On Engaging Communities in Smart Societies: Crowdsourcing, Gamification, and Participatory Design for Accessible, Sustainable, and Safer Urban Mobility

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Abstract	Smart Cities aim to improve urban life by making cities more accessible, sustainable, and safer. From this concept emerged the idea of smart society. In smart societies, pervasive and innovative technologies and data are exploited to enhance society’s overall functioning and well-being. In this context, smart mobility plays a relevant role. This chapter aims to present three case studies, developed as a proof-of-concept (PoC), in the context of sustainable and accessible urban mobility. In comparing them, different dimensions of interest will be considered, such as (i) the community of interest, (ii) the design process, (iii) the exploited technologies, and (iv) the engagement strategies. Ultimately, some final remarks are presented, discussing the relevance of actively engaging communities in creating smart services for our cities and society.

6 On Engaging Communities in Smart Societies: Crowdsourcing, Gamification, and Participatory Design for Accessible, Sustainable, and Safer Urban Mobility

Catia Prandi

Abstract

Smart Cities aim to improve urban life by making cities more accessible, sustainable, and safer. From this concept emerged the idea of smart society. In smart societies, pervasive and innovative technologies and data are exploited to enhance society's overall functioning and well-being. In this context, smart mobility plays a relevant role. This chapter aims to present three case studies, developed as a proof-of-concept (PoC), in the context of sustainable and accessible urban mobility. In comparing them, different dimensions of interest will be considered, such as (i) the community of interest, (ii) the design process, (iii) the exploited technologies, and (iv) the engagement strategies. Ultimately, some final remarks are presented, discussing the relevance of actively engaging communities in creating smart services for our cities and society.

1 Background

A smart city can be defined as an urban area that exploits pervasive technology to enhance the productivity, livability, and sustainability of the city for its citizens [1]. This scenario can include deploying sensors, Internet of Things (IoT) devices, and intelligent infrastructure to improve transportation, energy usage, public services, and public safety, to name a few. The overall aim is to create a more connected, accessible, and sustainable city that better serves the needs of its citizens [2].

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In this light, the concept of smart societies emerged [3]. Smart societies refer to integrating technology and data to improve the quality of life of their inhabitants. Ideally, smart societies aim to enhance society's efficiency, sustainability, and inclusivity through the intelligent use of Information and Communication Technologies (ICT). To this aim, smart societies use a combination of smart city and smart government concepts to enhance the overall functioning and well-being of society as a whole [3]. A smart society should address several challenges like urbanization, sustainability, resources, transportation/mobility, and health. In the following, we will focus our discussion on the mobility concept as a person's ability to move or be moved (capable of movement).

Smart mobility refers to using pervasive technology and data to improve mobility within a city [4]. It usually involves integrating different technologies like real-time traffic data, GPS, and mobile apps to make mobility more efficient, accessible, and sustainable [5]. In the end, smart mobility aims to make people move easily within the urban environment and eventually improve a city's overall livability and sustainability, creating a more pleasant and healthy environment for residents and visitors.

When designing new smart mobility services, it is crucial to consider people's needs [6]. There are two main motivations behind this assertion. First, people are the ultimate beneficiaries of smart mobility solutions. Second, people often have an active role in the smart mobility process by using, for example, mobile apps to access data and plan their trips. This means that people need to be involved in the design process, ensuring the creation of smart mobility services tailored to the community's needs and preferences.

Within the Human-Computer Interaction (HCI) field, several approaches have been studied to consider users' needs in the design of services and products. These strategies range from User-Centred Design (UCD) [7], where users are not directly involved in the design process, yet designers create the system considering their needs, to co-design [8] and participatory design (PD) [9], where people have an active role in the design of the system, side by side with designers.

In this Chapter, we will focus on the discussion of some of the main objectives of creating smart mobility services: having more accessible, sustainable, and safer urban mobility. In doing that, we will present three case studies, developed as a Proof-of-Concept(PoC), focusing on different community needs. In particular, three are the communities of interest: (i) people with disabilities and special needs, including mobility and visually impaired people; (ii) citizens and visitors living in a well-known tourist destination, where tourism represents the main income source but it also represents a concern in terms of sustainability; (iii) children who would like to develop their independent mobility. For the three case studies, some dimensions of interest are analyzed, such as (i) the peculiarity of the community of interest, (ii) the design process, (iii) the exploited technologies, and (iv) the engagement strategies. Finally, the paper concludes with some final remarks and general recommendations.

2 Related Work

The related work section focuses on three smart mobility macro areas, accordingly with three case studies. In fact, despite being indisputable that urban areas and the people living in them are dealing with daily issues related to mobility, such as traffic congestion, air and noise pollution, and the effectiveness of public transportation, the concerns depend on the specific communities' needs.

2.1 Urban Accessibility

Urban mobility is the ability of people to move around the city, living and interacting with the space. Individuals with limited mobility, such as those with disabilities or the elderly, often face accessibility challenges while moving in an urban environment, including obstacles in the urban landscape and public transportation [10]. The absence of information about the accessibility of transportation and the surrounding environment further hinders their ability to move around the city independently [11]. Over the years, several solutions have been developed to provide people with wayfinding and navigation technologies [12]. Wayfinding systems are used to guide people through a physical environment, enhancing the individual understanding and experience of a space. In simple words, the main objective of a wayfinding system should be to aid the users in orienting themselves in a space and then navigating to a specific destination. However, these same devices and software applications can also act as a barrier if their user interface is not accessible or not compatible with assistive technologies. This can prevent individuals with disabilities from fully utilizing these tools to enhance their independent living.

Over the last decade, a significant amount of research has been carried out to study and develop wayfinding software and devices that aim to improve the quality of life for individuals with disabilities as they move through the urban environment [13, 14]. In 2021, Prandi et al. presented a systematic mapping survey where they analyzed 111 out of 806 papers published in the period 2009–2020 [15]. The wayfinding systems were analyzed considering six dimensions. First, they exploited the used device, such as smartphones (e.g., [16, 17]), web applications (e.g., [18]), wearable devices (e.g., [14]), and smart devices (e.g., [19]). Then, the context of use, that is, indoor (e.g., [19]), outdoor (e.g., [11]), or both (e.g., [20]). The target user is another analyzed dimension; applications can focus on a single target (i.e., blind users [21]) or a larger community (i.e., people with special needs [22]). The used data source is another dimension of interest; examples are open data and/or official data (e.g., [23]), data provided by users through crowdsourcing and/or crowdsensing mechanisms (e.g., [21]), multi-source data (e.g., [24]).

In this first case study, we exploited a mobile and a web wayfinding system designed to consider the special needs of people with impairments, exploiting multi-source data to provide personalized paths.

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2.2 Sustainable Mobility and Tourism

Smart cities have arisen as a potential solution to the sustainability issues resulting from the rapid growth of urban areas [25]. Smart mobility plays a vital role in fostering the sustainability of an area. The tourism sector is strongly related to the ability of people to move and travel, and is one of the largest industries globally, rooted in mobility as a form of capital [26]. In destination islands with delicate ecosystems to preserve, this source of revenue can pose sustainability challenges [27].

Due to the widespread use of innovative and interconnected technologies, the world has become highly connected, enabling access to vast amounts of data to gain new understandings and knowledge. These pervasive technologies allow researchers to examine the overall effect of complex human and economic activities, such as tourism (e.g., [28,29]). To this end, several technologies have been developed. As an example, different strategies can be employed to sense mobility flows. Some projects analyzed mobile phone data (e.g., [30,31]). Others used GPS traces (e.g., [32]). Interesting is also the possibility of gathering information using Wi-Fi technologies (e.g., [33,34]). Finally, some studies exploited social network usage (e.g., [35,36]).

When discussing sustainability and mobility, collecting data on environmental conditions is essential. Over the last few decades, various research initiatives have utilized citizen science contributions and participatory sensing, including crowdsourcing and crowdsensing, to identify and monitor a broad spectrum of environmental characteristics [37]. Such attributes range from physical characteristics (as urban accessibility [11]) to actual measurements (such as noise [38], air quality [39], and so on), including also environmental-related dimensions (such as biodiversity [40]). In some instances, participants provide written reports on specific observations such as weather conditions [41], hydrological monitoring [42], and daily precipitation [43]. Some researchers have also developed specialized hardware to achieve specific objectives (e.g., [44]). Several initiatives have involved citizens using smart devices, exploiting their built-in sensors to create a network of participatory sensing (e.g., [45]).

This second case study presents a platform composed of a low-cost community-based pervasive collaborative infrastructure to sense the presence and movement of people exploiting passive Wi-Fi tracking and a web-based application that combines and visualizes the data collected by the sensing infrastructure and other urban data sets (such as energy consumption, weather information, and CO_2 emission).

2.3 Children Independent Mobility

Children's independent mobility could be defined as the use of public space by people under 18 years unaccompanied and unsupervised by adults [46]. Independent mobility for children has been shown to significantly impact their well-being, social and cognitive development, and spatial awareness [47]. Despite the growing investment in urban mobility and incentives for sustainable use of public transport and shared mobility, the trend of declining independent mobility for children is evident in several countries [48]. At the same time, the rise in mobile device ownership presents exciting opportunities for location- and map-based applications and services specifically tailored for children.

The focus of several location-based approaches designed for children, including mobile apps and wearable devices, is on tracking the child's movements and whereabouts to increase safety and security and address the concerns of parents [49,50]. However, many of these studies neglect the needs and desires of children and their caregivers and instead concentrate on ICT issues [51,52]. A limited number of studies have included children and caregivers in the evaluation process, raising concerns about the impact of new technologies, privacy and ethical issues, security, and the caregivers' false sense of security [53,54].

This third case study aims to involve children and caregivers in the early stages of designing future location-based technologies to understand the challenges and limitations of these systems.

3 The Three Case Studies

In this Section, the three case studies defined in the previous section are detailed, with a particular focus on some dimensions of interest, such as (i) the community of interest, (ii) the design process, (iii) the exploited technologies, and (iv) the engagement strategies.

3.1 Urban Accessibility and Personalized Path

With the aim at mitigating the problem of lack of information about urban accessibility, and to facilitate people with special needs to experience the urban environment, we designed and developed a wayfinding system called mPASS (mobile Pervasive Accessibility Social Sensing) [11]. In a few words, mPASS aims to provide people with special needs with personalized geo-referenced information and routing services to provide users with personalized and accessible paths. In the following, the platform will be presented, focusing on the different dimensions of interests.

Community of interest

In designing the system, we focused on the needs of people with special needs. In particular, we considered the needs of people with mobility disabilities (either permanent or temporary) and visual impairment (either partial or complete). Nonetheless, the community of interest can be extended to all the people with particular needs, such as healthy elderly people, people with temporary health conditions, children, pregnant women, or mothers with baby strollers. In fact, based on the person's needs, a personalized path can be accessible, safer, brighter, less crowded, etc.

To consider the needs of such a diversified community, we modeled the user's profile in terms of (i) urban accessibility and (ii) E-accessibility. Through the urban accessibility profile, the user can declare which architectural elements (Accessibility Point of Interest—aPOI) represent barriers (steps, stairs, objects blocking the walking path, etc.) and which represent facilities (audible traffic lights, zebra crossing, wheelchair ramps, etc.), using labels such as "neutral", "like", "dislike" and "avoid". This classification allows us to manage situations where an aPOI can be a barrier for one person and a facility for another. For example, a blind user can set as "like" a stairway because it can represent a reference point for orientation, while clearly it represents a barrier for a wheelchair user. On the basis of these preferences, mPASS computes a route that comes across the liked aPOIs when feasible, gets around the disliked aPOIs if possible, and always rejects the avoided aPOIs.

Through the E-accessibility profile, the user can customize the mPASS interface and interaction in terms of accessibility of information. The main selection is related to textual/graphical representation of the map and the personalized path, where the user can choose specific styles and customize the visualization. Moreover, we exploited cartographic techniques for rendering of the maps, making them accessible. For example, we applied the Map-to-text technique to provide users with visual impairments with a textual description of the personalized paths.

The Design Process

To design the system, we exploited a universal design approach [55]. We first collected users' needs and requirements with a questionnaire. We engaged 60 European users (including blind people and people with impaired vision, wheelchair users and users with physical impairments, deaf and hard of hearing users, and elderly people). The questionnaire reveals some relevant information. To provide some examples here, 63% of the participants usually use GPS navigation systems to get information about urban pedestrian paths, and 70% of the users declare they trust systems that provide geo-referenced information based on crowdsourced data. Moreover, all the users declare their willingness to use a mobile system that provides personalized pedestrian paths on the basis of their specific needs and preferences. 80% of the users claim they could afford a 30% longer path to reach their destination if the path is tailored to their preferences and needs. 73% of the participants would prefer choosing a longer path in order to avoid a detected barrier that is not actually present on the path instead of meeting an undetected barrier in their path. Most of the users (81%) expressed their willingness to share their personal data and information about their preferences, including details about the routes they usually follow in their daily life. We also interviewed 15 participants to collect additional data.

Accordingly, with the questionnaire and interview output, we designed and developed a first prototype. To evaluate it, we involved three blind people, three wheelchair users, and four elderly people, equipped with their mobile devices (mounting different versions of Android and the assistive technologies they usually rely on) and our mPASS prototype. The participants appreciated our system; in fact, all of them declared that the interface and the interaction mechanisms were clear and easy to be used.

The Exploited Technologies

To provide effective routing/mapping services, mPASS needs to reach a critical mass of data (in quantity and quality), which is very difficult to achieve. In fact, data need to be trustworthy enough to avoid errors about a specific barrier or facility and dense enough to decide about a path effectively. To this aim, we designed mPASS to integrate different data sources. (i) Crowdsensing and participatory sensing—data produced by the user's smartphone, exploiting built-in sensors (i.e., gyroscope, accelerator, and GPS). While data sensed by a single user can be considered inaccurate, multiple sensing of the same aPOI makes the data valid. (ii) Crowdsourcing—information produced by users interested in reporting urban accessibility. The report can include textual information and multimedia (pictures, video) data. Even in this case, multiple data support the validity of the gathered information. (iii) Authoritative reviews—many authorities and organizations (e.g., local administrations, disability rights organizations, hotel associations, etc.) do official reviews about indoor and outdoor accessibility. Usually, these evaluations are too few to be significant in computing a route, but they are surely valid. Accordingly, we defined a data model that keeps into consideration the origin of the data and its level of trustworthiness [11,24]. Then, we implemented it in a client (mobile and web)-server architecture.

The Engagement Strategies

In designing the system, we encountered a relevant challenge. As previously mentioned, an effective crowdsourcing/crowdsensing system needs a dense, trustworthy, and updated dataset of aPOIs. This is especially hard to get in mPASS since the main target population (people with disabilities) represents a small group of citizens compared with other communities. In addition, in order to evaluate data trustworthiness, our system requires multiple mapping of the same urban element. Finally, data should cover all the urban areas (i.e., not only the most frequented areas); this is a problem for people with disabilities who are unlikely to move freely in the environment.

To overcome this problem and enlarge the data contributors community, we investigated gamification strategies in designing mobile applications targeting young adult walkers. In particular, we designed and implemented two mobile apps: (i) a gamified app, called HINT! where the user obtains a piece of a puzzle every time she/he reports an aPOI; the completed puzzle corresponds to a voucher; (ii) a pervasive game, called GeoZombie where the user's goal is to stay alive, avoiding being eaten by zombies. While trying to do that, the user is exploring the surroundings while reporting the location of aPOI for the mPASS application in order to get weapons and ammunition to shoot the zombies [56].

To evaluate our approach, we engaged 50 undergraduate students using the three apps (mPASS, HINT! and GeoZombie) for one week each. Results proved that the game mechanics increased the students' wiliness to contribute to the system [57].

3.2 Sustainable Mobility and Tourism

In this case study, we collected data about mobility through the use of cutting-edge technologies and a smart object infrastructure. The main objective was to use the data to provide: (i) citizens and tourists with personalized location-based services to increase the use of public transportation; (ii) locals with interactive data visualization systems to foster sustainability awareness.

The case study was conducted in Madeira, an Atlantic Ocean archipelago, a popular tourist destination. With 270.000 inhabitants, Madeira attracts more than 1.3 million tourists per year, with significant impact on the economy but also on the environment, especially considering that Madeira accounts for 80% of the biodiversity of the European continent. For these reasons, the archipelago represents a unique testbed for investigating sustainable mobility. The following subsections will present the case study, focusing on the defined dimensions of interests.

Community of Interest

In this case, we focus on two communities that are very distant if we consider the way in which they experience the island, i.e., tourists and residents.

Due to its volcanic origin, the main island is very mountainous, making buses the only feasible public transport system. Despite that, tourists prefer to pay for a private mode of transportation to explore the island freely. This can be motivated by the fact that tourists usually enjoy the island for a relatively short time, and want to get the most out of the island experience. Additionally, several bus companies run on the island, making the public transportation system difficult to navigate for a foreigner, and the language can be a barrier as well.

Considering locals, the private car remains the most frequently used means of transportation. There are different reasons for that; some are grounded in society and culture, others are simply related to the convenience (in terms of ease, comfort, and efficiency) of moving around the island with a private car. Having said that, a change of behavior can be fostered in this community by increasing the awareness about sustainability. To this end, we engaged residents in the deployment of the smart objects infrastructure and also in the evaluation of the final system.

The Design Process

Considering the overall idea of investigating how pervasive digital technologies can be used to improve the adoption public transport systems, their efficiency and convenience, we launched an interaction design challenge to redesign the local bus stops [58]. A group of international master-level HCI students participated in the challenge. The first phase in the design process involved students researching in the field to understand how users interact with the bus stops and how they use public transportation to find opportunities to improve the system and engage more users. Several problems were discovered, such as accessibility, difficulty in extracting information using the static map and timetable panel, and lack of real-time information. The results from the exercise were the ideation and early-stage prototyping of innovative sustainable mobility solutions for tourists in the city of Funchal [59].

Citizens were also included in the evaluation of a data visualization system (called ViTFlow), designed and developed to increase awareness about sustainability (and the effect of mobility) in the island [34]. We first collected the users' reactions and feedback in a preliminary field study during a local public event, shadowing the users and taking notes of their interactions with the system and comments made

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aloud. Then, we used an online survey to collect quantitative data about the sessions and interactions, leaving the users free to interact with the system as long as they wanted. The obtained results were very positive. Considering the interaction with the system, most users enjoyed it, found it simple to use, and the information very easy to understand.

The Exploited Technologies

We aimed to gather location-based mobility data by deploying a cost-effective system to offer personalized services and promote sustainable mobility solutions. To achieve this, we deployed a low-cost community-based Wi-Fi passive tracking infrastructure, called Beanstalk [60], which we complemented with environmental condition-detecting sensors. We installed our routers for the Wi-Fi passive tracking in 65 points of interest and 20 buses across the entire Madeira island to ensure widespread coverage. Moreover, we deployed 10 low-cost environmental stations. We collected a vast amount of real-time data about mobility flows through the Wi-Fi passive tracking system. We used such data to implement different interactive systems [59]. For example, we prototyped a mobile app able to provide real-time information about buses (including their level of crowdedness) and weather forecasting at the arrival destination, to inform about air quality and CO_2 level, to exploit machine learning to learn about the users' habits and suggest more sustainable behavior.

As anticipated in the previous section, we also designed and developed an interactive web-based data visualization system, presenting different data affecting the island's sustainability, with the final aim of increasing the awareness of locals. In this case, we integrated several sources of information besides the Beanstalk, including: tourism flows, common mobility paths, tourist distribution, energy consumption, and CO_2 emission.

The Engagement Strategies

Particularly interesting is the fact that we engaged locals to deploy the routers (needed for the Wi-Fi passive tracking) across the whole island. In fact, Beanstalk is a community-based infrastructure in the sense that we asked citizens to install our routers in their facilities, such as restaurants, bars, and strategic touristic points of interest. To stress the fact that we did not promise them any reward or benefit, but only the possibility to access the collected data.

Considering the community of tourists, we employed gamification to motivate them to use public transportation [61]. Thanks to the developed infrastructure (the Beanstalk infrastructure together with iBeacon sensors), our mobile app could detect the tourist inside the bus and at the tourist destination. To add more details, the iBeacon sensors (Bluetooth low energy proximity sensing) were installed in the tourist points of interest to detect the tourist (i.e., a check-in/out mechanism) and to provide special and authentic touristic content related to the visited location. Additionally, we implemented typical gamification mechanisms, such as points, badges, and achievements, to stimuate the tourists' participation.

3.3 Children Independent Mobility

This case study aimed to exploit smart technologies to increase children's independent mobility. In particular, considering the increasing popularity of mobile devices among children worldwide, we saw a compelling research opportunity in the design of a children-targeted location-based application. As for the other two case studies, details about the different dimensions of interest are presented in the following.

Community of Interest

We considered children between 9 and 12 years as our main community of interest. The decision was based on two main motivations: (i) at that age, children start craving for more independence; (ii) an analysis of several articles that report on the increasing number of children (9–12) owning a personal mobile device.

Considering the specific target, we also decided to include the children's parents in the picture. Indeed, a location-based app for children of that age needs to be approved by the parents first. Interesting to notice, this community will not be the one using the final technological product, but it is fundamental in designing its characteristics: parents, in fact, need to consider the app safe/secure to use, respectfulof the child's privacy, and not susceptible of becoming a threat.

The Design Process

To collect children's needs and requirements, we engaged the community of interest in a participatory design process, following the children as "protagonists" [62]. We performed two activities, exploiting two methods to grasp design implications: (i) cognitive maps as a research method, and (ii) scenario-based design.

In the first activity, we engaged children in drawing the cognitive maps of their journey from home to school. We conducted the study involving 70 fifth-grade students (9–12 years old) at three different public schools in Funchal (Madeira), and 27 sixth-grade students (11–12-year-old) from Lisbon. After the drawing phase, students replied to a brief survey and some of them responded to a face-to-face interview. The analysis of the drawings, survey, and interviews led us to define a set of 10 themes related to landmarks and design ideas for the creation of digital maps for children, to be exploited in the location-based mobile app [63,64]. Children also directly reported some design suggestions, as presented in [65].

In the second activity, seven families (nine children and seven adults) were engaged exploiting scenario-based design, storyboards, and questionnaires. To begin with, participants were asked to reply individually to a pencil-and-paper questionnaire. Then, we used scenario-based design and storyboards/pencil-and-paper questionnaires to interactively collect qualitative data about how children and their parents/caregivers perceive the future design of a child-targeted locative system. Data were collected, analyzed, and discussed, generating some design implications in terms of children's preferences and parents' concerns [51].

Finally, the developed prototype was tested by engaging four children, using an adapted version of the System Usability Scale (SUS) for user testing with children [66].

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The Exploited Technologies

Exploiting the output of the design sessions, we prototyped a location-based wayfinding Android application. Through the app, the child can select his/her preferred avatar. The avatar is then used as a marker on the map, oriented based on the child's direction and actual position. Moreover, the child can simply click on the map to add points of interest and landmarks or add friends or family contact. The child can also select an area of interest in the map (drawing it with a finger) and see all the relevant points of interest and landmarks in that area. The system also provides eco-feedback to increase the child's awareness about sustainable mobility.

The Engagement Strategies

Some children mentioned the possibility of exploiting gamification in the locative mobile app. One child suggested: "the application could enable the user to have points if s/he catch things like Pokemon type of thing and this way, people could collect those things and learn about the city" [65]. Another one suggested: "[The app] could notify us about monuments as we walk back home. And we could gain medals if we walk a lot. We could also gain coins if we go to certain places. The coins could help us to have an avatar instead of that annoying dot that we have. (…) I do not know, it could even be a way to personalize with our face. An avatar of a person/character, or so" [65].

In particular, children envisioned three ways to exploit gamification: (i) gamification and customization, as, for example, the use of a personalized avatar; (ii) gamification and safety, as, for example, suggesting trust itineraries that can be enjoyed by the child while learning something new related to the city and its culture, having the further benefit of gaining points; (iii) gamification and e-Ticket, as, for example, exploiting the e-Ticket to gain points and receiving badges.

4 Final Remarks and Conclusion

This chapter presented three case studies in the context of smart mobility for a smart society. The case studies have been analyzed considering four dimensions of interest, which are: (i) the community of interest, (ii) the design process, (iii) the exploited technologies, and (iv) the engagement strategies. In the following, some final remarks and lessons learnt are reported.

Community of Interest

First of all, when designing smart mobility services, it is fundamental to reflect on the community of interest for which the system is being designed. Each community has characteristics, needs, and requirements that have to be considered to provide the community with an efficient and successful service. The community can be "at large" (i.e., locals) or very specific (i.e., children in the 9–12 age range). Indeed, the more the community is diversified, the more difficult it is to collect all the requirements, needs, and expectations. In such a case, it becomes fundamental to focus on what all members have in common to be part of a specific community so as to extract the core needs. As an example, in the second case study, we considered two large communities, i.e., tourists and locals. In both cases, before starting the design process (see next subsection), we analyzed each community to extract the main interests and needs, at a high level, without entering too much into the details of the diversified members.

That said, in two of the three case studies presented above, we showed how sometimes defining one main community of interest is not enough to ensure the success of the implemented services. In particular, in the case of urban accessibility, the engagement of young adults turned out to be critical to reach the critical mass of data needed to provide accessible and trustworthy paths to people with disabilities (the primary target group). It is crucial to notice that this need was generated by the use of crowdsourcing as the main way to collect data and feed our way-finding algorithm. Crowdsourcing is a call to the public to participate in the data collection. Still, in this specific context, the community of people with disabilities is limited in number and in the freedom to explore the environment, requiring additional communities to come to help. Considering a different context, in the children's independent mobility case study, we resorted to parents to make sure to design a system that they approve and allow children to use. Indeed, parents are not the main target group of our service, but ignoring them can lead to wrong design decisions and, consequently, to an app that children can not install or use.

The Design Process

The target community can be very diversified; hence, a universal design approach should be employed to be inclusive and consider the needs of all people, especially those with special needs and disabilities.

Involving people in the design process is also very important to collect requirements and needs and design the new services based on them. This can be done with different degrees of involvement. Requirements and needs can be collected through field observation (users are not directly involved) or through questionnaires and interviews (users are directly involved in a specific phase of the design process or evaluation). For example, we performed field observation in designing new services for tourists and locals. This method allows designers to passively observe and take notes of people's behavior when interacting with the public transportation system. This method can provide interesting output, particularly when involving people actively is impossible. Then questionnaires are a powerful method to collect information in terms of requirements and needs. Indeed, designing a clear and compelling questionnaire is not always an easy task. Still, once this obstacle has been overcome, it allows the collection of data offline (no need to perform physical sessions with users) and, if widely distributed, can allow managing a relevant number of answers in a limited time. In the urban accessibility case study, the questionnaire data we collected were fundamental in understating the community's interest in using a system like the one we were about to develop, its feasibility, accessibility concerns, etc. Interviews are a more interactive way to collect data, allowing researchers to go deeper into the discussion and collect richer data than questionnaires. The downside is that interviews are time-consuming both for the designers and users, often resulting in a limited number of involved people. Often, questionnaires are used to drive (structured) interviews. In the third case study, where we engaged children, we exploited an alternative type of questionnaires, called "pencil-and-paper questionnaire", together with storyboards. This questionnaire typology requires live interaction between the researcher and the engaged people. Finally, the ultimate degree of user engagement is through co-design and participatory design as methods to directly engage some users representing the community of interest in developing the technology (not only in collecting needs and requirements). These methods allow to design the solution for and with the community, and have to do with the technology itself (functions, user interfaces, tools, etc.), not just requirements.

The methods and solutions to adopt depend on the community, the context, the available time and budget, and the number of participants (to name the main apects).

The Exploited Technologies

Technologies vary based on the provided services. Crowdsourcing and data fusion proved to be effective methods to collect rich data while resorting to people. Crowdsourcing has unique advantages: it allows for collecting up-to-date information, data that can not be collected automatically or using sensors, and data related to a vast territory (users just need to have the app). At the same time, it has limitations. First of all, if the crowd does not participate in the data collection or loses motivation, the system becomes inoperable (no data, no functions). For this reason, motivation strategies are fundamental to avoid this risk. This limitation becomes very clear in case study one (urban accessibility).

An IoT infrastructure can be exploited as an alternative to collect data when data can be collected without the contribution of people. In particular, in the second case study, we employed a low-cost passive Wi-Fi infrastructure to count people in a specific location and collect real-time data about mobility flows. Another technology that can be used to know the user's location is iBeacon. In fact, iBeacon sensors can be used to detect a person's smartphone within a short proximity.

In general, when discussing technologies for providing services, it is crucial to design and develop a mobile app. We can highlight two relevant motivations: (1) the widespread diffusion of smartphones; (2) the possibility of knowing the users' location, a piece of essential information when providing services in the context of smart mobility. In the third case study, we intensely focus on the design of a mobile application for children, but, in general, in all the three cases studies, a mobile application was developed. It is important to notice that the app needs to be customizable by the user. In fact, all the apps were developed considering user preferences and needs, making the system personalized and customizable. For example, in mPASS, the user can configure his/her accessibility requirements but also the needs in terms of aPoIs. In the second case study, the app was able to exploit machine learning to learn about the users' habits and suggest more sustainable behavior. In the children case study, the avatar appearance can be personalized based on the child preferences so as the interface and the information to display in the map.

The Engagement Strategies

Gamification (and, more generally, game thinking) has proved to be an effective way to engage different communities of interest. As such, gamification has been employed in all the case studies as a way to motivate users and make them enjoy the provided services. Nonetheless, it is worth noticing that the adopted strategies changed based on the specific community of interest. In fact, one solution does not fit all; contrariwise, it is crucial to design the correct strategy for the specific community. When engaging young adults in the first case study, we designed two different strategies: a gamified app (HINT!) exploiting external motivations and a pervasive game (GeoZombie) exploiting internal motivations. With the former, HINT!, we collected a high number of aPoI reports, since users wanted to receive the voucher (one voucher every six reports). With the latter, GeoZombie, we obtained fewer reports but more distributed across the environment since the virtual zombies ran toward the users, pushing them into areas where reports were missing and needed. In the second case study, gamification was used to engage tourists in two different ways: providing them with original content and virtual gadgets about the visited area, and with basic game mechanics such as badges, leaderboards, and points. In the third case study, children themselves suggested using gamification in the app to personalize the avatar, or to gain points the more they walk or use sustainable means of transportation.

It is important to highlight that gamification is a well-known strategy to answer the need to engage users, but it is not the only one. Over the years, researchers have proven gamification efficacy in motivating users, although it tends to work well only in short-term campaigns. This is one of the main limitations of the use of gamification.

Limitations

As presented and discussed in the previous subsections, all the employed methods or strategies have advantages but also limitations. In general, we would like to point out the main limitation that is common with the three case studies: we developed them as a proof of concept (PoC) to prove that the suggested solution can work in a real word scenario. This means that we did not run them for an extended, continuous period of time; we merely prototyped the system and tested it with the specific community of interest. Although this can be considered a critical limitation, it is essential to unravel the main motivations behind the creation and deployment of the three systems: designing, implementing, and validating smart mobility services, engaging an inclusive and diversified community, and eventually extracting guidelines and best practices to employ in real work solutions. Focusing on these objectives, the developed PoCs proved the feasibility of the proposed innovative solutions.

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