensing system to the behaviour of crowds, which is the result of self-organizing phenomena governed by the local interactions among the involved individuals: due to the limited perception range of the individual sensing systems and the complexity patterns, the involved individuals often fail to detect the existence of a crowd behaviour, do not recognize their involvement and cannot perceive the extent and characteristics of the pattern. Awareness of occurring crowd behaviour, however, is critical in many every-day situations.

II. Innovative Aspects

In the CitySense project the identified research challenges are being tackled during the development of the following innovative services:

- Personal sensing: personal devices (e.g. smartphones, wearable) will be able to infer about the activities (e.g. walking, standing, talking) of different people, meaning that such system should not use generic sensing models. To address this issue, affinity networks may be used to make classification models practical through a combination of crowd-sourced data and leveraging networks that measure users' similarity.

- Dynamic contextualization: behaviour may depend on the user's context (physical environment, surroundings), as well as the users' dynamic behaviour (in terms of social interactions and mobility). Hence, there is the need to devise a system able to identify users' context in real-time. For instance, using Wi-Fi information to infer about indoor location.

- Behaviour inference: human behaviour (sociable, isolated, lost, afraid, anxious) is defined as a complex activity derived from the analysis of data about different activities done in different contexts. The major challenge is achieving accurate integration based on the time synchronization of sensing activities.

- Group sensing: sensing in urban scenarios may require the coordination of different agents, namely for the inference of behaviour across a set of users. Cooperation among different sensing systems aims to allow system-level sensing behaviour to emerge from the collective behaviour (e.g. human swarms) of simple sensing devices.

III. Applicability

In our society people are vulnerable to social isolation and owing to loss of friends and family, mobility or income. The impact of social isolation on an individual's wellbeing has cost implications for health and social care services. Hence, one of ours use-case aims to induce Interaction Stimulation, as illustrated in figure 2. This is done in two phases: detection low levels of social interaction; ii) induction of more social contacts aiming to reduce social isolation.

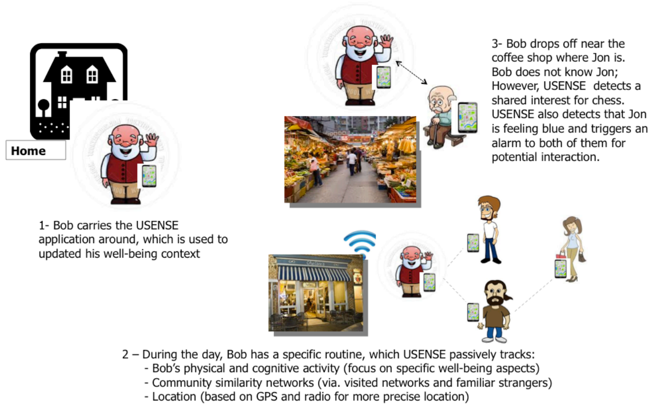

Fig. 2. Interaction Stimulation Scenario

Moreover, civil disturbances may occur due to the outbreak of disorder and possible riots. Examples are at soccer matches, when club fan engage into physical confrontation, refugee control, or mass quarantine situations. In such situations there is a need for real-time awareness of the context of a crowd for successful management during mass gatherings. Hence, a second use-case will support the investigation of several questions related to crowd context recognition.

Acknowledgment

The CitySense project has received funding from the COPELABS. The COPELABS team in CitySense encompasses Paulo Mendes, Rute Sofia, Waldir Moreira, Luis Amaral, Saeik Firdose, Pallavali Reddy.

References

[1] Paulo Mendes, Waldir Moreira, Crowd Assisted Approach for Pervasive Opportunistic Sensing, in: Proceedings of the 2nd IEEE PerCom International Workshop on Crowd Assisted Sensing Pervasive Systems and Communications (CASPer'15), St. Louis, USA, 2015

[2] Rute C. Sofia, EP 13186562.9, Method and Apparatus for Ranking Visited Networks, 2013