Fostering Accessible Urban Mobility through Smart Mobile Applications

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***Abstract*— Cities have evolved as a natural environment for cars rather than people. This has limited people's ability to move around, living and interacting with the urban space affecting the experienced quality of life. Clearly, this regards all of us and, in particular, people affected by impairments. One of the main barriers in building services to fill the gap between the urban environment and people living in it is surprisingly represented by the lack of information. Think for instance to Google maps; you can ask for a path between any two destinations and you will receive a response with the shortest path whether you are travelling by car, public transportation or just walking. Yet, there is no path or information available regarding people on a wheelchair or blind. Instead, we discuss in this paper how the vast popularity of sensor-endowed smartphones can be exploited to create unprecedented services able to improve the interaction with the environment, the social inclusion and the quality of life.**

Keywords—city accessibility; mobile; smart application

I. Introduction

Our cities are more and more crowded with vehicles that we use even for short transfers. This evolution of our urban environments is affecting our quality of life and is widening the gap between people that can freely move and people with limited movements due to impairments. As a representative example, think of people moving between any two locations. If the path to destination is unknown, Google Maps or any other map service can provide it. Yet, these services do not provide paths tailored for people on a wheel chair or with sight impairments. We could go further and claim that each of us may prefer to have paths suggested taking into considerations our preferences, whether in terms of safety, noise levels, nice view along the road, possibility to meet friends, etc.

The main issue related to the development of a digital service able to generate personalized and accessible urban mobility is represented by the lack of information. Indeed, if we would like to generate paths only including curbs with ramps or traffic lights with audible signals we need first to acquire and store in a database the data about all the curbs and traffic lights. Clearly, this would represent a huge and expensive work. Yet, with the wide proliferation of smartphones we have the possibility to exploit the pervasive presence of sensors with communication capabilities through crowdsourcing and crowdsensing in order to collect all needed georeferenced urban data.

This vision is not unrealistic and we can demonstrate it by overviewing related work that embodies the current state of the art in this area and discussing some promising case studies.

II. Related Work

We can split our analysis of the state of the art in two subsections. In the first one, we overview how to exploit smartphones as a sensor net to gather data that can then be processed and used to generate new information and services. In the second one, instead, we focus specifically on solutions devoted to urban accessibility for people with impairments.

A. General Urban Sensing

Mobile technology provides ubiquitous sensing and communication capabilities thus enabling the possibility to gather data regarding our surrounding environment. The people-centric sensing paradigm has been around for some years and many research effort has been devoted ranging from algorithms and techniques proposed to measure specific environmental properties to hierarchical system architectures and communication paradigms [1, 2].

In this context, PRISM supports participatory data acquisition of environmental data using off-the-shelf mobile devices [3]. PRISM is both an architecture that orchestrates the mobile nodes participating in the data acquisition process and a mobile component installed in smartphones that acquires environmental data.

Other solutions are specifically devoted to the detection of pollution indexes through mobile devices [4]. Then, a microblogging service could exploit mobile devices to record local multimedia content and share it in real-time [5].

Environmental data such as temperature and humidity can be collected also through low cost sensors and then forwarded via Bluetooth to a smartphone [6]. In this way, it is possible to monitor conditions about a particular environment, and exploit Internet connectivity only when necessary to alert a central station or a specific user.

Solutions for data acquisition using smartphones in urban environments could also include vehicular networks. In particular, the on-board GPS and information about speed could be used to create in real-time a heatmap of traffic intensity in a city [7]. Alternatively, audio samples of streets could be collected by pedestrians to generate a noise map.

B. Sensing to Improve Urban Accessibility

Researchers and practitioners have developed several smartphone's apps with the aim of monitoring human activities [8]-[10]. These apps allows to realize whether the user is travelling in a vehicle, or walking, climbing stairs, or falling down, and so on. Clearly, the technology at their base could also be used to detect accessibility related features (e.g., a curb with no ramp) [11], [12]. For instance, data gathered by the smartphone's accelerometer could be used to detect whether a person is crossing a street and also whether pedestrian traffic lights are present [13]. Clearly, cooperative sensing can be exploited to improve the reliability and coverage of sensed data [14], [15].

Considering the case of users on a wheelchair, it is interesting to mention the existence of applications able to find wheelchair accessible restrooms, parking spaces, and services in general [16]. Some app is also based on crowdsourcing; users have to actively upload information and pictures documenting the lack of accessibility in a certain location [17].

Similar approaches also make use of official reviews done by accessibility expert volunteers. This is particularly useful in case of indoor evaluations, when autonomous sensing may fail [18]. Even hybrid approaches that leverage on both experts and non-experts have been proposed to help impaired pedestrians by providing them a map of the city with information about accessibility barriers and facilities [19].

Finally, mPASS is a system able to provide paths to users based on their needs [20], [21]. It can hence take into account accessibility barriers for impaired people but also other needs such as safety, strollers-friendly, and many others [22], [23].

III. ACCESSIBLE URBAN MOBILITY: CASE STUDY #1

Solutions have been proposed by researchers to support mobility-impaired pedestrian through specifically designed route generators [24]-[28]. Unfortunately, they are based either on the existence of accessibility information related to each road, or on the active participation of users that should create and augment geospatial data. Yet, the crucial problem of gathering accessibility information for every road still remains unsolved.

One possible solution may leverage on those people that, due to a permanent disability or to a temporary illness, are forced to move around one of such cities on a wheelchair. These people create their knowledge on how to move around their neighborhood, or how to reach their job site, from a frustrating trial and error approach that leads them to determine the accessible routes in their area of interest. However, the road accessibility knowledge that is individually created by all the people that walk around a neighborhood can be put to good use for the greater good: all the routes generated by all users can be combined and later used to establish not only the shortest path towards a new destination, but also the most suitable route for people moving on wheelchairs, hence improving city road accessibility. Such service, performs the following tasks:

i) The smartphone belonging to each person with impairments records the regular routes of its owner (leftmost part of Fig. 1);

ii) Any user (both with and without impairments) may actively provide the centralized server with a detailed report on some encountered obstacle (e.g., by uploading a photo, video, text or audio fragment) or its own evaluation of its most frequently utilized road segments (rightmost part of Fig. 1);

iii) The centralized server, in turn, while collecting all this information also processes it, identifying the paths that best result to be accessible to wheelchairs;

iv) Any user on a wheelchair that needs to walk through an unfamiliar area can query the centralized server asking for the most accessible route, indicating that she/he will be traversing the area on a wheelchair;

v) The centralized server computes and returns the most suitable route for a person that moves on a wheelchair (Fig. 2, accessible roads are highlighted in purple).

A. Autonomous Monitoring of Frequent Paths

Clearly, the aforementioned steps provide a useful service; yet, it is based on the assumption that people will participate to the community by sending their evaluations of roads' accessibility. It is hence crucial to motivate users in participating in such task.

Alternatively, an even better approach would be able to collect information about the accessibility of a road even with no active intervention done by the user [29], [30]. To do so, we can imagine that people on a wheelchair will be willing to let an app monitor their movements and send to a remote server (in an anonymous way) those paths that are frequently used.

Fig. 1. Accessible road management app.

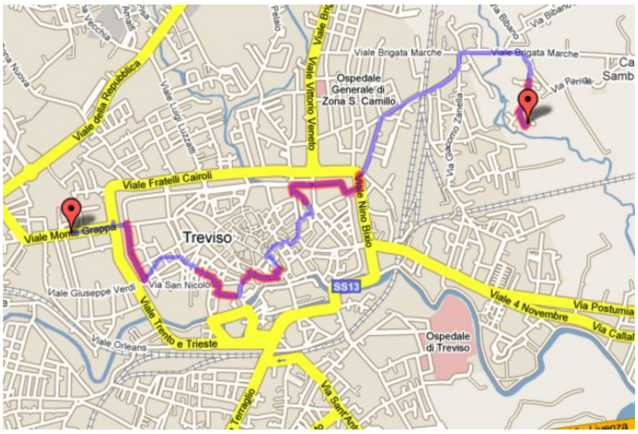

Fig. 2. A path obtained by giving high priority to accessible roads.

Indeed, if a person frequently traverses certain roads, it means that she/he deems them adequate for her/his need. Therefore, roads frequently used by a person on a wheelchair will probably be adequate even for other people in the same conditions. By storing these frequent paths, we can create a database of information about accessibility that is the main requirement for an accessible path generator service.

IV. Accessible Urban Mobility: Case Study #2

We deem that it would be interesting to integrate in the route search provided by Google Maps service also information about the presence at crossroads of traffic signals with audible signals. This new functionality requires the existence of a database of information about each traffic light at each crossroads. Unfortunately, this database does not exist and cannot be created by just hiring somebody to verify all crossroads and populate the database: it would be too time consuming and too expensive.

An alternative approach could utilize the pervasive presence of smartphones in our cities and associate a game. Through a rewarding mechanism, users will be motivated in participating in a serious game that involves the recording of as many audible signals as possible from different traffic lights. All the recorded audio files will be transmitted toward a server hosted by a cloud service where they will be processed and possibly utilized to compose the aforementioned database.

To encourage the contribution of as many people as possible, willing to record traffic light audible signals and transmit them toward the server cloud, we devised a serious game where each player receives points for the provided information. Our serious game has to enable the creation of a database with information about the location of traffic lights with audible signals. Main principles of our game are:

- to gain points, players have to record as many audible signals from different traffic lights as possible;
- all the recorded audio files are associated with geographical coordinates provided by the smartphone's GPS and then transmitted toward remote servers;
- the player receives points depending on the contribution's trustworthiness and originality.

Each player receives a certain amount of game points each time she/he records the audible signal of a traffic light she/he had not recorded before; local GPS information are used by the smartphone to determine whether that traffic light was already considered by the same user. To encourage a wide coverage of the town, when an audible signal is recorded from a position that was not yet present in the database, the player's total score is increased by 10% thus providing a significant motivation in looking forward for unrecorded data.

Traffic lights that have been recorded in the database are also visible on a Google Maps-like service with, as a further reward, the name (or nickname) of the first person that identified that traffic light as accessible (i.e. endowed with audible signal). Through a map available on the Web, users can also indicate that a traffic light that has been wrongly identified as accessible. In case several users agree on the fact that a traffic light is not (anymore) accessible, then twice the points previously given to players associated with that traffic lights are removed to discourage wrong advertising.

In summary, this rewarding scheme aims at encouraging players to explore new crossroads and provide new information about their accessibility, rewarding particularly those who first identify a traffic light with audible signal. At the same time, possible cheating behaviors are discouraged through penalties.

A. Autonomous Monitoring of Audible Traffic Lights

Even for this case study, the main drawback is represented by the need to have a community of active participants; the system autonomous should be autonomous. In particular, we need a solution able to detect when a user (any) is close to a traffic light and only then activate the microphone. To this aim, it is possible to exploit the smartphone's accelerometer to detect when the user is crossing a street [31]-[32].

Data collected from the accelerometer have the following attributes: acceleration along x axis, acceleration along y axis and acceleration along z axis. The basic idea is to be able to recognize a simple sequence of activities, such as:

- walking at regular speed;
- stopping at a red light and going across the road at slightly higher speed on green light and then
- continuing straight forward or turning left/right;
- walking again at regular speed.

A high-pass filter is applied on the collected raw data, in order to obtain only higher values, which are the most representative for movements. Additionally, rather than working on three different vectors (x, y, z), we chose to join the three axes into one single vector and compute the magnitude. The main reason is that we do not want to have to discriminate among the various position that a smartphone can have with respect to the user's body (in her/his hand or pocket, etc.).

Clearly, with training methods the system could improve its performance. Yet, even in its simple form described above, we have been able to achieve very high positive rates even if at the cost of some false positives (see Fig. 3).

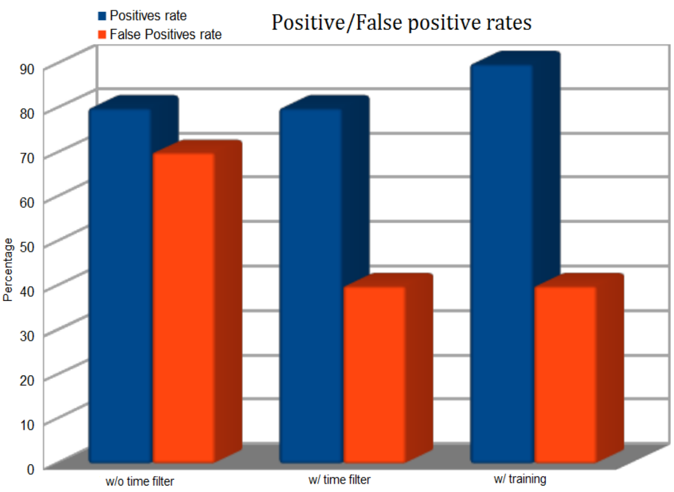

Fig. 3. Positive vs. False positive rates.

V. CONCLUSION

We discussed how the vast popularity of sensor-endowed smartphones can be exploited to create unprecedented services able to improve the interaction with the environment, the social inclusion and the quality of life. To this aim we have overviewed the state of the art in scientific literature and discussed two exemplar case studies.

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