A mobile application for assessment of air pollution exposure

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Abstract. In this paper the architecture of a mobile air quality monitoring system is introduced. A mobile application will act as a personal assistant, monitoring and giving advices about gas pollutants daily exposure. Currently in development stage as part of a larger air quality monitoring system project, the application will enable users to monitor their daily exposure to gas pollutants by combining user location data and urban air quality information provided by the network of fixed monitoring stations of the city of Palermo.

Keywords: air pollution exposure assessment, smartphone application, people tracking

1 Introduction

In the last decade, due to their cost reduction, there has been an important increase of the adoption rate of wireless technologies and mobile phones. The advances in this fields, not only shape people's daily life, changing way of behaving and thinking, but they also have a deep impact in the way of health care services can be deployed and delivered. Exploiting mobile phones acceptance, popularity, mobility and technological capabilities, it is possible to build systems able to provide users with completely new health care services. Mobile-Health (M-Health) systems [18] have been proposed to improve disease management or promote healthy behaviors [10]. This emerging concept represents the evolution of e-health systems from traditional desktop "telemedicine" platforms to wireless and mofbile configurations [19]. Indeed, ubiquitous systems may monitor physical, physiological and biochemical parameters in any environment and without constraints on the activities that the patient can perform. Monitoring people's behavior, sending motivational messages, can help users to obtain help when needed or to reach fixed goals [8, 11]. Mobile technology integration in health care offers also the great opportunity to improve the quality of life by promoting healthy lifestyles through better communication and better decision-making. In this paper we introduce the development of a mobile system able to provide users with information about their daily exposure to urban air pollution. One of the main health concerns in modern cities is, in fact, represented by high levels of air pollutants that have a significant impact on human health and on the environment. The remainder of the paper is organized as follows. In section 2, we give an overview of previous main mobile-health systems. In section 3 we discuss our system. Then we draw some conclusions in section 4.

2 Related Work

There are several studies and projects in literature that target the development of low-cost health care services through smartphones. Some of these studies focus on specific mobile functions [5, 9] or types of illness and diseases [15, 11, 26]. A systematic review that aims to quantify the effectiveness of mobile technology-based interventions to health care consumers for health behavior change and diseases management is showed in [10]. An emerging paradigm uses the technologies of wireless body area networks (WBANs) for measuring critical physical and physiological parameters. The hardware and software organization of a sensor network for health monitoring that utilizes off-the-shelf 802.15.4 compliant network nodes and custom-built motion and heart activity sensors is presented in [21]. Dai et al. [6] propose a wireless physiological multi-parameter monitoring system based on mobile communication networks. This system monitors vital signs such as ECG, SP02, body temperature and respiration, and transmits gathered data to a mobile monitoring station through mobile communications networks. In [3] the prototype of a cloud mobile health monitoring system is presented. The system uses a Wireless Body Area Sensor Network and a Smartphone application that uses cloud computing, location data and a neural network to determine the state of patients. The design of an Android mobile platform to serve as a connection center for peripheral and personal health record servers, combining the frameworks of mobile health management and WBAN is showed in [4]. A more detailed review which give a comprehensive analysis of the benefits and challenges of the development of wearable biosensor systems for health monitoring can be found in [2, 24]. Due to the importance of the air quality and his impact on human health, several projects have been deployed to acquire real-time air quality conditions using embedded technologies. Some of these studies propose the use of non-conventional media, such as vehicles to gather and send air pollution data to a central storage system implementing an extended air quality monitoring system [1, 17, 20, 7, 25]. AIR[1] is a public, social experiment in which people are invited to use portable air monitoring devices to see pollutant levels in their current location. The AIR devices regularly transmit data to a central database allowing for real time data visualization on a website. Urban Atmospheres[2] instead exploit mobile phones to gather air pollution levels from user mobile phones, in order to suggest a public health policy to mitigate risk associated with outdoor air pollution. The use of smartphones to gather air pollution data has been widely adopted by several studies. GasMobile [14] is an air pollution smartphone-based monitoring platform able to measure ozone concentration using a low-cost sensor. A similar project, developed jointly by UC Berkeley and Intel, is N-SMARTS [16] makes use of GPS-enabled cell phones with attached sensors to gather raw air pollution data. The UCLA Personal Environmental Impact Report (PEIR) project [22] exploit phones' sensors to implement a system that tracks user's actions in order to monitor environmental impact on individual health of exposure to carbon emissions. In [23] the authors demonstrate the usability and relevance of the CalFit smartphone technology to track person-level time, geographic location, and physical activity patterns for improved air pollution exposure assessment. In particular some CalFit-equipped smartphones were used to obtain information on physical activity and geographic location to be linked to space-time air pollution mapping in Barcelona, Spain. In this paper we propose the design of a mobile application implementing an ubiquitous and unobtrusive monitoring system able to inform users about their daily air pollution exposure.

3 The Proposed System

The impact of pollutants on humans depends on the area of their production and dispersion. The large fixed sources, often located far from the major population centers, disperse pollutants in the air at great heights, while home heating and traffic produce pollutants that are released at ground level in densely populated areas. As a result, the mobile and stationary sources of small dimensions contribute more to air pollution in urban areas, thus their impact on human health does not go unnoticed. Today m-Health projects are an important component of the health care sector, and in order to give a much more detailed and fine-grained information about daily outdoor urban air pollution exposure, we propose a sensing application that is able to calculate the amount of air pollutants a user is exposed to during the day. In particular, we designed a smartphone application that, while running continuously in the background, is able to model daily individual exposure to air pollution by tagging and monitoring user's movements through smartphone GPS data. The application queries a urban air pollution database built from public air quality data provided by the fixed monitoring stations located in the urban area of Palermo. Air quality is, in fact, as in most other urban areas, monitored by networks of fixed stations that can accurately measure a wide range of pollutants. Today, air quality in Palermo is monitored by ten static stations which are equipped with a personal computer that processes data from the analysis equipment and transmits them to a central system. The fixed stations provide measures about the following pollutants: sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and PM_{10}. Modeling individual exposure to air pollution requires the combination of two types of information: concentration fields and individual trajectories [12]. The concentration *C(t,s)* of an air pollutant is a spatiotemporal variant phenomenon and is commonly represented by modeled or interpolated grids with discrete time steps, with the grid cell value representing a spatially and temporally averaged estimate of the true concentration. So, to the extent of our application, the Palermo city map is discretized in uniform rectangular cells, each one spatially dimensioned according to the action range of fixed monitoring stations. The map, as a sparse matrix, has few cells that can be addressed directly through current GPS coordinates. Each cell holds the information about urban air pollution levels. Regarding temporal resolution, available air pollutant information given by the network of fixed monitoring stations, are given as day averages. Individual trajectories *I(t,s)* are space-time paths as defined by Hgerstrand [13]. The representations used for exposure modeling are the GPS tracks, that are discrete points (locations) in space and time. According to available spatiotemporal air pollution data resolution, GPS raw data are locally processed in order to find which cell is occupied by the user in a certain moment. In particular the application will extract the current occupied cell, and will compare it with the previous stored information, in order to detect and record when the user enters or exits from

[1] Air Project. http://www.pm-air.net/

[2] Urban Atmosphere Project. http://www.urban-atmospheres.net/

a cell, thus calculating the user exposure levels to pollutants according to the amount of time spent in that region. The user can have such data be displayed by simply tapping the grid cells. We use an interactive map to visualize location traces that are color-coded by level of impact or exposure (Fig. 1). The more intensely colored a trace, the higher the impact or exposure metric is. If required, a short summary can be also displayed.

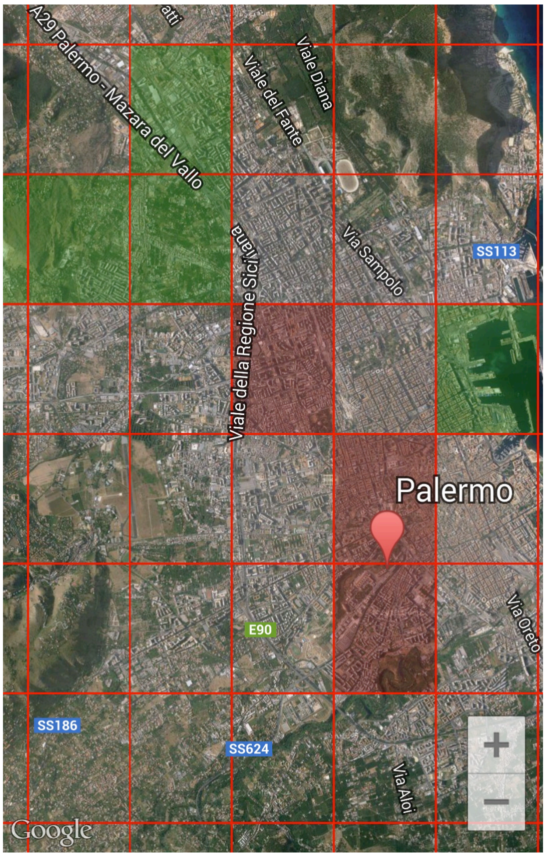

Fig. 1. Application graphical user interface. The urban area is discretized in uniform rectangular cells spatially dimensioned according to the action range of fixed monitoring stations. The location traces are color-coded by level of impact or exposure. The more intesely colored a trace, the higher the impact or exposure metric is.

Capturing GPS tracks and displaying inferences based on them is critical and potentially invasive. Shared or stolen data on individuals routes and habits may compromise user privacy and safety. In order to minimize these concerns, our application does not store directly trajectories (composed by latitude and longitude points) of users but records coarse-grained location data that is the indexes of the crossed map cells, and the amount of time spent in the cell. The application thus stores only low resolution, in both space and time, location traces. Our application is designed to be storage efficient. In fact GPS records are sampled every few minutes in order to reduce power and bandwidth consumption. Moreover, the usage and the description of more complex models to approximate better the concentration of air pollutants is beyond the scope of this article. Air pollution is an important and underestimate problem in our daily life, so our goal is to create an unobtrusive and complete monitoring system that exploits smartphones. Indeed, the mobile application is currently in development stage as part of a larger air quality monitoring system project. In fact, we are in the process of designing and evaluating a framework of applications, models and on-line services, through an extensible platform to be deployed for experimentation, improved and enhanced in the near future.

4 Conclusions

Mobile Health is an emerging area that has the potential to change the way the health care is provided. Mobile technology integration in health care may improve the quality of life, and has the potential to make health care evolve. Mobile phones are underused tools that have the potential to offer a wide range of benefits through unobtrusive continuous monitoring, becoming a means to provide their users with personalized advices for a healthier lifestyle. In this paper the working principles of a smartphone application for mobile health care monitoring are described. This ubiquitous health care system integrates mobile computation, GPS location data and air quality information in order to give users a complete overview of their daily exposure to air pollutants. The mobile application, as part of a larger project on air quality assessment, will enable users to monitor their daily exposure to gas pollutants by combining user location data and urban air quality information provided by the network of fixed monitoring stations of the city of Palermo.

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