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“Geo-Indoor” Design of an indoor navigation app to help elderly people to navigate in buildings

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Abstract –Some elderly people can experience problems to use new technology having feelings of distrust and indecision because technology is not accessible to their cognitive needs and mobility’s. For example: some of them can have problems of disorientation and it can be difficult to arrive independently to an unknown destination if the paths are not adapted to their mobility needs; additionally, the use of technology is not intuitive in complex interfaces. Depending on the level of mobility of the elderly person, they can use canes, walkers, wheelchairs. Taking into account previous work done in the Altran Research Medic@ team, our proposition is to develop a mobile app, which gives direction in indoor places using the minimum quantity of beacons in the place. The app will be adapted for every kind of cognitive and mobility needs. This work shows the first part of the project in which we have worked on indoor navigation for the pedestrian mode; a data fusion has been programmed in order to compute the position estimation. Tests have been done in a 2D map showing encouraging results with less than 6% of error in all cases.

Keywords: elderly people, indoor navigation, pedestrian navigation, beacons.

I. INTRODUCTION

Nowadays, the IoT technology [1] and mobile devices have been used to help elderly people in different contexts: for example for navigation and localization systems, health monitoring, nutrition monitoring, safety monitoring, social network for improving social activities [2]. Goodman et al have been working on the study of the use of navigation apps by elderly people. They have concluded that a well carefully design of the app can be used effectively by older persons [3]. Moreover, a second investigation has also been done to analyze the usability of touchscreen smartphones; it shows that old people have been interested in learning and using new technologies [4]. Other researchers also work on solutions about smart home technologies [5] to detect for example when old people fall down.

However, the difficulty of the use of the technology and the complex utilization of the user interfaces can increase the feeling of distrust and indecision of the person resulting in not acceptance of new technologies. Additionally, doing daily activities like walking to an unknown destination accompanied by a third person can increase the feeling of dependence.

We will work on the indoor navigation field. From a technological point GPS systems and apps have been widely used for outdoor activities, for example trekking. GPS antennas are also widely used in car navigation. However, GPS signals are not available in indoor places. To overcome this problem, different technologies have been used for indoor navigation, for example UWB, Wi-Fi [6] or beacons are placed in the building for computing the absolute position. The main problem is that the building needs to be equipped with a large quantity of these devices in order to obtain a good estimation of the position. Another technique is the use of dead reckoning for having relative position estimation; the main problem is that the error increases rapidly at every new position.

From a user interface point of view, Aoki et al. have used augmented reality for showing arrows on the view of the camera for guidance understanding [7].

The purpose of our work is to propose a hybrid system (absolute and relative positioning) and an adapted interface to give the possibility to elderly people to use a mobile application that helps them with their daily life and allow them to walk independently in unknown indoor places increasing his quality of live.

The mobile app will include an agenda where the users can fill their daily activities and help them remember important tasks to do: for example, it will notify the user 15 minutes in advance of a doctor’s appointment. Additionally, the app includes a navigation system to guide the user to his destination inside of a building (for example hospitals).

In order to implement the app, we used a data fusion between the data given by smart phone sensors (compass and accelerometer) with the data provided by beacons (Bluetooth signals) signals.

In the second section, we will discuss about the materials used such as sensors and Bluetooth connection. In the third part, we will describe the methodology used from an interface and technological point of view determining the configuration of the position of the beacons on the building and the different paths tested. In the results section we will analyze the error in the estimation of the position of the person with 2 different configuration of the beacons position. The tests have been done with 3 different subjects. Finally, we will talk about the conclusion of this first approach and the future work.

II. MATERIALS

The mobile app was developed using Android Studio. We used java android as a programming language. We have used the different sensors of the smartphone and the Bluetooth connection for recovering RSSI signals (Received Signal Strength Indicators). We have used commercial beacons (Bluetooth antennas) and integrated the corresponding SDK (library) in our program. This SDK serves to compute the position of the phone just using the RSSI coming from the different beacons. Wi Fi signals were not used for the localization of the phone.

In order to develop the app, we will use a user center design. All the technology used such as: real time positioning, cartography of the place, user interface, adapted pathfinding, data fusion and the navigation will take into account the specific needs of the person (Figure 1).

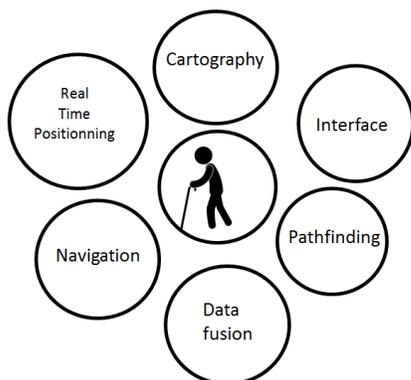


Figure 1: user center design

The pathfinding was obtained using image processing algorithms in the image of the map (floor) which is embedded in the app (Figure 2). The image of the real indoor map (1024x1080) has been reduced to a smaller pixel size (90x70) to reduce the computing time for the pathfinding in the phone.

This pathfinding algorithm is able to detect obstacles (black lines that correspond to a wall) and white spaces which represent walkable zones. The path is calculated using the Dijkstra algorithm [8] based on the nodes and the link between them; in this case every node is represented by a pixel on the image. Every pixel is connected to another pixel if the pixels are white; however, the black pixels are considered as pixels without connection.

This algorithm computes the closest path collecting the position of the pixels (Blue line as in figure 2) on the white pixels. The algorithm is able to calculate the paths including elevators for reduced mobility persons. We do not use the camera of the phone for the real time navigation.

Our use case is the 1st floor of Altran. In figure 2, we can see the map used for the Dijkstra algorithm which contains mainly 4 corridors, an open space and about 30 offices.



Figure 2 Altran indoor map, the blue line corresponds to the closest path using the Dijkstra algorithm.

Real time positioning was used in a hybrid way. After running some tests, we observed that the estimation of the position using the Bluetooth signal alone is not sufficient especially when the user walks out of the Beacons' network RSSI.

III. METHODOLOGY.

A. From an Interface point of view:

The interface created will take into account: the possibility to have an agenda / day planner. The system will also notify the user of the next task to do, for example a doctor's appointment, and to choose the kind of mobility. The person can interact with the app using "Speech to text" functions and "zoom-in/out" functions. During navigation functions, the person can be guided using Text-to speech functions.



Figures 3 Screens and functions for the user interface

-For elderly people with vision loss, zoom functions can be proposed.

-For elderly people with hearing impairments, a Bluetooth hearing can be added to the phone.

-For elderly people in wheelchairs and walkers, specific pathfinding has been programmed passing through elevators and avoiding the stairs.

B. From a technical point of view :

We have used four commercial beacons. The beacons are able to estimate the position of the user using a specific SDK imported in the android application. However, the estimation of the position takes few seconds (2-3 seconds) to be updated. This may not be a problem for people who walk slowly (less than 2km/h)

Another problem with the beacon's estimation is that sometimes the position given by them can be wrong by 2 or 3 meters compared to the real position of the user, giving the feeling that we are inside an office, when we really are in the corridor. In addition, if the person goes outside the beacons network, his position will be estimated to the last given position (because Bluetooth connection is lost) or it will estimate another false position and it will not follow the movement of the person correctly.

In order to overcome these problems: our algorithm of data fusion takes into account the compass, accelerometer, the position of the beacons and the pathfinding for the new position estimation (Figure 4).

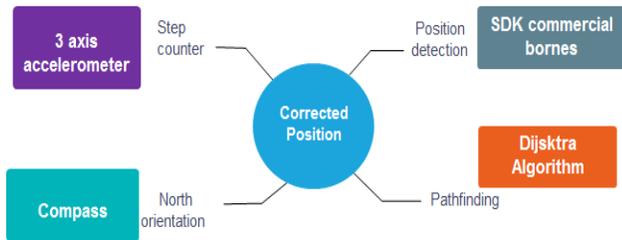


Figure 4 Data fusion for obtaining the corrected position

Therefore, to be able to test the precision of our application, we have run different tests in the lab, with three different users, and two different beacon-positioning configurations:

- **Configuration 1:** Beacons placed in front of the entrance door (Figure 5).



Figure 5 Beacons placed closed to the entrance (pink circles)

- **Configuration 2:** Beacons placed at the intersections of the corridors (Figure 6).

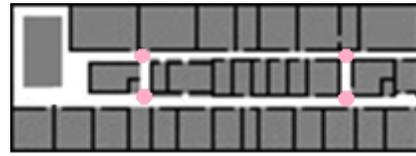


Figure 6 Beacons placed in every corridor intersection (pink circles)

We have evaluated the case: EXT-INT-EXT which means that the person starts outside of the Beacon network, he walks into the beacons network and after he goes out from the beacons network.

IV. RESULTS

We have tested the mobile app in these 2 cases with different people (by the moment between 20-40 years old) and the 2 configurations mentioned in the methodology part. The paths tested (in blue) are shown in the Figure 7 and 8.

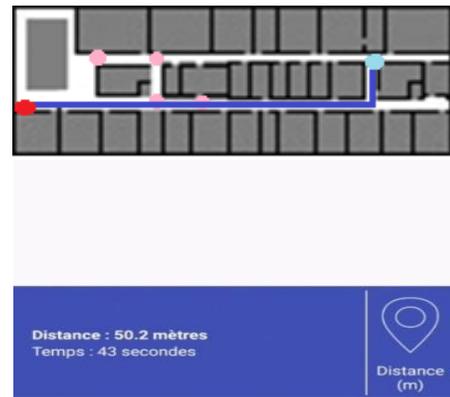


Figure 7 Path in blue line in configuration 1, in cyan circle the departure point and in red circle the destination point



Figure 8 Path in blue line in the second configuration, in cyan circle the departure point and in red circle the destination point

We show, below, tables I and II comparing the results in terms of time, distance and error of precision.

For the first case:

TABLE I

Subjects	Time app (s)	Real Time (s)	Distance (m)	Distance error (m)	Error (%)	Mean Speed (Km/h)
Subject 1	43	47	50.2	1	2.0	3.8
Subject 2	43	50	49.3	1.4	2.8	3.5

We have noticed that the error rate in the case of subject 2 is higher because he walks slower. A way of explaining the error is that the hand in which the subject holds the phone, is strongly amortizing the impact of the foot on the floor and the signals of the accelerometers are not clear enough to be detected by the step counter algorithm. Additionally, when the person is walking slowly, the impact of the foot with the floor is not very strong and is not clearly detected by the accelerometers on the phone. Therefore, some steps are not counted. However, for the subject 1, when the person walks in a normal gait and the phone on the hand detects clearly the impact of the foot on the floor, it is possible to have a better accuracy.

For the second case:

TABLE II

Subjects	Time app (s)	Real Time (s)	Distance (m)	Distance error (m)	Error (%)	Mean Speed (Km/h)
Subject 1	39	45	44	1.5	3.4	3.5
Subject 2	39	51	47.6	2	4.2	3.3
Subject 3	39	53	46.8	2.5	5.3	3.2

It has also been noticed that among those who are familiar with the application and the map, the error rate is lower than for subjects who are using the application for the first time (subject 3 in Table II). Because the subject who does not know the app will take more time to explore and understand directions, therefore he walks more slowly than the subjects who are familiar with the app.

Finally, we found that even though the step length is fixed to 65 cm and in spite of distance error (less than 6%), the person arrives at his destination.

V. CONCLUSIONS

In summary, we have developed an "indoor" geolocation / navigation application that guides the user inside a building in 2D using data fusion.

The position of the subject is found and followed using the data from the Bluetooth signals transmitters, the pathfinding and the combination of the accelerometer and compass data of the phone.

In the two configurations of the beacons, we have seen that the error rate is below to 6% compared to the distance traveled for around 50 meters, and despite the error, the subject arrives at his destination. We can conclude that the data fusion seems to be pertinent.

It was also observed that when the person walks in a normal gait (more than 3.5 km/h), the system has a better estimation than when he walks in a slowly way (less than 3.5km/h). In slow movement, when the person holds the phone on the hand, the smartphone does not detect clearly the impact of the foot on the floor; in this case, the sensibility of our step counter algorithm should decrease in order to detect the steps. A function to change the sensibility of the peak detection of the accelerometer and the value of the step length has been added in the parameters menu.

The app was tested in different Android operating systems versions from 4 to 9, having good performance in the update of the position.

VI. FUTURE WORK

We will continue the development of the app using other sensors like barometers (passing from one floor to another) in order to implement 3D Navigation.

We will test the app in larger spaces with complex architecture configuration (For example: hospitals)

Next tests will include the validation of our system with end user (between 60 – 90 years old).

We will upgrade the app to include cases where the old persons use wheelchairs and walkers.

Deeper research will be done for detect automatically the right sensibility for step counter depending on the speed of the person.

The maps will also be simplified for a better and simpler understanding.

The system will include the analysis of errors if the person goes out from the path created. For instance; if he takes another corridor, the system will detect the closest beacons in order to propose a new path.

The system will be adapted to be used in retirement homes.

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