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Towards a Collaborative Model to Assist People with Disabilities and the Elderly People in Smart Assistive Cities

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Abstract: People with disabilities and the elderly face difficulties to fulfill their accessibility needs in their daily life routines, mainly when they have an emergency demanding speedy and specific assistance. This article proposes the SafeFollowing, a collaborative model to help people with disabilities and the elderly in smart assistive cities. The main contribution of this work is the specification of a decentralized model of ubiquitous accessibility, which involves public agents and volunteers to attend the users' requests. SafeFollowing also allows the use of police vehicles mapping, in order to provide a specific follow-up in adverse situations of daily life. The model was validated through experiments in real case scenarios by 14 public agents and 11 elderly and people with disabilities. The results showed that 100% of evaluators (users and agents) stated that the model was useful and 82% of users and 100% of agents considered that SafeFollowing was easy to use. The experiments also allowed the learning of 5 relevant lessons on technological and usability aspects of SafeFollowing that are recorded in this article.

Keywords: social issues, virtual community, collaboration, smart assistive cities, ubiquitous computing
Categories: K.4.1, K.4.2, L.6.1, L.6.2, L7
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1 Introduction

The Brazilian Demographic Census conducted by the Brazilian Institute of Geography and Statistics (IBGE) in 2010, showed that more than 45.6 million people reported having disabilities, which corresponds to 23.9% of Brazil's population. The visual disability was the most cited by the interviewees, about 35.7 million people, 506 thousand of these being blind. 6 million people indicated a profound level of visual deficiency and about 29 million mentioned some level of visual difficulty [IBGE 2011].

According to the IBGE survey, the number of elderly (people older than sixty) has been increasing over the years and already represents 12.1% of the Brazil's population, around 23.5 million people. This number is growing and the forecast for 2025s is that 30 million elderly will be living in Brazil [Silva 2005].

In this context, there is an increasing need for public policies and a specific law that will be able to guarantee this population's rights, as well as stated by the Brazilian Statute of the Elderly [EI 2003] and the Brazilian Statute of the People with Disabilities [EPD 2015]. However, it is also necessary to develop new technologies to meet their daily special needs.

Otherwise, even in developed countries with a high level of digital inclusion, like Sweden, as presented by [Johansson et al. 2020], subgroups of People With Disabilities (PWD) face particular difficulties to achieve digital inclusion. Hence, this project is aware of the unwanted but present inequality of technological inclusion. Also, this work considers people with disabilities and the elderly as potential end-users that have smartphones with permanent internet access.

The popularization of mobile devices, such as smartphones and tablets, brought opportunities for applications that aim to facilitate the elderly lives. These devices are present everywhere and the access to their services often works unconsciously with minimal visibility on the part of the user. This tendency is called ubiquitous computing [Weiser 1999, Barbosa 2015], with which the user has access to several services and interacts with the devices unconsciously. In the same way, the evolution of ubiquitous computing provided applications in areas including health, commerce, games, education, among others. In this sense, new concepts such as U-Learning [Barbosa et al. 2011, Barbosa et al. 2012, Barbosa et al. 2013, Wagner et al. 2014, Abech et al. 2016, Ferreira et al. 2020], U-Commerce [Franco et al. 2011, Barbosa et al. 2016], U-Health [Vianna et al. 2014, Barcelos et al. 2015, Pittoli et al. 2018, Dias et al. 2018, Larentis et al. 2019, Damasceno et al. 2019, Bavaresco et al. 2020, Vianna et al. 2020], and recently the ubiquitous accessibility (U-accessibility), which was first cited by [Vanderheiden 2008] and, according to [Tavares et al. 2016] and [Barbosa et al. 2018], it is the research area dedicated to the application of ubiquitous computing as assistive technology.

The concept of assistive city refers to the accessibility in cities. A city that adopts ubiquitous computing becomes a smart city [Orrego et al. 2019, Zummach et al. 2019]. Therefore, by adding the concepts of ubiquitous accessibility in a smart city, a new paradigm called Smart Assistive City arises [Telles et al. 2019]. The literature describes applications that support ubiquitous accessibility in urban environments. In this sense, Hefestos [Tavares et al. 2016] aims to provide support for people with disabilities and the elderly, taking into consideration their profiles. Through the user profile, the system suggests accessibility features that are recommended to people with similar characteristics and needs. Besides, the recommendation considers the user's location to indicate resources close to them geographically during their movements, using track management and context awareness. Other work named MASC [Telles et al. 2019] also uses the smart assistive city concept. The authors proposed a generic model that supports many types of disability (e.g., hearing, visual, mental). The model allows continuous monitoring of users as they move through the city. The interactions of the users are recorded to compose trails, which are offered as a service.

[Zummach et al. 2019] proposed the AccompCare, which uses mobile devices to create an accessibility tracking model. The model looks for a problem or difficulty that users may be having while they are traveling around the city and enables them to locate people close that will be able to assist them through their mobile devices. The people near them receive a notification on their devices and if they accept the request for help, they can go to the site where the person asked for help to provide assistance. The model also presents the role of Agent (e.g., city guards, firefighters, police, among others). These agents are notified through a Central, which will be activated if there are no volunteers near the person who requested the assistance.

One way to support the most different requests avoiding convergence to the Central is to extend the AccompCare model [Zummach et al. 2019]. So, the users can make specific aid requests directly to the agents. The SafeFollowing model proposes the extension of AccompCare through a predefined list of possible adverse situations that users might face. If the user has selected a specific aid in the list, the application will trigger a notification to particular agents' categories that can assist the user according to their skills. When agents find an unusual situation that they cannot solve, they can request resources or help from other agents at the second level of the collaborative network.

There are solutions proposed for the care of PWD and the elderly in cities [Baranski and Polanczyk 2010, Schlieder et al. 2013, Ferreira et al. 2013, Vergara et al. 2015, Tavares et al. 2016]. However, there is a lack of a proposal that covers the following features: (1) support simultaneously people with disabilities and the elderly; (2) use of an application on the personal smartphone; (3) monitor the users in realtime and support them through the internet in specific situations or emergencies; and (4) support public agents and volunteers in a collaborative and integrated manner.

Therefore, the challenges addressed by SafeFollowing are the collaborative support for PWD and the elderly in adverse situations. The model can help the elderly in a fall situation or wheelchair user in a security issue, for instance. This can be achieved through a distributed assistance made by qualified agents and volunteers in a collaboratively and dynamically way. Thus, SafeFollowing can respond to healthcare, accessibility and security requests from these populations by a mobile application interface over a cloud computing architecture.

The paper is organized as follows. Section 2 presents related works. Section 3 describes the SafeFollowing model. Section 4 discusses the implementation aspects. Sections 5 and 6 deal with case studies and evaluation results. Section 6 also contains the lessons learned. Finally, Section 7 presents the conclusions and directions for future work.

2 Related work

This section presents research papers that aim to assist people with disabilities and the elderly in cities. The works used ubiquitous computing and provided support (assist, monitoring or follow-up) to the user.

A mobile application named Acompáñame [Vergara et al. 2015] proposed to help caregivers to assist their patients. The application has two leading roles in the system: caregiver and patient. Although both roles have similar characteristics, the caregiver can control the application and defines geographic areas where the patient can go. The caregiver's view has a map that shows the patient's location. The caregiver can also invite others, find places or patients nearby, and check if the patient leaves the safe zone.

[Baranski and Polanczyk 2010] proposed a remote guidance system for people with visual disabilities called RGSBlind. The application has two parts: a remote operator terminal and a mobile terminal. The mobile terminal has a digital camera, a GPS receiver, and a headset, which connect through a smartphone with Bluetooth, GSM or Internet wireless network. The terminal connections send real-time video through the handset camera, while the location data is obtained through the GPS receiver. Thus, the remote terminal operator can guide the visually impaired to reach their destinations, warning them of dangerous obstacles that may be in the way.

MoNa (Mobile Neighborhood Assistance) [Schlieder et al. 2013] is a platform to promote support for external accessibility in residential neighborhoods. The platform provides support for the permanent or temporary identification of barriers, as well as recommendations for alternative routes through the Geo-Wiki component. The barriers depend on people's disabilities, which can be the streets, guides of the elevated sidewalks, or even a bus stop with precarious illumination at night. The system can also look for volunteer assistance to overcome mobility impairments or to find partners for joint outdoor activities through a Matchmaking component. The volunteer support can assist people to overcome barriers. For instance, a neighbor can help a person to walk up a stair or assist someone at the bus stop at night.

Hefestos [Tavares et al. 2016] provides ubiquitous accessibility support for people with disabilities. The model offers accessibility features in real-time, according to the user profile. Hefestos uses four concepts: user profile, special needs, context, and track. The model uses the data to suggest accessibility resources based on user profiles and special needs. The system also considers features from other users behavior through log tracking. The suggestions are made during their movement, suggesting mapped resources that are in the same environment or close to the users. The main focus of the model is to provide to the person with disability or the elderly a more independent locomotion experience and improve their movements.

[Ferreira et al. 2013] proposed a mobile health application for a model called Protege. The application is available on Android smartphones with a custom user interface, which enables better communication between the elderly and the caregiver. The Protege main feature for the elderly is a help request (SOS) that works according to an algorithm that performs the following sequence: it tries to get the GPS location, it sends an SMS with the GPS location to the caregiver and it makes a phone call to the caregiver as a last resource. The SMS sent to the caregiver includes location, time, a custom text message, and a link to Google Maps. The elderly can send SMS messages with free-text or predefined texts to the caregiver.

Table 1 shows a comparison between the works. The study expands the criteria proposed by [Zummach et al. 2019] with additional criteria considered strategic for SafeFollowing.

– **User type:** It identifies the user type, namely people with disabilities and the elderly;
– **Device:** It identifies the device used in the work, which could be smartphones, tablets, and similar devices;
– **Monitoring:** It evaluates if the system monitors users and their locations. Three groups are possible: real-time, partial, or none;
– **Support communication:** It identifies the way that communication occurs between the user and the system. There are five options: Internet, SMS, E-mail, Phone call, Other;
– **Support type:** If the work has the support service, the comparison identifies how the request will be made, which could be centralized (only one person receives the support request) or distributed (more than one person receive the request);
– **Support agents:** It identifies if the system supports qualified agents for specialized care;
– **Specific support:** It indicates the possibility of specifying the type of aid that the user needs.

	Acompáñame [Vergara et al. 2015]	**RGSBlind [Baranski and Polanczyk 2010]**	**MoNa [Schlieder et al. 2013]**	**Hefestos [Tavares et al. 2016]**	**Protégé [Ferreira et al. 2013]**
User type	PWD	Visually impaired	The elderly	PWD	The elderly
Device	Smartphone	Own	Smartphon e	Smartphon e	Smartphone
Monitoring	Real-time	Partial	Partial	Real-time	Partial
Supp. com.	Internet	Internet	SMS/Email	SMS	SMS/Phone call
Supp. type	Distributed	Centralized	Distributed	Centralized	Centralized
Support agents	No	No	No	No	No
Specific support	No	No	No	No	Yes

Table 1: Related work comparison

None of the analyzed works addresses all highlighted criteria. Hence, there is an opportunity to develop a model that approaches all of these: support people with disabilities and the elderly, use smartphones (as they are widely used devices), monitor the users in real-time, offer support through the internet for specific situations or emergencies and support public agents with their resources in a collaborative and integrated manner.

3 SafeFollowing model

This section presents the proposed model, mainly its principles, ontology and architecture.

3.1 Principles

The SafeFollowing model uses AccompCare [Zummach et al. 2019] as a basis, enabling requests for special monitoring. The SafeFollowing changes the role of the agent in the system, which starts to use the application more actively. In this way, SafeFollowing can be seen as an extension of AccompCare.

AccompCare is a model for tracking and assisting people with disabilities and the eldery in their displacement in urban environments. It uses mobile and ubiquitous computing to provide accessibility services. The focus of this model is to offer help to people seeking collaborators and, not finding them, directing the request to a remote call center. The call center can guide the user through the resources of the mobile device [Zummach et al. 2019].

The SafeFollowing consists of a mobile application, which allows people with disabilities or the elderly to ask a simple Request for Assistance (RA) or a Specific Request for Assistance (SRA). For the RA, the application sends a notification to volunteers who are nearby. In the SRA, there will be a list with predefined options for the user to choose according to the type of assistance needed at that time. According to the user's choice, the SRA will request one or more agents' categories taking into account if the agent has skills with the type of disability that the user has.

SafeFollowing also provides the agent with the possibility to make an Enforcement Request (ER). ER enables agents to request help from others (from the same or different category) if they cannot help users alone or do not have the necessary resources. For this, the agent can check on the map where the other agents are and what type of vehicle they are driving. The agent profile must include the types of users which they have skills or similar qualifications. On the registration step, users must inform categories according to the organization that they belong to. On the authentication, agents must inform the user if they are walking or have any vehicles. This information is necessary for the scheduling of SRAs. SafeFollowing targets an appropriate agent for each specific type of aid, as well it makes the proper mapping of the agent or the vehicle in the system.

3.2 Ontology

SafeFollowing has the six profiles encompassed in AccompCare: People with Disabilities (PWD), Elderly, Volunteer, Agent, Attendant, and Administrator. However, the agent profile was expanded and divided into categories according to the institution that they belong to. The profiles creation is directly related to the operations that each person can perform through the applications that communicate with SafeFollowing. The agent categories are essential for the scheduling of SRAs. Hence, the agent profile was modified according to the professionals who generally work in the cities. Figure 1 shows that the original ontology is an extension of the ontology proposed by MASC [Telles et al. 2019].

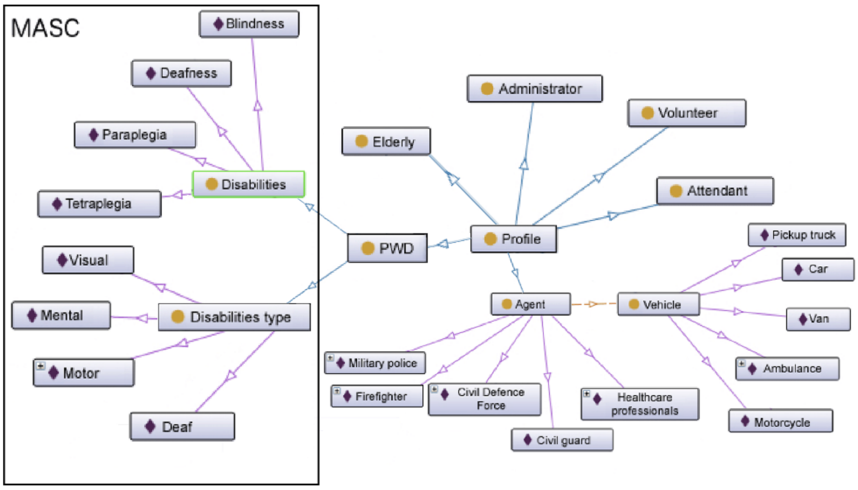

Figure 1: The SafeFollowing ontology for representation of profiles

SafeFollowing proposes changes in the profiles through the following new descriptions:

– **PWD and the Elderly:** These descriptions refer to people with disabilities and the elderly. The PWD or the elderly can use SafeFollowing to create the requests of RAs and SRAs aiming to receive the care of volunteers or agents. For all types of disabilities, SafeFollowing considers at least a medium level of impairment. The ontology summarizes the accepted types of disabilities;

– **Agent:** They are public employees who have the qualification to assist the users. The agents are classified into five categories: Military police, Firefighter, Civil Defence Force, Civil Guard, and Healthcare Professional. Almost all cities have most of these categories that represent professionals who generally act on the streets. The communication with the users and the Agent Center is carried out through the mobile application, in which the agent must have a registration. To perform the authentication, the agents must also inform if they have or not vehicles and which the types that they are working with, and also what types of disabilities care skills they have. This information is essential for targeting SRAs.

3.3 Architecture

Figure 2 presents the SafeFollowing architecture. The architecture is made up of the client application SafeFollowing App, the services offered by the Firebase[1] (database, cloud messaging and notification service) and a server that performs communication with these services. The SafeFollowing server also communicates with the AccompCare server.

The application features are available through five modules. The Authentication focused on all profiles of the system, it allows the access and registration of users to the application through email and password. It also checks the authenticated user type and

[1] https://firebase.google.com

directs it to the corresponding module. The Agent module supports the agents allowing them to receive or disable SRA calls besides receiving or requesting reinforcement requests, check nearby agents on the map or change their information (name, vehicle, and disabilities skills). The User module allows users to follow the request of RAs and SRAs, which are stored in the database and sent to the nearby agents and volunteers according to the type of assistance requested. The user can set a time-out limit in case of no volunteer or agent accepts the request. In this case, the request is canceled and removed from the database. The Volunteer module allows the volunteers to receive or disable requests for RAs, as well as to change their personal information. The push notification service receives Firebase Cloud Messages (FCM server messages)[2] with the order information. This service also checks if the application is running foreground when it receives a message, in which case, a dialog box on the user's screen is prompted; otherwise, a notification is displayed in the smartphone notification tray.

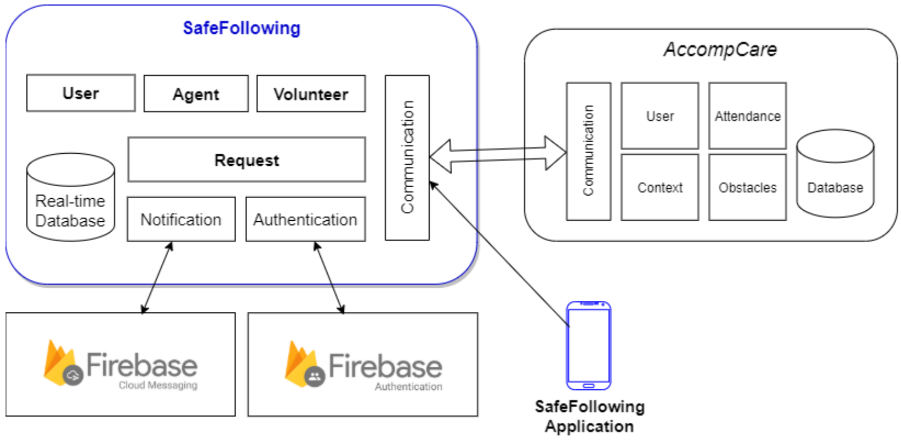

Figure 2: The SafeFollowing architecture

The SafeFollowing server communicates directly with the database through event-oriented functions. If the user triggers a RA, the application creates a record in the database and then triggers an asynchronous function responsible for determining which attendants are supposed to receive the notifications this time. The function uses an algorithm that checks the user who requested the assistance data and performs a search in the database of the attendants, to check if they contemplate the requirements of the request, in the following order:

– **Monitoring type:** This feature is designed for RAs, search for volunteers, and agents;

– **User impairment:** This requirement is verified only for SRA requests, giving preference to those agents that have skill with the respective user disability;

– **User location:** The algorithm calculates the approximate distance between the request and the attendant using the latitude and longitude, which are updated continuously through the device's GPS location. For RAs, the maximum distance

[2] https://firebase.google.com/docs/cloud-messaging

considered is 300 meters. However, for SRAs the distance limit is 10 kilometers, since agents may be using vehicles and the displacement can be done in a shorter period. This metric was defined as an average distance from downtown to peri-urban areas of a Brazilian medium-scale city.

When there are attendants located near the user who requested the assistance, the user's requirements are compared to the attendant's care skills. If the attendants can fulfill the requirements, the server will request the endpoint of the Firebase Cloud Messages server, which is in charge of notifying it. Once the first agent accepts the request, the call is then marked with a tag and disables it for the others who also received the notification. In this way, the application could ensure that only one agent can carry out assistance. In case of multiple requests from different users arrive simultaneously, the server prioritizes by the level of disability before notifying the attendant.

Figure 3 shows the classes with relationships and attribute types. The SafeFollowing's class diagram determines the integration between the request and the user information that was requesting assistance. The User class has the main characteristics that shape the profile of the individual who will benefit from the application. The class has the identification, location, and type of agent, which are crucial information to ensure efficiency in activities. The Request class displays the identification, order status, and information that facilitates communication with the agent.

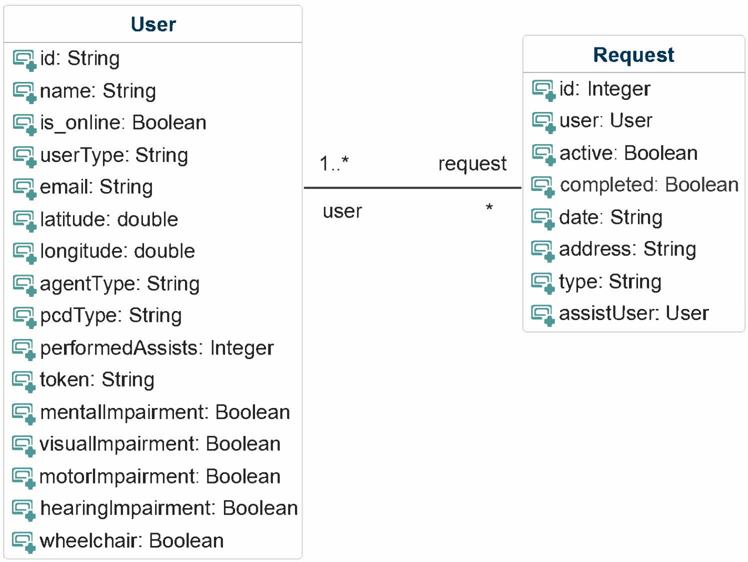

Figure 3: The SafeFollowing class diagram

4 Implementation aspects

This section describes the implementation of SafeFollowing, focusing mainly on the development of the prototype and the tools used in this process. The model application was developed for mobile devices using the Android Studio programming environment (version 3.1.2), Java 8, and XML programming language. The SafeFollowing Android SDK minimum target was set to 21 (version 5.0 of Lollipop), which currently covers 84.7% of the devices that own the operating system according to the Android Team[3]. The data persistence used Firebase NoSQL database, which communicates directly with the application through the methods that its API provides for reading and writing data. The update takes place in real-time whenever changes occur in the monitoring data nodes. The monitoring triggers use event-driven methods that watch a particular node and execute the scheduled action when data was changed, without the need for periodic database queries to check for any changes.

Notifications are sent to the FCM service using a token (unique identifier), which is associated to each application instance. When users perform the authentication in the system, they receive a token from the instances, which are saved in their database users registries. The server is in charge of defining which tokens the notification should be sent to. The server is an application coded with NodeJS[4], hosted at the level IaaS (Infrastructure as a Service) of cloud Google Cloud Platform[5] and implemented with the Software Development Kit (SDK) Firebase Admin[6] to communicate with the database. Through the events of the database's request node, the server will be activated and, according to the request information (user location and type of follow-up), it will search in the attendants' register those who meet the conditions to receive the request monitoring. It then sends an HTTP POST request with the request information and the corresponding token of the user in the body of the message to the endpoint of the FCM server, which will be responsible for sending notification to the destination user.

Figure 4 shows the prototype screens obtained from tests in scenarios where users and agents interact with SafeFollowing. Authentication allows to fill the email and password. If users do not have a registration, they must click on the register button and they will be taken to the registration screen. Figure 4a shows the users' main screen when they perform the authentication, allowing them to request an RA or an SRA. The request can be canceled at any time.

The agent receives a notification about the SRA if the application is in the background with the options to accept or decline the request. If it is in the foreground, the main screen shows a dialog box. When accepting the request, the agent receives a screen with the following request information: user data, address, type of aid the user needs and the approximate distance to reach the user, as well as a map showing the location (Figure 4b). Similarly, the user who requested the follow-up sees a screen with the information of the agent that accepted it and can cancel the request or conclude it at any time, according to Figure 4c. Figure 4d displays the agents' information and an avatar according to the institution to which they belong to.

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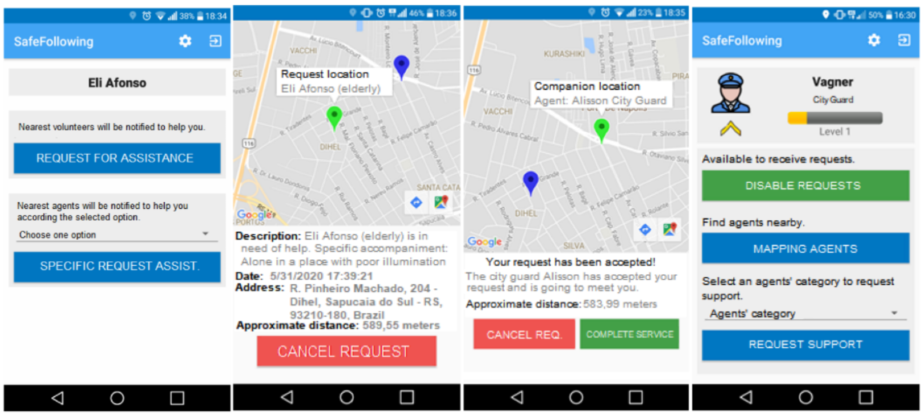
[3] https://developer.android.com/about/dashboards/

[4] https://nodejs.org/en/

[5] https://cloud.google.com/?hl=en

[6] https://firebase.google.com/docs/admin/setup?hl=en

The application has additional features as follows:
– **Map Agents:** The agent can visualize on the map the location of all active agents in the system and the type of vehicle they are driving if they are not walking;
– **Request support:** If agents are unable to assist the users or encounter situations that require the help of another professional, they may request an Enforcement Request (ER) by selecting the category of agent required for that care. All agents in the nearby selected category receive the ER notification;
– **Preferences:** Agents can check data and update information, such as the vehicle they are driving, what types of disabilities care skills they have, and their names.



(a) (b) (c) (d)

Figure 4: Users' screenshots

The initial screen of the volunteer contains the button that activates or deactivates receiving RAs. When accepting an RA request, the volunteer gets directed to a screen similar to the agents' screen, which has information about the user who requested the assistance and a map with the user's current location.

5 Case studies

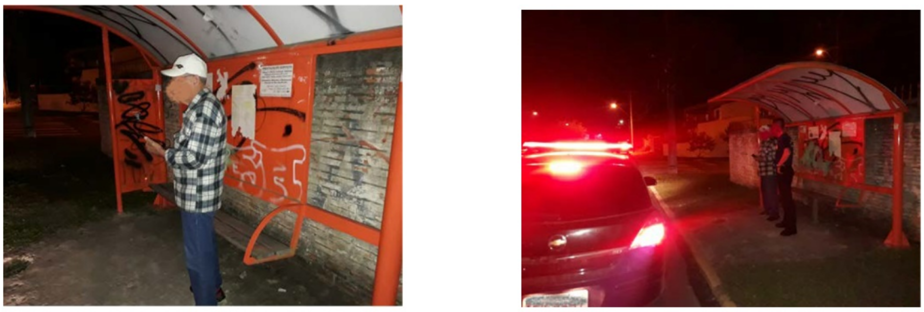
SafeFollowing evaluation consisted of two scenarios. The academic community has been using this approach to validate ubiquitous systems [Satyanarayanan 2001, Tavares et al. 2016, Barbosa et al. 2018]. The two scenarios counted with the participation of users and agents for the validation of the model. Scenario A describes a situation in which an elderly needs special care provided by an agent. Scenario B describes an agent who helps a wheelchair user. When the agent arrives at the place, he needs to demand an ER to assist the user.

The scenario A is the following:

Eli, an elderly man who was attending a hospital, goes to the nearby bus stop to await his driving. After a few minutes, the other people who were there already took their destinations, and he was alone at the bus stop. Even so, it is already night and the place in question has low light, so it generates the SRA in this circumstance (Figure

5a). Faced with this situation, Eli feels insecure and afraid of being mugged, so he decides to use his SafeFollowing application. It performs authentication with e-mail and password and on his home screen, he requests the option "Alone in a dark place".

Alisson is a city guard and uses the application while on duty. He is close to this bus stop and receives a notification about the call. Alisson accepts the request and moves to the user's location, obtained through the information available on the screen (Figure 4b). Meanwhile, the elderly man gets notified that his request got accepted, and from there, he can follow the agent's displacement on the map (Figure 4c). Arriving at the scene, Eli reports to the agent that he is alone and waiting for his bus. Eli, faced with the current violence levels, asks as much as possible that he stays there for a few minutes accompanying him. The agent understands that it is a situation of vulnerability and remains in place to provide greater security to the elderly (Figure 5b). Finally, after a few minutes, Eli takes his bus and completes the service in the application.



(a) (b)

Figure 5: Actors' interaction on scenario A

The scenario B is the following:

Rogerio is a wheelchair user who lives in a place with no accessibility and he has to go to a bank downtown. However, the buses do not pass through his street and the neighbors who usually offered rides are not at home. Then, Rogerio uses the SafeFollowing application (he already has a registration) to request an SRA with the option "Lack of mobility" (Figure 6a).

Vagner is a city guard that is close to the Rogerio location and receives a notification about the call. The agent accepts the request and goes to the address to check the user's need. Arriving at the location (Figure 6b), Vagner realizes that he will have to transport Rogerio but will not be able to do it himself. Thus, in the initial screen of his SafeFollowing application (Figure 4d), Vagner triggers the MAPPING AGENTS button to check if there is any agent nearby with a vehicle to assist in the help request. The SafeFollowing map identifies that there is a civil defense agent who drives an ambulance near them. Then, he comes back to the application's main screen and triggers the REQUEST SUPPORT button with the "Civil Defense Agent" option selected.

Cunha is the civil defense agent who receives the notification about the ER. He accepts the request and goes to the service location. Arriving at the scene (Figure 6c), *both Cunha and Vagner place Rogerio in the vehicle to take him downtown (Figure 6d).*

Figure 6: Actors' interaction on scenario B

6 Results

After performing the SafeFollowing tests on the scenarios, a questionnaire based on the Technology Acceptance Model (TAM) [Davis 1989, Marangunic and Granic 2015] was presented to agents and users. At the questionnaire, subjects answered questions regarding their profiles, the perceived utility, and the usability of the application.

The questionnaire consisted of ten statements about the experience of using the SafeFollowing. The statements could be classified employing a five-point Likert scale [Likert 1932]: Completely Disagree, Disagree, Indifferent, Agree and Completely Agree. The questionnaire items were elaborated based on the concepts of the Technology Acceptance Model (TAM) proposed by Davis [Davis 1989] and expanded by Yoon and Kim [Yoon and Kim 2007] in their study on the acceptance of wireless networks. The TAM has been considered a standard for the evaluation of the acceptance of new Technologies [Marangunic and Granic 2015]. The TAM model considers two main factors for the acceptance of a new technology: (1) the degree to which users believe the technology could reduce their effort (Perceived ease of use); (2) the degree to which users believe the technology could improve their performance (Perceived usefulness).

At first, the questions intended to analyze the profile of the interviewee, being: gender, age, education, experience in information technology. After, ten assertions were made regarding the validation analysis of the technology. The first five statements (items 1 to 5) on Table 2 refer to the perceived usability of SafeFollowing and the other five statements (items 6 to 10) are related to the proposed model utility. Finally, the subject could write critiques, compliments or suggestions for each question or the application.

Item	Statement
1	The SafeFollowing application is easy to understand
2	It would be easy to become adept at the SafeFollowing application
3	The request information for specific monitoring gets displayed in a clear and objective way
4	No effort is required to use the features available on SafeFollowing
5	No significant prior experience in technology resources is needed to utilize the features available on SafeFollowing
6	The use of SafeFollowing encourages accessibility and contributes to public safety
7	The SafeFollowing application could assist me in an emergency
8	The service provided by the SafeFollowing agent was efficient and helped me
9	The SafeFollowing application encourages the integration between agents
10	The SafeFollowing application would be useful to support the accessibility of people with disabilities and the elderly in adversities that may occur in their daily lives

Table 2: Model evaluation questionnaire

Two groups answered the questionnaire (users and agents). The first group consisted of users that interacted with the application during both test scenarios and users that had contact with the application during a presentation that demonstrated all features. In the second group the city guards, civil defense agents and other agents who also participated in the SafeFollowing demonstration answered the questionnaire.

The first group consisted of 11 users, 3 people with disabilities and 8 elderly, according to Figure 7, being 54.5% male and 45.5% female (Figure 7a). About 72.7% of people were over 60 years old (Figure 7b), 9.1% were between 41 to 60 years old, and 18.2% less than 40 years old. The education level answers reported that 63.6% have secondary, 27.3% only primary, and 9.1% have incomplete higher education (Figure 7c). Finally, about the experience with technology, 63.6% claimed to have a good level and 18.2% have an excellent experience and 18.2% a regular one (Figure 7d).

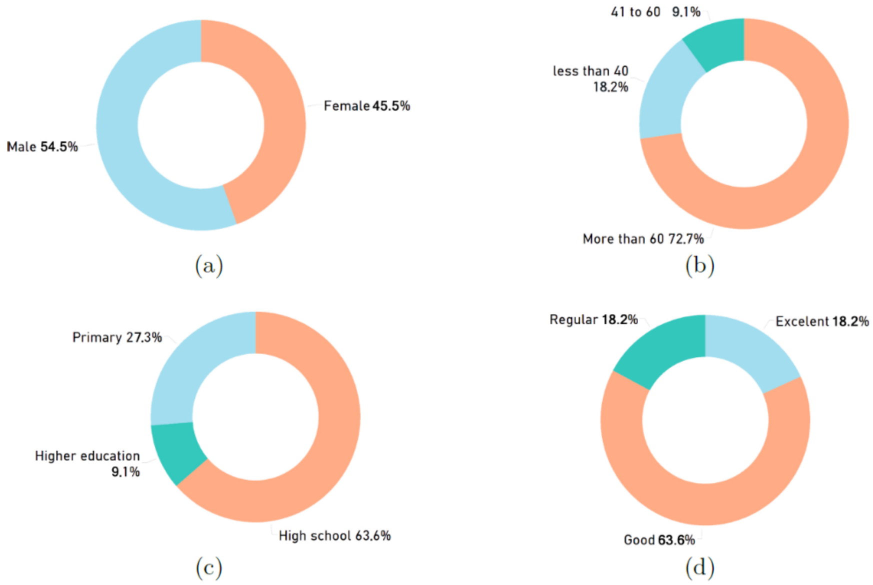


Figure 7: First group interviewees profile

The perceived ease of use answers (Figure 8a) obtained satisfactory results. About 82% of interviewees evaluated positively, which 18% answered “Strongly Agree” and 64% “Agree”. Also, 18% answered “Indifferent”, which can be explained by the lack of computer experience of some users, since the group is mostly composed of elders, who have greater difficulty in dealing with new technologies [Tavares et al. 2016]. As reported in an elderly comment: “The application could have an instruction manual to help those who have more difficulties”. Finally, regarding perceived utility, the acceptance was even higher, reaching 100% of interviewees’ approval, which 64% answered “Strongly Agree” and 36% “Agree” (Figure 8b). One user ratified this result in the general comments section: “This project is very interesting because many times we need some help on the streets and we do not know how and to whom to turn” and “This application would be of great use for all of us, besides being a new alternative to call for help in emergencies”.

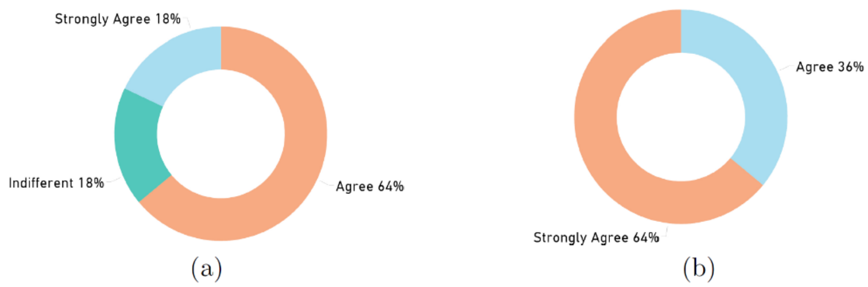


Figure 8: People with disabilities and the elderly answers

The second group consisted of 14 public agents (10 city guards and 4 civil defense agents). The profile of the interviewees was composed of 78.6% males and 21.4% females (Figure 9a). About of 42.9% interviewees were between 25 to 35 years old, 35.7% between 36 to 45 years old, and 21.4% between 50 to 60 years old (Figure 9b). The education level answers reported that 42.8% have secondary, 28.6% have incomplete secondary, and 28.6% have higher education (Figure 9c). Finally, about the experience with technology, 42.9% claimed to have excellent knowledge, 42.9% good, and 14.2% regular (Figure 9d).

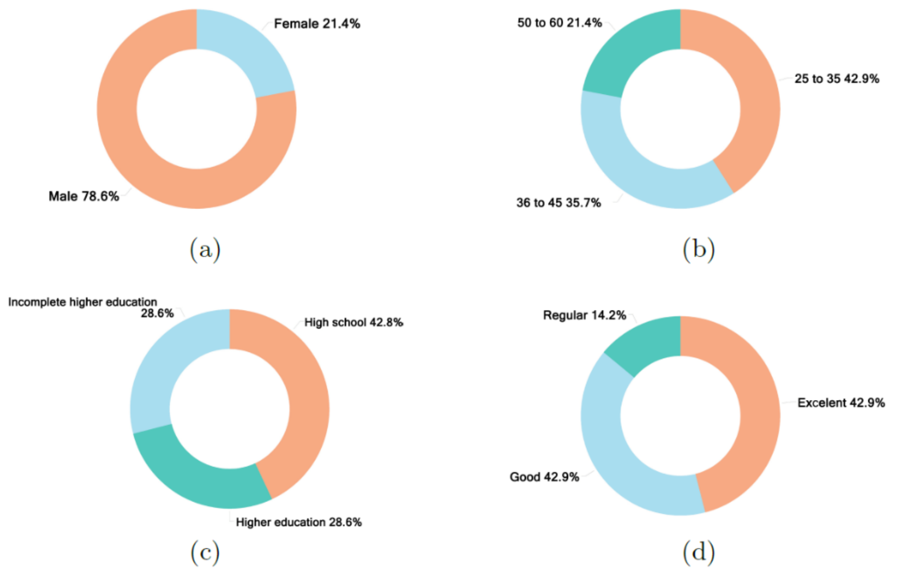


Figure 9: Second group interviewees profile

The perceived usability answers (Figure 10a) acceptance was 100%. About 67% of answers reported "Strongly Agree" and 33% "Agree", which is higher in comparison with the people with disabilities and the elderly group since the agents use technological resources in their daily activities. Concerning the perceived utility, the answers also obtained a high acceptance rate. About 79% "Strongly Agree" and 21% "Agree" (Figure 10b). These results could also be interpreted in agents' comments: "This tool would greatly facilitate our communication and could be used not only to help the elderly and people with disabilities but also to other occurrences that we work" and "I really loved the project, when the more resources we have to help the population, better will be the service provided. Congratulations!".

Finally, there are lessons learned from this work. The research focused on smart assistive cities [Telles et al. 2019], so the lessons were organized into two groups, that is, technological and usability lessons. Table 3 shows the five lessons considered the most strategic. The first three are related to technology and the last two focus on usability. Lessons were learned mainly during the experiments and, more specifically, usability lessons were learned not only by observing the agents and users while using

SafeFollowing but also by objective results and comments obtained in the questionnaire.

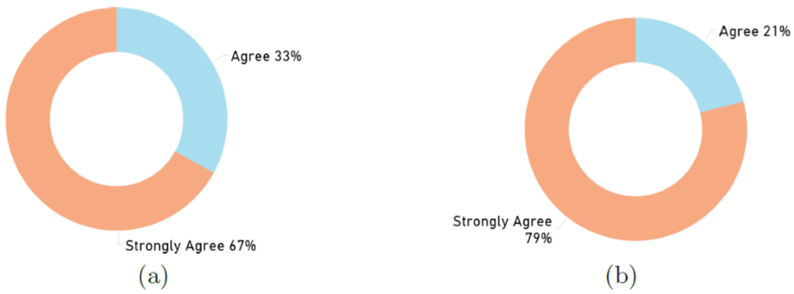


Figure 10: Agent group answers

Item	Lesson	Description
1	The SMS as an alternative and integrated communication	The SMS channel could be automatically used by SafeFollowing in cases of inferior quality of mobile internet connection or even in countryside places without an internet connection. The *notification* module could be improved to detect quality and connection availability and exchange the output message channel sending an SMS to a proxy that forwards the request for a qualified agent or volunteer.
2	Integration with wearables and healthcare devices could be helpful	The automatic integration of healthcare devices and wearables with SafeFollowing App could be useful not only to expand the possibilities of monitoring but also to overlap the difficulties with smartphones reported by some volunteers. The users with severe limitations also could benefit from more unobtrusive interfaces.
3	The biometric authentication can facilitate accessibility for users with lower digital experience or PWD	The specialized interface using voice, face or other biometric features could promote more accessibility for the elderly, PWD and people with low experience using smartphones.
4	The simple and accessible interface with a map is fair	The volunteers reported facility in the use of the clean and simple interface of SafeFollowing. The minimalist functionalities endossed by high metrics of evaluation corroborate to validate with this design pattern choice. The map view was approved by users, volunteers, and agents.
5	The *Request Support* is a highlighted feature	The agents detached that this feature is very important and could be expanded, enabling integration with more types of government agencies and civil institutions. This expansion could promote a bigger, and multi qualified support network for people with special needs.

Table 3: Lessons learned

7 Conclusions and future studies

This study proposed SafeFollowing, a model to assist the elderly and people with disabilities who are in adverse situations. The literature research showed an opportunity to propose a model that provides collaborative assistance to the accessibility of people with disabilities and the elderly in specific circumstances in daily lives due to their disabilities. SafeFollowing allows the participation of agents, who act in a collaborative, integrated, and dynamic way to provide help to these people. The features are made available through a mobile application - which is already part of people's lives - allowing interaction between users, volunteers, and agents (in real-time) with this new technological tool for social inclusion.

SafeFollowing was evaluated through scenarios with agents and users (people with disabilities and the elderly) to prove the model's usefulness. Based on the analysis of the questionnaire results, a high user acceptance of the usability and utility was observed. The results showed that 100% of answers (agents and users) stated that SafeFollowing was useful, providing not only an assist during the displacement of users in the city but also help in specific situations. Additionally, the results regarding the perceived ease of use showed that 82% of users and 100% of agents considered that SafeFollowing does not require much effort to use.

The main contributions of this work are: (1) the specification of a generic model of ubiquitous accessibility, which involves agents to attend people with disabilities and the elderly when they need assistance or help, either because of lack of mobility or because of any unusual situation they may require of a more qualified service; and (2) the social contribution, because SafeFollowing is a resource, which supports the inclusion of people with disabilities and the elderly in society. It contributes to public safety and encourages the improvement of the services provided to the population.

Future works will extend the model to attend the population in general, allowing people to request service to the agents for other types of occurrence, as commented by the users who answered the questionnaire. Another opportunity came from the model communication module, where agents could exchange messages regarding monitoring requests to provide better assistance to users. Crowdsourcing in assistive cities could be helpful to wider coverage for people with special needs [Orrego et al. 2019]. Additionally, health organizations and specialized companies could be invited to participate in future improvements and evaluations, especially the Freedom Company[7], which is the largest manufacturer of electric wheelchairs in Latin America and partner of the authors' lab (Mobilab)[8] [Tavares et al. 2016]. The evaluation process could be extended with de facto usability data to correlate with user-perceived usability and utility. Also, a larger period and higher amount of testers in the assessment process could qualify the results. The historical records of users' requests and needs could be used to make predictions and recommendations [Da Rosa et al. 2016, Barbosa et al. 2018]. The performance and scalability evaluation could contribute to the analysis of a large adoption of the SafeFollowing. Finally, future studies could create a gamification module on the SafeFollowing to increase engagement and user satisfaction [Dias et al. 2018, Dalmina et al. 2019].

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[7] http://www.freedom.ind.br

[8] http://professor.unisinos.br/barbosa/mobilab/index.php?lang=en

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