Interactive guiding and localization platform

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ABSTRACT

Technology is now part of everyone's life, being widespread and present in the most innocuous objects, making people able to benefit from several technological solutions that only a few years ago were impossible to be implemented. For instance, the smartphone is one example of this type of technology. Usually, this device is equipped with several sensors and a GPS module, which may be used as an orientation system when it carries the right features. The current trend is providing advanced applications to the common public, excluding some fringes of the population, like the people with cognitive disabilities. Thus, everyday technology can be used for helping on several tasks, becoming an interactive terminal, aware of the user conditions. There may be orientation applications that are too complex to be used by people with cognitive disabilities. Therefore, the main goal of this work is to build and implement an orientation method that may be used by people with mild cognitive disabilities and provides several tools to the caregivers. Furthermore, the system is linked to external services like iGenda so the user is stimulated to go outside and increase his/her social participation or not to miss an appointment. The developed system is also a localization system, enabling caregivers to know in real-time the location of the person with cognitive disabilities. Allowing the user to have an independent life.

Keywords: Cognitive Disabilities, Mobile Communication, Localization, Orientation, Person Tracking, Ambient Intelligence.

Computing Classification System (CCS) : I.2.11

1 Introduction

A new paradigm has resulted from aged populations (United Nations, Department of Economic and Social Affairs, 2011; Instituto Nacional de Estatística, 2012), this type of population is very costly to the countries' social security systems, and to take care of them facilities like nursing homes or services like caregivers are needed. The use of these alternatives implies the loss of independence of the elderly, some forcing them to leave their house while others may let the person to stay in his/her house with a caregiver, which may be a relative or not, exponentially increasing the costs to the user.

This loss of independence may be overcome by using the concept of smart houses (Sadri, 2007). Besides being physically versatile, the smart house do not restrict the user movements

(Augusto and Mccullagh, 2007). The objective of this technology is to provide comfort and safety to the user. It may also monitor the user health through embedded devices in the environment. These devices may allow a remote access to the obtained information by a physician or other caregiver (Augusto and Mccullagh, 2007; Carneiro, Novais, Costa, Gomes, Neves, Tscheligi, De Ruyter, Markopoulus, Wichert, Mirlacher, Meschterjakov and Reitberger, 2009; Stefanov, Bien and Bang, 2004). A smart house is a good alternative to keep the user independence, but it has a drawback: the user may only be monitored when he/she is inside the house. This disadvantage may limit the person's independence, being constricted to the house boundaries, and relying in external services or people for the additional tasks, since the person may not be able or medically allowed to go outside alone.

The capacity to improve the functional needs of people with cognitive disabilities has increased the interest and the attention on assisted technologies since 1988 (Alper and Raharinirina, 2006). The development of some projects in this field has increased the awareness of the general public to the usefulness of assisted technology on the life of people with cognitive disabilities and how their life quality could be improved.

The developments made so far are very significative and were not exclusive to the development of new devices, covering other areas like Health. In this field new diagnostic techniques have been created/discovered and some existing ones have been enhanced. Thereby the well-being of people has grown. However, despite all the progress, there are some diseases that still do not have a cure like Alzheimer, Down's syndrome, among others. According to the severity of the cognitive disabilities the person may have a normal life (when the disability is mild) or may need help in every task of the day (when the disability is severe), not being able to live alone.

Although smart houses are now available to people in need, they lack in mobility, thus, not being an answer to people that are physically able to leave the house. Thereby researchers have been developing new ways to assist people with cognitive disabilities when they are outside, so they may have a normal life and actively participate in the society (Cesta, Cortellessa, Giuliani, Iocchi, Leone, Nardi, Pecora, Rasconi, Scopelliti and Tiberio, 2004; Pellegrino, Bonino and Corno, 2006; Mulvenna, Bergvall-KaŁreborn, Wallace, Galbraith and Martin, 2010). To accommodate the users conditions a set of requirements must be met, thus, the devices developed to assist these people must be easy-to-use, small, lightweight and resistant, so the person may easily use and carry them, otherwise the user may lost the interest and may not use it (Dawe, 2006; Dawe, 2007; Novais, Costa, Carneiro and Neves, 2010).

In (Ramos, Anacleto, Novais, Figueiredo, Almeida and Neves, 2013) we describe our system and present an archetype. Our developments provide an orientation method for people with mild cognitive disabilities so they may go outside and travel by themselves without getting lost. The system also enables the caregivers to know in real-time the current location of the person with cognitive disabilities. Thereby, the independence of the caregiver is also increased since he/she may do another activity without neglecting the provided care.

Section 2 presents in detail some of the work developed by other authors in this area. In Section 3 is described in detail the proposed system including all its features and the link to external services like iGenda (Costa, Castillo, Novais, Fernández-Caballero and Simoes, 2012). Finally, at Section 4, a brief reflection about this work is presented including future lines of development.

2 Related Work

Dawe (2005) started her research by analyzing the usability challenges and the user needs of a handled remote communication system for people with cognitive disabilities. Through 20 semi-structured interviews the author found three major aspects when developing and adopting new technologies to assist people with cognitive disabilities. The first finding was that the adoption of assistive technologies, besides involving several caregivers, is a staged process. The second finding was that caregivers believe that technology has potential to increase the independence and the social interaction of this people. Lastly the author found that there are some barriers in the adoption of new technologies like the complexity when the user is setting up the device.

Also in (Dawe, 2006; Dawe, 2007), it is shown how useful a simple cell phone could be to a person with cognitive disabilities and how this device could improve the life quality. Through this device the user could interact and communicate with other people like family, caregivers or friends. This project was successful, thus providing it's feasibility.

Based on the conducted research the author developed an application, as seen in Figure 1, that has simple interfaces with several pictures that act like buttons, which could start or receive calls. The application also have a voice memo to alert the user for incoming activities and a programmed remainder.

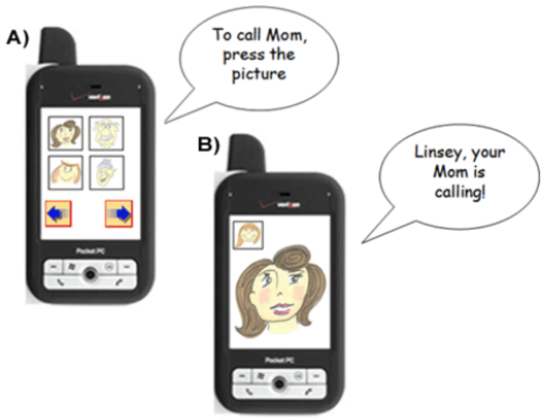

Figure 1: Simple user interface developed in (Dawe, 2007): A) making a call; B) receiving a call

In order to stimulate the user and to create an application that fullfils the user needs, people with cognitive disabilities have participated in the development of the application. The author concluded that the system improved the interaction of the users with the surrounding society.

In (Carmien, Dawe, Fischer, Gorman, Kintsch and Sullivan, 2005) the authors developed a system that helps people with cognitive disabilities to travel by themselves using public transportation, namely the bus. Before developing the system, the authors studied the traditional techniques used by these people to travel, using routes like home to school/office. Using a standard bus map each user creates its own map by coloring the important routes (Figure 2a)) and highlighting significant landmarks. To increase the number of possible destinations each user has a set of time cards (Figure 2b)). This cards were used to travel to other destinations like the shopping center or a friend house. The paper cards have information about the bus route and the schedule.

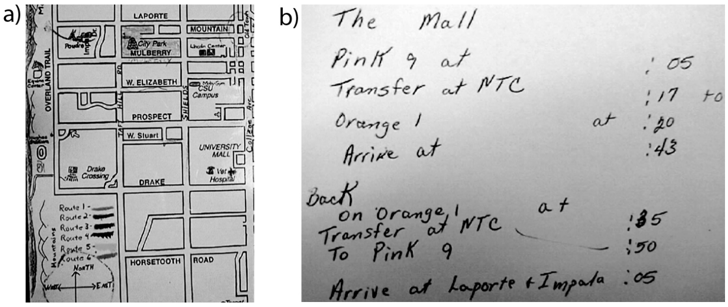

Figure 2: Traditional artifacts personalized during training (Carmien et al., 2005): a) Personal colored map; b) Time cards

The architecture was developed after the first analysis. In this system the time cards and maps, that were initially used by the user, were replaced by a PDA. This project has two main goals: assist the mobile user through just-in-time information for several tasks, which includes information related to the travel path (the route that the user should do and the bus that should be used); create a communication channel between the user and the caregiver.

The developed prototype, based on this architecture, is presented in Figure 3. After the selection of the destination in the application menu (left side of the figure) by the user, the system calculates the route based on the information stored in the server. This information includes the real-time position of the bus (visible on the right side of the figure), which is given by a GPS module installed on the bus and is sent wirelessly to the server.

This prototype enables the user to travel using the public transportation system without getting lost or taking the wrong bus. The mobile device has the capability to generate visual and audio prompts whenever is necessary to keep the user in the right path.

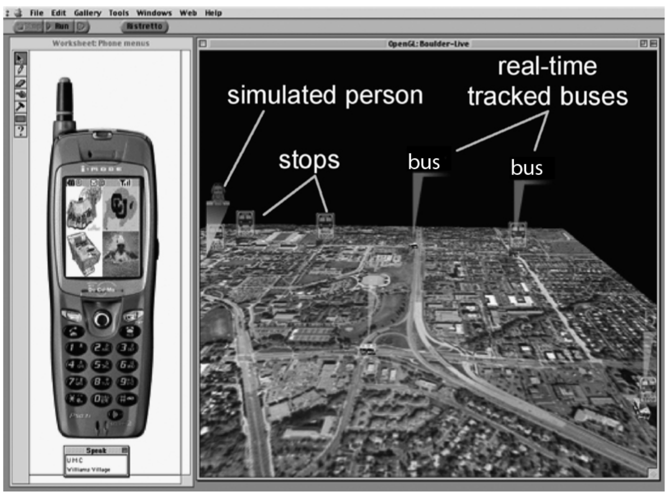

Figure 3: Prototype showing a prompting device (on left) and a real-time bus system (on right) (Carmien et al., 2005)

Carmien et al. (2005) also developed a second prototype, which did not need a supporting structure. Using the developed tool, the caregivers could create several scripts taking into account the user needs or the activities that should be carried out by him/her. In order to keep the attention of the mobile user the scripts have audio and/or visual stimulation.

Liu, Hile, Borriello, Kautz, Brown, Harniss and Johnson (2009) developed an orientation system for people with cognitive disabilities. The authors tested the prototype in people with cerebral encephalopathy, traumatic brain injury and Down's syndrome. During the tests the user could freely use the prototype, being remotely controlled. Thus the user could walk and explore all system functionalities without being disturbed.

Before developing the prototype to do the outdoor orientation of the user, the authors studied how to orientate the user indoor. Then they tried to identify which features could be extrapolated to the outdoor system, like the combination of pictures with overlaid arrows, audio and text messages (Figure 4).

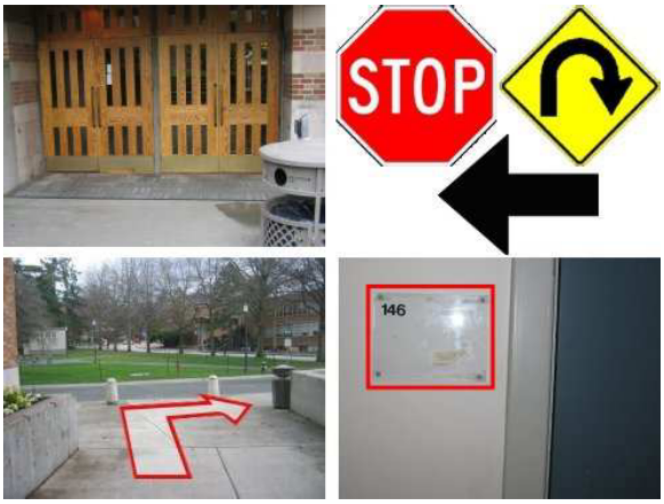

Figure 4: Sample pictures used in the interface (Liu et al., 2009)

When the user is outside the orientation is a more complex task since the environment is more dynamic. There is traffic, other people passing by, noise, which may distract the user. In another study the authors examined the usability of landmarks in the orientation process. They concluded that a near landmark should be used instead of a landmark outside the user view (*e.g.*, behind a tall building) and the image shown to the user should be in the same perspective of the user so he/she could more easily identify the mark. If this considerations were not taken, the picture may be harder to associate to the real landmark and the orientation system may fail.

An assistance system with interactive activity recognition and prompting was developed by Chu, Song, Kautz and Levinson (2011). Through a hierarchical partially-observed Markov decision process the system may learn and adapt the user interface to each user and help him/her in his/hers daily activities. The data needed to determine the user's state is obtained from sensors like IR (infrared) motion sensors and RFID (radio frequency identification) touch sensors. The system queries the user for additional information when the sensors are unable to retrieve the user state.

A more recent project is being developed by Fraunnhover Portugal (2012) and the goal is to orientate elder people or people in early stages of dementia. To indicate the path the system shows an arrow that rotates like a compass, showing information about the street where he/she currently is and the selected destination (Figure 5).

Figure 5: Interface for the orientation of AlzNav application (Fraunnhover Portugal, 2012)

Besides these functionalities the system allows the establishment of a perimeter in which the user may freely walk without alerting the caregivers. To know the current location of the user the caregiver may send a text message to the server, receiving the information.

3 System Description

Nowadays, due to the technology progress and the reduction of production costs, almost every person has a smartphone. This device may have applications installed according to the user needs, helping him/her in tasks of his/her life. However these applications are not specifically developed for people with disabilities, so not everyone may benefit from all device capacities.
This work describes a system that is specially being developed for people with mild cognitive disabilities. The system intends to help not only the user (person with disabilities) but also his/her caregiver. The main goal of the project is the development of an application that helps the user travelling between two locations without getting lost. Due to the typical user profile the application must be simple, not requiring a significant cognitive effort. The system has a localization capability which allows the caregiver to be aware of the current user location without being physically present. This feature allows the caregiver to develop another activity without neglecting the user.
A simplified framework of the system is presented in Figure 6, which is divided in four major parts according to its destinated user/application: the mobile application for the person with cognitive disabilities (named *Cognitive Helper Mobile Solution*, Section 3.1), two applications for the caregiver (*Caregiver Applications - Mobile and Web*, Section 3.2), external services that

could be coupled to the system (*External Services*, Section 3.3) and the server.

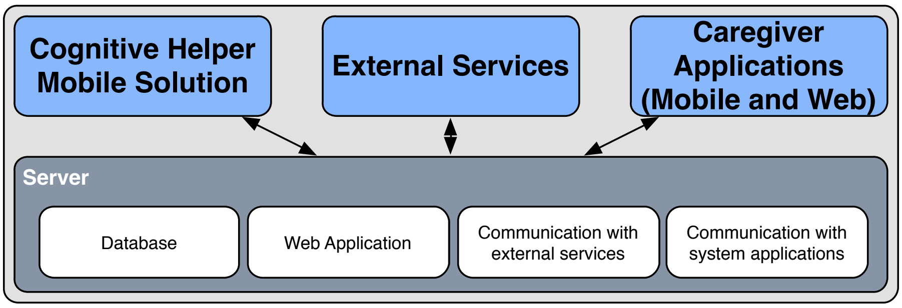

Figure 6: Simplified framework of the system

The server is composed by four modules. The database stores all the data needed to the correct operation of the system like usernames, locations, points of interest (destinations), among others. The web application used by caregivers is stored in the server and is accessed whenever the caregiver uses the application in his/hers computer. There are two types of communication layers according to whom the system needs to communicate with. Thus the system has a communication model to connect with external applications like iGenda and another communication model that connects the server with the system applications.

3.1 Cognitive Helper Mobile Application

With the use of mobile devices with a high processing power means that what was usually done by fixed computers can now be done by a device that fits in a pocket. This has lead to the development of the Body Area Network (BAN) concept (Jain, 2011; Micallef, Grech, Brincat, Traver and Monto, 2008; Wolf and Saadaoui, 2007), which instead relying on fixed sensors and a home environment, it uses mobile devices and sensors, creating a portable monitoring sphere. Using this concept as a starting point, the person with cognitive disabilities (also named user) has access to an application developed to operate on Android Operative System. This application has two main objectives: the first is to orientate the user so he/she may travel between two locations without getting lost and the second is to provide a localization service so the caregivers know the current location of the user.
On Figure 7 is presented the detailed framework of this application. The framework is divided in three parts. On the left it is the *Localization Layer*, which has the methods used to get the user position. This may be done through the GPS module of the device and by a coarse location from the network. This information is used to learn the user frequent paths and after the GPS has a locked location the orientation process may start, since the system needs the user location to calculate the path to the selected destination.
The orientation of the user is done through augmented reality (Figure 8). This specific environment uses the device's camera and several sensors like the accelerometer and the gyroscope. These sensors are needed to get the direction in which the user is pointing the device. These three elements allow the augmented reality environment and let the application to know where the user is facing. If the user is correctly oriented with the path then a green arrow appears indicating the correct direction. If the user is a wrong path a red cross is showed to the user.

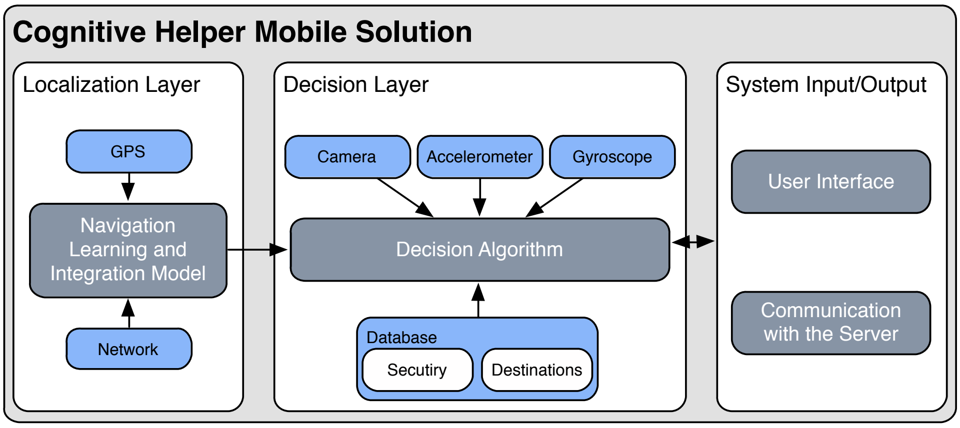

Figure 7: Detailed framework of the mobile application for people with cognitive disabilities

Using this environment (augmented reality) it is possible to guide the user, ensuring that he/she is moving correctly.

Figure 8: Orientation system using augmented reality

The *Decision Algorithm* (at the center in Figure 7) is the one responsible for this last task. To guarantee that the user is in the correct path this module may generate warnings stimulating the user, but if the user is going in the wrong direction this module generates audio and/or visual alerts. If the system detects that the user is confused, *e.g.* the user is shaking to much the device or is going forwards and backwards in a constricted area, it creates alerts and may send an email, sms or start a call between the user and the caregiver.
The interaction between the user and the application is done through the interface (right part in Figure 7). The interface presents to the user the information about the route and allows him/her to select the intended destination. This selection is done through menus and options. According to the destination stored in the database the user may choose a starred destination (those used more frequently like home and school or office) or generic locations like the mall. Since

this information is private it is necessary to be securely store it in the database guaranteeing that only a set of predetermined users have access to it.
In addition to the *User Interface*, the input/output of the application is composed by a *Communication Model* which is responsible for establishing the connections between the application and the server. Through this module the application may update the user destinations, update his/her current position, receive or send messages to the caregiver and receive information from external services that are linked to the server.
If the caregiver notices that the user is capable to use the application correctly, it is possible to allow him/her to choose a destination that is not present in the database (manual insertion). This extra option allows the user not to be limited to the destinations previously created by the caregiver.

3.2 Caregiver Applications

Caregivers have access to two different platforms with similar functionalities: a mobile application for Android Operative System and a Web application. The main goal of both applications is to inform the caregiver about the current location of the user. These applications also show the current guiding process or the accomplished paths done by the user. Through these applications the caregiver receives the alerts triggered by the user application and the caregiver may also send short messages to the user. The Web application has more functionalities where it is possible to edit some preferences like create/update/remove user destinations.
The framework of these applications is presented in Figure 9 and is divided according to the application type. On the left there are the modules related to the mobile application and on the right those related to the Web application. The difference between them is that the web application is composed by one more module than the mobile application (*User Preferences*). Both applications communicate with the server through a *Communication Layer* to transmit different types of information: caregiver's personal information (password, username, name, among others), user data (location points, name, destinations stored in the database), and information from the external services.

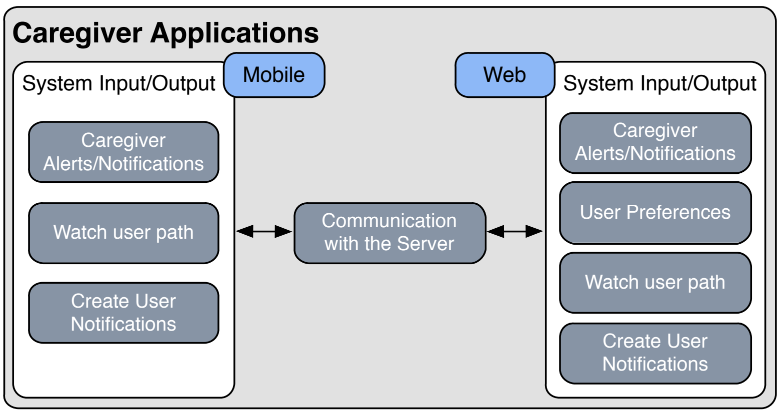

Figure 9: Detailed framework of the caregiver applications

Through the *Caregiver Alerts/Notifications* module the caregiver may receive the alerts or notifications generated by the application of the person with cognitive disabilities. These alerts/notifications may inform the caregiver that the user has started a new path or may alert the caregiver indicating that the user is lost.

Create User Notifications enables the caregiver to send simple messages to the user. This feature allows an easier and fast communication between caregivers and users, since the answer may be *Yes* or *No*. This feature may be useful when the caregiver wants to know if the user is well or to enquire about small tasks, *e.g.* the caregiver is watching the traveling path and sees that the user is passing by a grocery and asks if he/she wants to buy fruit. Instead of calling and pausing the navigation, this feature enables a fast answer without interfering with the person routing.

Figure 10 represents the module that allows the caregiver to watch the travelling path of the person with cognitive disabilities. Figure 10a) shows the android application in which the path was already done by the user. Figure 10b) represents the Web application, showing a travel path that is being done (the line is updated when the user changes his/hers position). A specific marker indicates the start and ending point of the route.

Figure 10: Localization system - a) Android application; b) Web Application

One of the functions of the caregiver is the creation of destination points (through *User Preferences*) that may be used by the person with cognitive disabilities. This function is only available in the Web application and the creation of a point may be done by directly selecting it on the map or by searching a location through its address and, if necessary, adjust the point on the map. Besides this task, the caregiver may also specify if the destination point is starred (more used destination) or is a normal one.

3.3 External Services

One of the aims was to provide the system architecture with the resources required to integrate the resultant applications in an AAL environment. Displayed in the Figure 6 the system is already prepared to receive and send information, using a secure communication tunnel. Allowing the connection to external services is beneficial to the localization system as well as to the system that is going to be connected. The previously referred iGenda was used to prove the feasibility of the External Services.

The iGenda project (Costa, Novais, Corchado and Neves, 2011) consists in an intelligent scheduler and time manager designed for cognitive impaired people. The iGenda architecture is composed of a server and mobile/desktop client. The platform logic is set in the server as the client displays only the relevant information and serves as a communication platform between the users. Unlike the CogHelper the caregivers are users as well, being the only difference the set of permissions that the caregiver has over the user profile. In the Figure 11 it is showed an overview of the iGenda architecture.

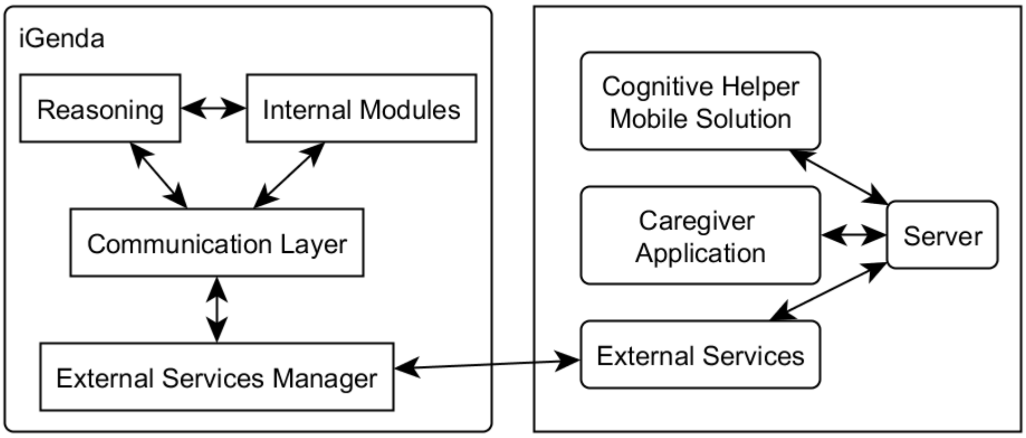

Figure 11: Overview of the iGenda architecture

The objective of the integration of the CogHelper with the iGenda is to provide the users with extra features, and at the same time improving the automation process. One can easily grasp the intentions of joining an localization and augmented reality guiding system with an intelligent scheduler. So, the main aim is releasing the user of the destination selection action and allowing the system to verify if there is any task that requires the user leaving his house and automatically present a visual/audio warning of the pending task as well as starting the guiding process with the directions to the destination.

Although is seems a fairly simple task to select a destination between a list of favorite destinations, to a cognitive impaired person this task is very perilous, as they may be unable to recollect the association between the task and the location of this task, or even worst, being confused and select an erroneous location.

Thus in terms of the mobile platform, the iGenda continuous monitoring establishes the visual interfaces and the communication systems, thus, being the primary application. This business logic is established according to the following work flow: the mobile system warns the user of any incoming task, if the task requires the user to leave his house the guiding system will be activated showing the path to the task location; if the user wants to leave his house he/she has to willingly open the guiding application and select the destination. Due to the users cognitive impairment conditionings, the CogHelper will be inactive, securing the user of improper operation, like selecting a random destination. Providing security to the user is of the utmost importance, so, interfaces, actions and buttons were carefully planned to be as simple and safe as possible. Moreover, some actions are stricly defined, leaving few to none options to the user, providing a controlled environment, hence, these options can only be edited by the user's caregiver.

In terms of the architecture, the CogHelper and the iGenda are clearly separated, the motive of this approach is the application logic of each project and the development process. They communicate using web services, structured by a WSDL standard and HTTP protocol. The security resides in a 2-step user verification, while the communication process is done recurring to high level data description. As an example the content of a message between the iGenda and the CogHelper is represented in the following example, after establishing the secure communication:


```
{
 "event" : {
            "user" : "Jack Higgins",
            "description" : "Buy groceries",
            "Lat" : "41.0509605",
            "Lon" : "-8.4342343",
            "Location" : "Street of London, 31, PT"
            }
}
```


The message is represented in common JSON format. This approach was due to keep the compatibility between all platforms involved. In it is described an event, in this case going to the grocery, providing digital information, such as the latitude and longitude, and human readable information. The human readable information is the visual representation sent both to the user and the caregiver, thus easier to provide an early detection of the user intents.

Being the iGenda an interactive scheduling system it has the ability of receiving events and schedule them according to their importance. The importance is provided by a set of internal rules that establish the relation between the sender role and importance to the user, and the urgency that the sender established in the event. To better illustrate the hierarchic process we have the following examples: if is the user's personal physician the system assumes the maximum importance to every event that he schedules, even if the physician marks the event with low importance, whereas if is a user's friend that schedules an event it will not surpass any physician or medical-related event. For instance, the user's friend has scheduled a match of tennis Tuesday with the importance level of ”1” (ultra-high), being this friend a particularly important one the iGenda has scheduled internally this event with an importance of ”9”, meaning that any other event that is more important can replace this event. Furthermore, in case there is a overlapping of events, the rescheduling process of the iGenda is able to move the event, asking to each user his consent, deleting the event if it is unable to do it so.

Finally, the iGenda platform is also able to receive high-level information, processing different type of incoming commands. Therefore, in conjugation with the CogHelper the iGenda is able to reschedule events or re-route the user to other events. This is useful for elderly people as their locomotion is limited or unforeseen circumstances happen. As an example, the user can be late to an event, due to perform several stop along the route, the CogHelper can communicate the TOA (Time Of Arrival) to the iGenda an the iGenda can verify the lateness of the user and perform two actions: notify the other users involved in the event, or re-route the user to the following event. The action that the iGenda performs is dictated by the importance of the event and the TOA relative to the event duration. It is clear that if the event has a duration of 40 minutes and the user is going to be late 30 minutes the event may as well be cancelled and redirect the user to his home or to other event. Although these rules are quite strict their are able to be reconfigured to better attend to the user requests or conditionings, like most of the iGenda configurations.

4 Conclusion and Future Work

One of the problems that arise when a person with cognitive disabilities goes outside his/her house alone is the lack of orientation, thus the risk of getting lost is very high. The developed solutions covered one issue: guiding the user. However caregivers are not considered in this equation, thus they are oblivious of what the user is doing, not being able to perform their tasks conveniently.

To guide the user, our system uses augmented reality, which surpasses the limitation of using static pictures or the need to interpret the direction given by a compass. Besides, the caregivers may know in real time the location of the user. To further increase the system features it is possible to link it to external services, like the iGenda.

Currently, the system is at its final stage. The core of the CogHelper is already developed, providing the localization and guidance features. The user mobile platform and the web platform have reached a mature stage, and are ready to be used in field tests. The iGenda is a completed projected, thus fully mature and able to be integrated with the CogHelper. Our most recent developments are in the integration stage and the route calculation.

Although the communication layer and the external modules layer are part of the core, they are object of continuous development, thus, with every new module a wrapper and interpreter have to be developed to support the full integration. Furthermore, being most of the possible communication in a high-level format, the coordination between the ontologies is critical, implementing an answer to every request.

In terms of routes and warnings, now the system is using the standard Android protocols and the Android Maps. This assures full compatibility between the different user devices and the Operating System version. But, our aim is to provide personalized warnings, and implement smart routes, being in the roadmap the development of a routes engine, mobile-side and server-side.

Lastly, in the upcoming work we plan to do field tests with users, being able to receive feedback from them, polishing the application towards the elderly and cognitive impaired users, and, to reason upon the legal implications of this system and adapt it to the current privacy and data protection legal requirements.

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