A Context-Aware System for Personalized and Accessible Pedestrian Paths

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***Abstract*—This work presents mPASS (mobile Pervasive Accessibility Social Sensing), a social and ubiquitous context aware system to provide users with personalized and accessible pedestrian paths and maps. In order to collect a complete data set, our system gathers information from different sources: sensing, crowdsourcing and data produced by local authors and disability organizations. Gathered information are tailored to user's needs and preferences on the basis of his/her context, defined by his/her location, his/her profile and quality of data about the personalized path. To support the effectiveness of our approach, we have developed a prototype, which is described in this paper, together with some results of the context-based adaptation.**

Keywords- social location-based context aware systems; location aware applications in smartphones; user interfaces and usability issues for ubiquitous applications

I. INTRODUCTION

Location-based systems and applications should provide information which is of interest to the user and it is personalized to his/her preferences and needs [1]. This is especially true for those navigation systems which are devoted to guide pedestrian users in urban environments. In fact, such systems are more susceptible to errors and to specific details in computing paths than more common navigation systems tailored for vehicles [2]. Moreover, users are very different, from one another, in terms of capabilities and preferences.

In particular, in the urban environment there are several issues that can affect or improve the experience of pedestrians (e.g. obstacles and barriers, but also facilities); different paths, with the same starting point and destination, but with different characteristics and distances, can make a huge difference for pedestrians. This becomes a key issue for those target users with specific preferences and needs, for instance people with reduced mobility (i.e., people with physical disabilities, elderly people, etc.) or citizens with particular preferences in terms of safeness (i.e., kids coming back from school, women who require to avoid unsafe areas at night, and so on) [3].

Unfortunately, the availability of information about urban accessibility and security is very limited if compared with other location-based and ubiquitous data and a multiple-source gathering seems to be the only effective mean to collect an adequate set of information [4]. Urban accessibility is a primary factor for social inclusion and the effective exercise of citizenship for everybody, including people with disabilities and elderly people. Moreover, the lack of information about the urban environment and its accessibility represents itself a barrier to those citizens, who are strongly discouraged from step out of well-known paths [3].

We have designed and developed a system, called mPASS (mobile Pervasive Accessibility Social Sensing) [3], which aims to collect data about urban accessibility and to provide citizens with personalized and accessible pedestrian paths and maps. This context-aware system combines data produced by sensors and data gathered via crowdsourcing by users, together with information provided by experts. mPASS also re-uses information got by geo referenced social systems by filtering or mashing up, e.g., accessibility data provided via foursquare [5].

Such data are selected and transformed in order to provide personalized maps and routes and to meet specific users' needs. The adaptation performed by mPASS works on three main dimensions: (i) the user location; (ii) the user profile; (iii) data trustworthiness. The profile describes users' preferences and needs in terms of:

- Urban accessibility: the user can declare barriers that limit or inhibit his/her ability to move and facilities which support it.
- E-accessibility: the user can customize mPASS in terms of accessibility of information.

The need of considering data trustworthiness in the adaptation process is due to the multiple sources nature of mPASS, which has to consider the quality of data gathered by users and sensors as a key element in computing personalized routes. To improve trustworthiness of collected information, mPASS runs a location-based notification system which involves volunteered and trustable users in verifying the actual position of barriers/facilities.

The remainder of this paper is organized as follows. Section II compares related work with our approach. Section III presents the Data Model, while Section IV illustrates how we profile the user. Section V describes the main adaptation techniques adopted by mPASS. Section VI presents the prototype and reports some results of the context aware adaptation performed. Finally, Section VII concludes the paper and presents some future works.

II. Background and Related Work

There is a wide literature related to topics which are involved in our research. In this context, we are going to introduce related work in the following areas of research and applications: (i) platforms and systems devoted to urban accessibility for citizen with special needs; (ii) research and techniques devoted to provide location-based and/or context-aware services, on the basis of adaptive maps.

A. *Mapping Urban Accessibility*

Several projects and publications are devoted to support users in collaborating each other with the aim of improving the quality of life in their urban environment [6], gathering, storing and providing data about urban accessibility.

The application Wheel Map [7] offers different tools, letting users (i) find wheelchair accessible toilets and parking spaces, and (ii) rate the accessibility of a service (for instance, services related to tourism, sport, education, etc.). The system shows services in a map by means of icons, which are differently colored, according to their related accessibility level. The main lack of this system is that there is no information about what really affects the accessibility level of a service, in terms of barriers and/or facilities.

The authors of [8] have designed and developed a mobile app that permits users to add photos and comments related to barriers and obstacles on sidewalks. It integrates data from sensing and information from crowdsourcing.

These systems and projects provide users with accessibility maps, but they do not compute accessible and/or personalized routes. Moreover, they do not take into account official reviews done by experts. A project which involves users as well as experts is AccessibleMaps [9]. It provides blind people and wheelchair users with web-based urban maps, showing icons representing accessibility barriers and facilities.

Some mobile applications and systems which support urban accessibility are devoted to compute personalized paths for citizens with special needs. They perform routing algorithms based on geo-referenced data about accessibility barriers and facilities that are usually collected by crowdsourcing. RouteCheckr [10] is a client/server system for collaborative multimodal annotation of geo-referenced data. It provides personalized routing to mobility impaired people thought the configuration of a user profile. However, such a system does not integrate data coming from different sources (i.e., sensors, experts' reviews, etc.). Moreover, no evaluation of crowdsourced data quality has been provided.

B. *Context-Aware Services and Adaptive Maps*

Several works have been done with the aim of offering applications and services based on maps and geo-referenced data, which are personalized on the basis of pedestrians' location [2, 11, 12, 13]. Many of them take into account not only the position, but they adapt the maps on the basis of the user's direction and device orientation [14, 15].

To better adapt maps and the rendered information, several of these works are based on users' contexts, usually described by means of profiles, so as to include also his/her interests and/or behaviors [16, 17, 18]. On the basis of these user's profiles, such systems can provide suggestions and recommendations about specific Points of Interest (POIs) in the map [19]. These profiles can be directly configured by the user [19] or devised by means of recommendations systems and collaborative filtering techniques [20] or extracted by social networking profiles [1].

Among these works, some of them present interesting studies and techniques related to mobile map adaptation. In [21], the authors present the design and the development of map interfaces, so as to be exploited by means of mobile devices and tailored according to users' purposes. In particular, the authors discuss about what they experienced in terms of rendering, user interaction and adaptation techniques required for these mobile map interfaces, taking into account user experience and mobile device limitations (i.e., small screens, limited network connectivity, or reduced processing power) and not only users' interests. This work effectively describes map adaptation techniques and interaction mechanisms, giving us many interesting hints.

The need of adapting maps so as to meet needs of users equipped with mobile devices is the main motivation of the system named MediaMaps and presented in [22, 23]. Mobile devices limitations are taken into account in this work, which proposes maps personalized according to individual characteristics of the user, with the aim of improving mobile map-based visualization. The authors designed a model and developed a prototype of a mobile map-based visualization system, incorporating an adaptive user interface. Evaluation results show the effectiveness of personalized maps in supporting users' needs and requirements.

Both these previous systems just provide maps adaptation features, but they do not take into account the need of personalizing paths, tailored to the user profile and on the basis of user contexts.

Adapted maps and personalized paths, related to touristic activities, are at the basis of the work presented in [19]. This system lets the user explicitly declare his/her preferences and computes a personalized path, guiding him/her in a planned tour. The user can rate the visited POIs, enriching his/her profile. According to it, the system can adapt the map, showing different kinds and number of POIs.

III. Data Model

mPASS defines two main entities: accessibility Points of Interest and reports. Subsection A and B introduce them, while a more-in-depth description can be found in [3]. Both entities are associated to their trustworthiness, which is presented in subsection C.

A. *Accessibility Points of Interest*

An aPOI can be an element of the urban outdoor environment (urban design aPOIs) or of an indoor context, such as a restaurant or a public building (architectural design aPOIs). We have analyzed and grouped in categories more than 200 accessibility barriers and facilities, mainly focusing on the outdoor ones. Identified categories are: Gap, Crossing, Obstruction, Parking, Surface, Pathway and Light. An exhaustive description of these categories can be found in [3]. Categories can include both barriers and facilities, for example Gap contains barriers, such as gaps, steps, and stairs, and facilities, such as ramps, curb cuts, and handrails.

For each category we decided which barrier/facility can be identified by sensing and crowdsourcing and which one would be recognized only by users' reviews (i.e., only by crowdsourcing). For each aPOIs, one or more accessibility reports are collected.

B. Reports

A report contains information gathered by one of three possible sources: sensors, the crowd and data officially provided by experts. According to this, reports are classified in three different source classes, depending from how they are collected:

- Sensor reports (S-reports), which are gathered by smartphones, used as sensors, while users are moving in the urban environment. By exploiting gyroscope, accelerometer and GPS, the mPASS app (running on the smartphone) can identify simple barriers and facilities (such as steps or ramps) and can collect information so as to identify other barriers and facilities (such as semaphores) through a cooperative sensing activity.
- User reports (U-reports), which are obtained by crowdsourcing. Smartphones are used to provide data through reviews about urban accessibility made by users. The mPASS app collects reviews from users in two different ways: (i) volunteering: users who want to send a review about the place where they are (or a place where they have been) can use the mPASS app to fill a form to accomplish this task; (ii) on demand: users can be asked by the system to produce a review (filling an appropriate form) about a place where they are (or nearby). In this case, the system sends a notification to the user containing the review request.
- Experts reports (E-reports), which are obtained from official reviews done by authorities and organizations (e.g., local administrations, organizations that support people with disabilities, hotels associations, etc.). Experts involved in such activities can use the mPASS app to assess the actual accessibility of a place, adding reviews about barriers and facilities.

C. Trustworthiness

Working on the basis of possibly unreliable reports, mPASS can generate both false positives and false negatives. False positives are:

(i) due to non-existing barrier detected: in this case, mPASS can avoid an accessible path because of this incorrect detection, suggesting a longer route or a route that is actually less accessible than another one;

(ii) due to non-existing facility detected: in this case, the system can suggest a route considering it adequate because of this incorrect detection. In case the facility is needed by the user, this can prevent him/her from reaching his/her destination/goal.

False negative are:

(iii) due to undetected existing barrier: an existing barrier was not detected and the system computes paths or maps without considering its presence so that user could be unable to reach his/her destination/goal;

(iv) due to undetected exiting facility: in this case, mPASS can suggest paths without taking into account the facility or it can suggest a less accessible route instead of the best possible one.

Case (i) and (iv) can cause difficulties to users in terms of dealing with longer paths, but they are not preventing the user from reaching his/her goal or destination. On the contrary, cases (ii) and (iii) are highly critical, because they can stop the user from getting his/her goal or destination due to unexpected barriers or non-existing facilities. In order to avoid all these four mentioned situations, mPASS rates the trustworthiness of data related to aPOIs so as to decide if there is a specific type of barrier or facility and its characteristics.

Trustworthiness of reports depends on the information source:

- Trustworthiness of S-reports is measured in terms of each sensor accuracy and the number of sensors which contribute in those activities.
- Trustworthiness of U-reports is strictly related to the credibility of each user (considered as a single source of data) and the number of users who reviewed the same barrier/facility.
- E-reports are considered totally trustworthy.

Trustworthiness assessment evaluates each report on the basis of the source credibility/accuracy and it combines all the reports related to an aPOI, computing an aPOI trustworthiness value. On the basis of this value, an aPOI can be classified as:

- *present*: mPASS is sufficiently confident that the aPOI is present and uses it both while computing paths and while providing maps;
- *uncertain*: mPASS is not confident about the trustworthiness of the aPOI and cannot guarantee about its presence or absence. If the aPOI is a barrier, mPASS uses it (in order to avoid false negative, type iii) both in computing paths and providing maps. If the aPOI is a facility, mPASS uses it, neither in computing path, nor in providing maps (in order to avoid false positive, type ii);
- *absent*: mPASS is sufficiently confident that the aPOI is not present and uses it neither in computing path, nor in providing maps.

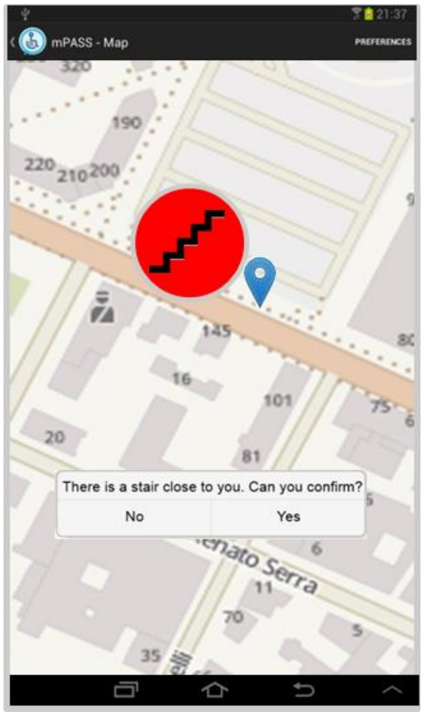

Fig. 1. Report request related to a barrier close to the user

To improve trustworthiness of aPOIs, mPASS asks confirmation to users with a high credibility who are nearby the point of interest. A specific system module devoted to manage notifications, sends requests to users on the basis of their location and credibility in order to explicitly ask new reports. Figure 1 shows the notification related to the presence of a stair.

IV. Profiling Users

To provide personalized services, mPASS exploits a user XML-based profile, structured in three interconnected parts: (i) the Urban Accessibility Profile (UAProfile), which describes user's preferences related to each urban accessibility barrier/facility; (ii) the e-Accessibility Profile (eAProfile), which describes user's preferences related to the e-accessibility of the map; and, (iii) the Basic User Profile which includes some more general data about the user, such as personal info, language, unit of measurement, device(s) in use, average speed and data about his/her credibility.

A. *Urban Accessibility Profile*

The Urban Accessibility Profile stores information about users' preferences related to each barrier/facility in the urban environment. In particular, users can define each aPOI as NEUTRAL, LIKE, DISLIKE and AVOID, as detailed in Table I. A more in depth description of such preferences can be found in [3].

On the basis of these preferences, mPASS computes a route, which:

- comes across the LIKEd aPOIs when feasible;
- gets round the DISLIKEd aPOIs if possible;
- totally avoids the AVOIDed aPOIs every time.

The system provides users with different paths characterized by different lengths and different matches with the user's preferences. Then the user can choose the best path, in terms of barriers/facility, trustworthiness of aPOIs, number of collected reports and distance.

It is worth noting that users cannot set any facility as NEED, because some paths and urban areas can be fully accessible even without any support or accommodation. Selecting ways on the basis of hypothetical needed facilities would mean to exclude paths which do not need any of them to become accessible. When the path is not fully accessible without those facilities, the set of above mentioned values drives the algorithm to appropriate solutions. Let us consider, for example, the case of a wheelchair user who wants to reach a place located at the second floor. In this case, user's preferences related to stair are set to AVOID while user's preferences related to ramp and elevator are set to LIKE. The routing algorithm searches for a way to reach the second floor which avoids stairs. This path, if it exists, would include the liked facilities (ramps and/or elevators).

Moreover, positive preferences can be associated to barriers and negative preferences can be associated to facilities. As an example, a blind user can set as LIKE some specific barriers, such as stairs and steps, because they can represent a reference point.

TABLE I. BARRIERS/FACILITIES PREFERENCES

Preference	Description	Example
NEUTRAL	The user has neither difficulties nor preferences related to the aPOI type. The presence of this type of barrier/facility on a path is irrelevant to the user.	Stairs aPOI type is set as NEUTRAL in the profile of a young pedestrian or in the profile of a blind user.
LIKE	The user prefers aPOIs of this type, when they are available. The presence of this type of barrier/facility on a path is positive to the user.	Zebra crossings and traffic lights aPOIs are set as LIKE in the profile of a user who wants to follow a safe path or in the profile of a blind user.
DISLIKE	The user can face this aPOI type, but with some efforts. In this case, an alternative path is preferred (when available), but it is not necessary. The presence of this type of barrier/facility on a path is negative to the user.	Stairs aPOIs in the profile of an elderly user or uneven road surfaces in the profile of a wheelchair user are set as DISLIKE.
AVOID	The user cannot face this aPOI type and an alternative path is necessary. The presence of this type of barrier/facility on a path prevents the user from following this path.	Stairs in the profile of a wheelchair user or obstructions in the profile of a blind user are set as AVOID.

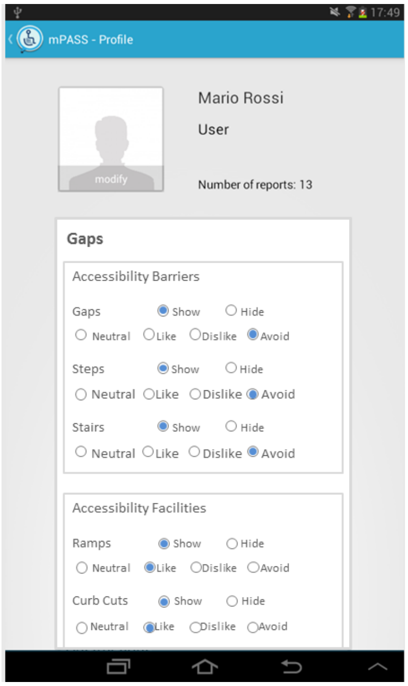

Fig. 2. Setting the user's profile

Analogously, wheelchair users can set tactile paving as DISLIKE, because such surfaces can be uncomfortable for them.

In the current version of our prototype, the profile is precompiled on the basis of self-declarations done by users, as depicted in Figure 2. It depicts the settings related to the Gaps aPOI type done by a wheelchair user.

B. *eAccessibility Profile*

The e-Accessibility Profile is devoted to store preferences and needs in terms of maps rendering. The main selection is the one related to textual/graphical representation of the map. On the basis of it, users can choose specific styles to represent aPOIs. For instance, the graphical representation can be personalized in terms of colors and size of the aPOIs icons in the map, addition of textual labels, visualization (show or hide) of aPOI categories or of aPOI types.

In particular, different style rules can be associated to the whole application, to a specific preference (LIKE, DISLIKE, etc.) or to a single type of aPOI.

V. MAP ADAPTATION TECHNIQUES IN MPASS

On the basis of the above described profile, mPASS customizes maps in order to meet the specific (and special) needs of users. Together with the user profile, adaptation is driven also by the trustworthiness of gathered data (as described in Section III). Maps are adapted with the aim of providing users with (i) data related to barriers/facilities which impact on their paths; (ii) information about trustworthiness of such data; (iii) accessible information.

To reach these goals, we have exploited a set of adaptation techniques, which have been previously used in the fields of e-accessibility [24] and perceptual cartography [21]. The main adaptation techniques we have applied in mPASS are: *Map-to-text*, *Exaggeration*, *Elimination*, *Typification*, *Color personalization* and *Textual detailing*, as described in Table II.

In particular, *Elimination* is automatically applied to aPOIs set as NEUTRAL: they are shown only if the user explicitly asks for them in the profile. In fact, some users can benefit from the rendering of neutral aPOIs, so as to better contextualize their position in the urban area (i.e., a blind user could ask for the textual rendering of stairs and steps, since they can be reference points). Moreover, *Elimination* is used to hide barriers and facilities which are classified as *absent* and facilities which are classified as *uncertain*, on the basis of the aPOI trustworthiness.

mPASS applies *Typification* by showing the aPOIs as colored icons (letting users select and zoom them, so as to enjoy the related icon). Different shapes are exploited to give information about the trustworthiness of the aPOI: a dot means that the aPOI is classified as *present*, while triangles are used to show those barriers considered *uncertain*.

TABLE II. ADAPTATION TECHNIQUES

Technique	Description	mPASS Application
Map-to-text	A textual description of the personalized paths is provided to users	This technique is applied with the aim of meeting needs of visually impaired users and of users who contextually set such a preference.
Exaggeration	Size magnification and line exaggeration rules are used to increase special details and the visibility of the map objects.	This technique is applied to meet needs of users with low vision and of elderly people. It can also give emphasis to those elements that are interesting for the user in a specific moment/context.
Elimination	Map objects are selectively removed because they are useless or too small to be presented in the map.	Map objects are removed on the basis of their trustworthiness and/or users' preferences.
Typification	Feature density and level of detail are reduced while maintaining the representative distribution pattern of the original feature group.	Map objects are grouped and/or typified on the basis of their trustworthiness and/or users' preferences
Color personalization	Colors are set up by users.	This technique consists of letting users set up the colors background of the aPOI icons. It is applied with the aim of meeting needs of users with color blindness, users with low vision and elderly people.
Textual detailng	Labels and tables are shown to add readable details to map objects.	This technique adds details to mPASS map, such as sizes of the aPOI (ramp width or step height), aPOI credibility, notes, etc. It is applied with the aim of meeting needs of users with low vision, elderly people and users with cognitive disabilities.

VI. MPASS AT WORK

We have currently developed a prototype of the mPASS system, which is described in detail in [3]. mPASS users can access to services both by using mobile devices and through the Web. Mobile services are provided by an Android app that includes the sensing activity. The remainder of this Section is devoted to present a case study which aims to describe how the system adapts content and presentation to the users' need. We have considered a wheelchair user who asks for an accessibility map of a particular area in the city of Cesena (Italy). Figure 3 shows a fragment of his Urban Accessibility profile, related to preferences on different types of gaps and surfaces.

The mPASS system computes and proposes different personalized paths, with different characteristics (in terms of length and number of involved aPOIs, grouped by categories). The user can set the number of personalized paths proposed by our system among which choosing his favorite one. After that he can start his path. In our case, the user has set the preference to select among three different paths.

Figure 4 shows the first map rendered by mPASS. The user can take a look to each one of the three proposed paths. Colored icons along the path are shown in the map, corresponding to the collected aPOIs. The map depicted in Figure 4 does not show NEUTRAL aPOIs, as set up by the user in the profile. Hence, mPASS has applied the elimination technique to those kinds of aPOI.

Beside the map, on the right, the user can move from one proposed path to another one. Some details about the path are also shown on the right: (i) the whole distance of the path (express in the unit of measurement as set up by the user); (ii) the estimated time to go through the path (express in terms of minutes), according to the average speed, as set up by the user; (iii) a summary of the aPOIs the user will meet in the path, grouped by their trustworthiness and according to user's preferences as he had expressed in the profile; (iv) the number of the reports collected from all the different sources.

```
 ...
<neutral style="hidden"/>
<like style="ok"/>
<dislike style="warning"/>
<avoid style="alert"/>
...
<gap>
  <steps type="barrier" pref="avoid"/>
  <gaps type="barrier" pref="avoid"/>
  <stairs type="barrier" pref="avoid"/>
  <ramps type="facility" pref="like"/>
  <curbcuts type="facility" pref="like"/>
  < handrails type="facility" pref="neutral"/>
 ...
</gap>
  ...
<surface>
  <uneven_road type="barrier" pref="dislike"/>
  <tactile_paving type="facility" pref="dislike"/>
   ...
</surface>
...
```

Fig. 3. Wheelchair user's profile fragment

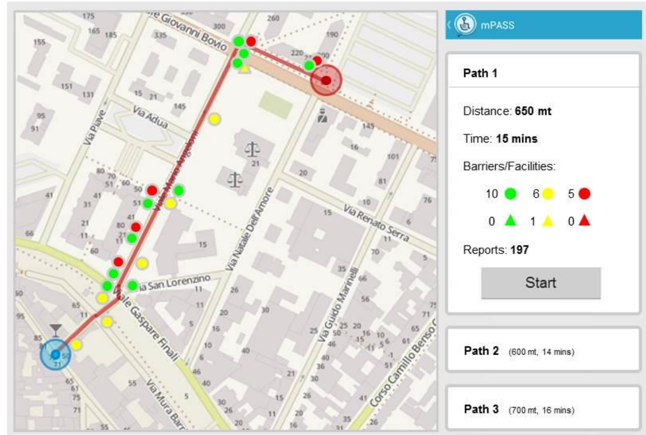

Fig. 4. A path personalized for a wheelchair user

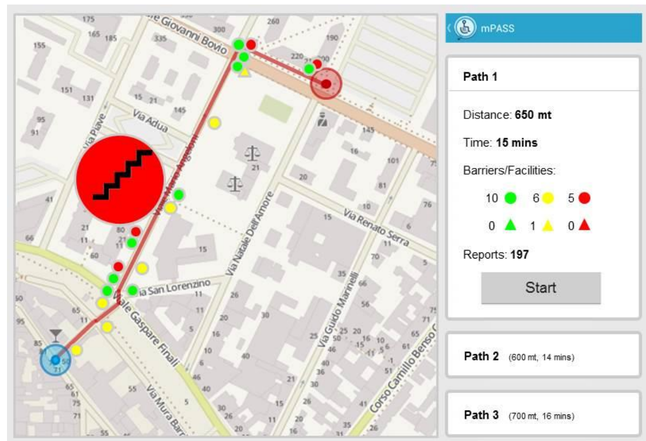

Fig. 5. A path personalized for a wheelchair user with an enlarge aPOI icon

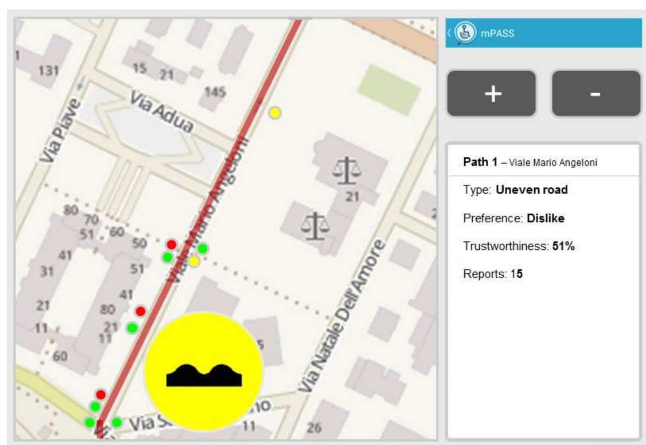

Fig. 6. A detail of path shown in Figure 4

Different colors and shapes (as selected by the user) are used in order to mark such different groups. A number, close to the related icon, shows the amount of that kind of aPOI. In the path proposed in Figure 4, the user will meet 21 aPOIs which are considered present on the basis of their trustworthiness (10 aPOIs marked as LIKE, 6 marked as DISLIKE and 5 marked as AVOID) and 1 barrier considered uncertain (DISLIKEd by the user).

The user can select and enlarge the related icons and then a symbol is shown, so as to let the user know the aPOI type. In Figure 5, the enlarged red icon shows the presence of a stair.

Figure 6 depicts a screenshot of the chosen personalized path, showing a portion zoomed by the user. The user is going through it and he is asking for details about a DISLIKE aPOI. On the right, the user can exploit the aPOI details, in particular: (i) the aPOI type (in this case: Uneven road, which belongs to the Surface category); (ii) the preference the user has set up in the profile for it; (iii) the aPOI trustworthiness expressed in terms of percentage; (iv) the number of collected reports related to this specific aPOI.

VII. CONCLUSIONS AND FUTURE WORK

In this paper, we introduced mPASS, a social and ubiquitous context-aware system which equips citizens with personalized and accessible pedestrian paths and maps. mPASS gathers data from many sources, with the aim of improving the accessibility of the urban environment. Maps and paths are customized to each user, on the basis of his/her location, his/her profile and the quality of data. A set of tailored map adaptation techniques has been used to provide users with an accessible map locating accessibility barriers and facilities. This paper describes a prototype we have developed and a case study, with the aim of showing the mPASS system at work.

Some organizations supporting people disabilities have been involved in the mPASS design and development. Thanks to such collaborations, tests with users have been planned and they will be conducted next months.

We are now doing further studies with the aim of profiling users from users' behavior. Adaptation mechanisms will be applied to the user's profile, so as to dynamically modify it according to user's actual abilities, which can change during time. Our idea is to exploit machine learning techniques and track users' behavior while interacting with the map and with the urban environment. In particular, we are integrating a discrete-event multi-agent simulation library (MASON, Multi-Agent Simulator Of Neighborhood) and a Q-Learning algorithm framework (PIQLE), with the aim of simulating users' behavior and of evaluating how their profiles change.

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REFERENCES

[1] P. Bereuter, R. Venkateswaran, and R. Weibel, "The Use of Filters for Adaptive Mobile Mapping Scenarios," in Proceedings of the AGILE Workshop on Adaptation in Spatial Communication, Bremen, Germany, 2009, pp. 39-44.

[2] G. Retscher, "Pedestrian Navigation Systems and Location-Based Services," in Proceedings of the Fifth IEE International Conference on 3G Mobile Communication Technologies, 2004, pp. 359-363.

[3] C. Prandi, P. Salomoni, and S. Mirri, "mPASS: Integrating People Sensing and Crowdsourcing to Map Urban Accessibility," in Proceedings of the IEEE International Conference on Consumer Communications and Networking Conference (CCNC '14), Las Vegas, Nevada, USA, January 10-13, 2014.

[4] C. Biancalana, F. Gasparetti, A. Micarelli, and G. Sansonetti, "An Approach to Social Recommendation for Context-Aware Mobile Services," in ACM Transaction on Intelligent Systems and Technology, Volume 4, Issue 1, Article 10, 2013, 31 pages.

[5] Foursquare. Available from: https://foursquare.com/ [Retrieved: March 2014].

[6] F. Zambonelli, "Pervasive Urban Crowdsourcing: Visions and challenges," in Proceedings of the International Conference on Pervasive Computing and Communications Workshops (PERCOM '11), Seattle, WA, USA, March 21-25, 2011, pp. 578-583.

[7] Wheel Map. Available from: http://wheelmap.org/en/ [retrieved: March, 2014].

[8] C. Cardonha, D. Gallo, P. Avegliano, R. Herrmann, F. Koch, and S. Borger, "A crowdsourcing platform for the construction of accessibility maps," in Proceedings of the 10th International Cross-Disciplinary Conference on Web Accessibility (W4A '13), Rio De Janeiro, Brazil, May 13-15, 2013, Article No. 26.

[9] AccessibleMaps. Available from: http://www.accessiblemaps.org/ [Retrieved: March 2014].

[10] T. Völkel and G. Weber, "RouteCheckr: personalized multicriteria routing for mobility impaired pedestrians," in Proceedings of the 10th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '08), Halifax, Nova Scotia, Canada, October 12-15, 2008, pp. 185-192.

[11] G. Gartner, "Location-based mobile pedestrian navigation services-the role of multimedia cartography," in Proceedings of International Joint Workshop on Ubiquitous, Pervasive and Internet Mapping, 2004, pp. 51-60.

[12] J. Raper, G. Gartner, H. Karimi, and C. Rizos, "A Critical Evaluation of Location Based Services and Their Potential," in Journal of Location Based Services, Volume 1, Issue 1, March 2007, pp. 5-45.

[13] M. S. Panahi, P. Woods, and H. Thwaites, "Designing and Developing a Location-Based Mobile Tourism Application by Using Cloud-Based Platform," in Proceedings of the International Conference on Technology, Informatics, Management, Engineering & Environment (TIME-E 2013), Bandung, Indonesia, June 23-26, 2013, pp. 151-156.

[14] J. Yin and J.D. Carswell, "Touch2Query Enabled Mobile Devices: a Case Study Usign OpenStreetMap and iPhone," in Proceedings of Web and Wireless Geographical Information Systems, Lecture Notes in Computer Science Volume 6574, 2011, pp. 203-218.

[15] M. Raubal and I. Panov, "A Formal Model for Mobile Map Adaptation," in Proceedings of Location Based Services and TeleCartography II, Lecture Notes in Geoinformation and Cartography 2009, pp. 11-34.

[16] G. Fischer, "Context-aware systems: the "right" information, at the "right" time, in the "right" place, in the "right" way, to the "right" person," In Proceedings of the International Working Conference on Advanced Visual Interfaces (AVI '12), May 21-25, 2012, Capri Island, Italy, pp. 287-294.

[17] A. Zipf and M. Jost, "Implementing adaptive mobile GI services based on ontologies: Examples from pedestrian navigation support," in Computers, Environment and Urban Systems, Volume 30, Issue 6, November 2006, pp. 784–798.

[18] F. Ricci, "Mobile Recommender Systems," in International Journal of Information Technology and Tourism, Volume 12, Issue 3, 2011, pp. 205-231.

[19] Y. Kurata, "Challenges in User-Adaptive Tour Planning Systems," in Proceedings of the AGILE Workshop on Adaptation in Spatial Communication, Bremen, Germany, 2009, pp. 19-26.

[20] M. J. Barranco, J. M. Noguera, J. Castro, and L. Martínez, "A Context-Aware Mobile Recommender System Based on Location and Trajectory," in Management Intelligent Systems, Advances in Intelligent Systems and Computing, Volume 171, 2012, pp. 153-162.

[21] V. Setlur, C. Kuo, and P. Mikelsons, "Towards Designing Better Map Interfaces for the Mobile: experiences from example," in Proceedings of the 1st International Conference and Exhibition on Computing for Geospatial Research & Application (COM.Geo '10), Washington, DC, USA, June 21-23, 2010, Article No. 31.

[22] B. Van Tonder and J. Wesson, “Using Adaptive Interfaces to Improve Mobile Map-Based Visualization,” in Proceedings of the 2008 annual research conference of the South African Institute of Computer Scientists and Information Technologists on IT research in developing countries: riding the wave of technology (SAICSIT ’08) Wilderness, South Africa, October 6-8, 2008, pp. 257-266.

[23] B. Van Tonder and J. Wesson, “Design and Evaluation of an Adaptive Mobile Map-Based Visualisation System,” in Proceedings of Human-Computer Interaction 2009 (INTERACT 2009), Lecture Notes in Computer Science Volume 5726, 2009, pp. 839-852.

[24] K. Miesenberger, “Accessible Maps,” from W3C Research and Development Working Group Wiki. http://www.w3.org/WAI/RD/wiki/Accessible_Maps [Retrieved: March 2014].