Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 181 (2021) 34–41

Procedia Computer Science

www.elsevier.com/locate/procedia

CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2020

A mobile application to enhance mobility of people with permanent or temporary mobility disability – a case study in Portugal

Sara Paiva*, Pedro Castro, Bruno Mateus, Carlos Pinheiro, Ruben Ferreira, Samuel Rodrigues, Júlio Silva, Ana Curralo

Instituto Politécnico de Viana do Castelo, Portugal

Abstract

This paper presents a mobile application developed in conjunction with the City Hall from Viana do Castelo, a city in the north of Portugal. This application targets people with permanent or temporary reduced mobility and intends to show them information about taxi points, parking spaces and reference points in the city with the possibility to navigate to them using an optimized algorithm, based on routes defined for each segment (deaf people, visually impaired people, etc.). The Dijkstra's algorithm was used to implement the *shortestPath* given an origin, destination and segment. In this paper we present implementation details as well as final layouts of the prototype. At the current moment, the application is ended and will soon enter in usability tests with the users.

© 2021 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2020

Keywords: smart mobility, reduced mobility, mobile app, smart cities.

* Corresponding author.
E-mail address: sara.paiva@estg.ipvc.pt

1877-0509 © 2021 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2020
10.1016/j.procs.2021.01.096

1. Introduction

Mobile applications are nowadays an increasingly used way of offering services to citizens, as cell phones are nowadays used by a large percentage of the population, even by older people who also end up using these devices for communication. with the family, among other situations. The location functionality that mobile phones have allows for a large number of features that can be of great value to citizens while taking public transport or even walking around the city. Urban mobility is nowadays particularly relevant for cities and with more emphasis on people with temporary or permanent reduced mobility, due to the additional challenges they feel. New technologies today have resources that can significantly contribute to mobility within cities through mobile phones and / or various other external equipment (sensors) that will certainly start to be part of future smart cities. This paper presents a case study in the city of Viana do Castelo, Portugal, initially described in [1] where, together with the City Council, a study on how to develop an app – Viana + Acessível (More Accessible Viana) - for people with reduced mobility is being developed. temporary or permanent. This includes blind, deaf, autistic, pregnant women or children and people in wheelchairs. The application development was made along with the City Council as well as with all institutions to support each of the segments that the application supports. The application will allow information about taxi points in the city, parking points, visualization of the routes optimized for each segment and location / navigation to points of reference in the city. The application is in its final stage of development and will soon pass to the testing phase, a little delayed at this point due to COVID-19. The paper is structured as follows: the next chapter presents a state of the art on applications to support citizens and some specific ones regarding their mobility. In section 3, we start by providing an overview and the requirements; next we introduce an important aspect of the app which are routes and how they are calculated using Dijkstra´s algorithm; present the usability concerns and the developed prototype. Finally, we present conclusions of this work.

2. Literature review

2.1. Mobile apps to aid citizens

Mobile citizen support applications are a constant in many cities around the world, with the advent of technology that is experiencing significant increases and progress every day. The health sector has nowadays a large number of applications for different audiences and with different scopes. The app entitled "Careggi Smart Hospital" is one such example and represents an application that was developed for Policlinica Careggi in Florence. The application provides hospital users with information such as the location of people, location of buildings, exits as well as medical records [2]. Another app is the one described in [3] aimed at the elderly with the aim of increasing and fostering interaction, anywhere and at any time, between the elderly and their families. The app described in [4] aims to help elderly people in Japan with the first signs of dementia that can be identified through problems that begin to exist in the manipulation of remote controls, simulated by the app in order to be able to gauge the ease of use. Fostering the physical and mental activity of the elderly is the objective of the app described in [5]. Other apps, in areas other than health, also exist to support citizens. An example is the app presented in [6] that uses the concept of crowdsourcing to improve disaster response, in conjunction with geographic information systems technologies. The app generates, collects, transmits and manages location information in real-time, enhancing universal and real-time access to data in an emergency. The Anecdata.org app [7] allows the hosting of projects that collect, manage and share data on climate change.

2.2. Mobile apps for mobility

In [8], the authors present the CityMapper app that provides information on urban means of transport, including optimization for people with reduced mobility. This app will allow the user to be able to plan his route, taking into account the place where he is, where he wants to go and also his profile. The CityMapper [9] and Here [10] apps fall into the category of apps that aim to give the user the best transportation options given their location. On the other hand, there are other apps that aim to improve the experience of using transport by citizens [11] [12] [13]. In terms of blind people, there are also several apps that aim to give more autonomy to this segment of people. In [14], computer vision algorithms of images obtained through smartphones are explored to detect crosswalks as well as to determine the best angle to cross them. A solution that uses a Nokia N95 camera and audio to determine how safe it is to pass a treadmill was explored in [15]. ZebraLocalizer is an iPhone application that uses the accelerometer to allow blind people to identify a treadmill and align themselves with its center to pass it safely [16].

3. Implementation

3.1. Overview and requirements

The application, entitled Viana + Acessível, had until now the participation of 1 student from Product Design degree and 5 students from Computer Science degree over the last 4 semesters. The project started in September 2018 and it is now getting the final stage of its development before entering the test stage in the next few months. Throughout this period, there were several meetings with the City Hall and the Associations that support the main segments. The usability of an application of this type is of extreme importance and a careful study was made which is described in the next section. Regarding the application, it is being developed for Android and iOS and with the main requirements:

- Allow the user to choose his condition among 6 possible (people in wheelchairs, deaf people, visually impaired people, autists, pregnant ladies or small children, elderly or people with reduced mobility.
- Inform of taxi points and allow navigation to each one (in an optimized way considering the segment)
- Inform of parking spaces and allow navigation to each one (in an optimized way considering the segment)
- Inform of main reference points of the city and navigation to each one (in an optimized way considering the segment)
- Inform of routes within the city optimized for the segment (in an optimized way considering the segment)

3.2. Routes

A crucial aspect of this project, fundamental for the navigation functionality, was the definition of optimized routes by each association so that routes given to the citizen, from its current location to an intended destiny, are optimized at its maximum. Example of the routes obtained for each main segment are represented in Figure1. Figure 1a) represents routes for autists with annotation of streets that have no traffic (which are safer), streets with loud and/or unexpected noises and streets that usually have more people and therefore should be avoided. Figure 1b) represents the optimized routes for people in general with reduced mobility. These routes were the starting point for studying the best way to develop an algorithm that informs the best route. The best route is one that takes into account the person's segment and uses the optimized routes during most of the route. In some cases, there are no optimized routes along the entire route, and it is necessary that part of the route uses non-optimized sub-routes. To determine the best path, the Dijkstra algorithm was used, which we describe in more detail in the next section.

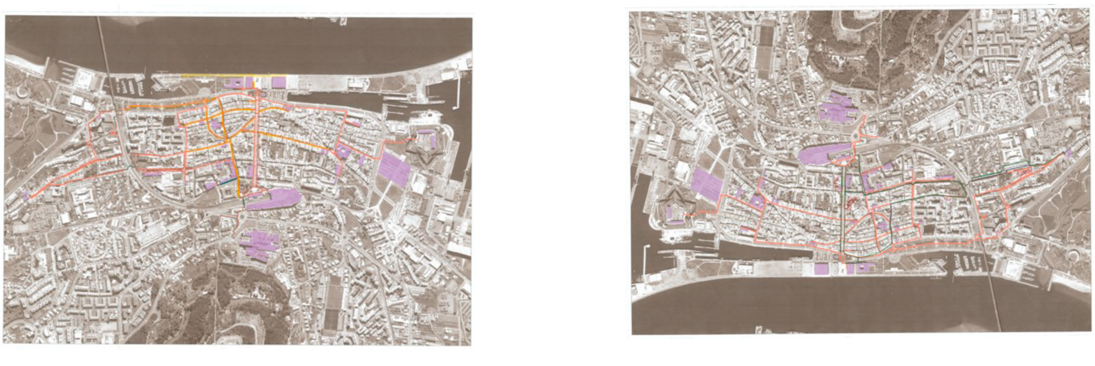

Fig. 1. (a) optimized routes for autists; (b) optimized routes for all other people with reduced mobility

3.3. Dijkstra Algorithm

Overview

Dijkstra's algorithm is an algorithm for finding the shortest paths between nodes in a graph. It was conceived by computer scientist Edsger W. Dijkstra in 1956 and published three years later. This algorithm has several variants. The original algorithm is given a starting point and an ending point, but a more common variant fixes a single node as the "source" node and finds shortest paths from the source to all other nodes in the graph, producing a shortest-path tree. The implementation of such an algorithm usually follows the following steps:

1. Mark the initial node with a current distance of 0 and the rest with infinity.
2. Set the non-visited node with the smallest current distance as the current node.
3. For each neighbor of the current node, add the current distance with the weight of the edge connecting both nodes. If it's smaller than the current distance, set it as the new current distance.
4. Mark the current node as visited.
5. If there are non-visited nodes, go to step 2.

Graph creation

In this project, we had the need to use this algorithm because we had information on the optimized routes pertaining to each condition and, given a starting point and an ending point (such as places of interest, parking points and taxi points), we had the goal to obtain an optimized path between these two points.

One situation we had to handle inside the algorithm was the possibility that the user was not inside the network of routes. If this happens, our solution is based on sending the user to the nearest point on the network in relation to their current location. In the next step, to guide the user to the intended location, it is necessary to use the Dijkstra algorithm. For this, we use a web services layer developed by the City Hall that return all segments of a route for a given segment (such as illustrated in Figure 1) which we add to a graph. The web service returns start point, end point and intermediary points of the segment. We only add to the graph the start and end point and create an edge between both with the weight equal to the distance. In the end of this process, two graphs are created: 1) one for the user's specific segment and 2) another graph with the union of all routes of all segments (for cases when there are no route just using a segment and the general one has to be used).

Determining a path

In determining a path given an origin and destination, we should consider two situations: 1) when the entire route is performed using an optimized route (only routes for that segment) and 2) when the route is not entirely optimized for the segment and needs to have sub-routes of the general route for people with reduced mobility.

<u>When the entire route is performed using an optimized route</u>

When the creation of the graph is complete and the user chooses the option to go to a given location (taxi, parking space or reference point), the *shortestPath* function of Dijkstra is called, which receives the start and end point as input parameters and returns the segments within the optimized route. After having these segments, we iterate through all of them and fetch the intermediary points in order to draw the entire route on the map.

<u>When the route can´t be fully optimized</u>

If some segments, there is no network throughout the all city and a part of the route has to use the general network, not specific of a given segment. In this case, the user will be notified, in the app, that certain parts of the presented route are not optimized so he can proceed with caution. For this situation, we use the general graph that will still give priority to the routes of the chosen segment but will also have general routes to fill the missing spaces. A priority to the segment is given because when the general graph is created, the routes of the segment of the user have the weight of the distance, but all others are multiplied by a factor of 2.5. After determining the most optimized path, the same procedure described above is followed, to present the route on the map.

3.4. UX Design and Disabled-Accessible Cities

User Experience (UX) Design is the process to create products, systems or services, providing relevant meanings and experiences for users. It is responsible for the usability of products, winning over users and making the process simple and user friendly. One of the areas responsible for the success of a digital product, UX Design concerns structure, personality and the ability to project emotions [17]. Targeting the promotion of a disabled-accessible city, the mobile application Viana + Acessível involved UX Design to identify the main obstacles of the city of Viana do Castelo, in the northwest of Portugal, and the needs of future users. In order to improve the app performance and the quality of the interaction with the interface, among the available methodologies in the scope of UX Design, the methodology proposed by Jesse James Garrett [18] was chosen. This methodology proposes a five-plane project development, as shown in Table 1.

Table 1. Five-plane project development | Source: Garrett [18], adapted by the Authors

The Strategy Plane> The Scope Plane> The Structure Plane> The Skeleton Plane> The Surface Plane

The Strategy Plane concerns the specifications for the app, taking into account its purpose and the needs of target users. Some meetings were held with the Viana City Council, in order to define the strategic cores of the app. Personas were also created as a representation of users, based on behavioral and demographic data characterizing the target users. Based on such data, stories were created with challenges and motivations, through fictional profiles that help understand those who will use the app. The Scope Plane: at this stage, together with the Viana do Castelo City Council, the app requirements were discussed. Some of the existing possibilities were checked, synthesizing the key cores of the project. The Structure Plane: this stage involved the organization of the information architecture for the app, defining all desired navigation between screens. The Skeleton Plane regards the organization of the app contents. A first sketch was made to visualize the graphic layout. These Wireframes, simple drawings usually without colors, help the designer understand the set of interactive elements on each screen. The Surface Plane consists of the graphic elements, as shown in Table 2. At this stage, the visual elements take shape. The purpose was to excel the generated meanings and emotions, since readability is paramount for this accessibility project.

Table 2: Structure

Screen Colors	Typography for Screen	Pictograms
#FFF72A #DB4437 #3399CC #FF3366 #CC33CC #66CC33 #FF9933 #000000 #F6F6F6		

As for screen colors, according to Garrett [18] they influence the communication of a product/ app and help to remain in people's imagination. They also affect emotions and sensations. Currently, there are several websites to check the overlapping of text over colors and help to identify the best compositions to ensure the optimal readability. Together with the City Hall, the design chosen for the app Viana + Acessível used the most vibrant colors, as shown on Table 2. An Open Sans font was chosen (Table 2), a sans serif font characterized by some vertical tension, open shapes and a neutral appearance. In addition to be a free font, it is available in several versions and with glyphs for many languages. Another important factor is that it was optimized for printing interfaces and for web and mobile interfaces, with excellent typeface legibility and readability. ISOTYPE patterns were used in the iconography of the app Viana + Acessível, with simple, easy to understand pictograms and single line shapes, which can be used in formats such as mobile phone screens. The inverted rounded triangles as widely seen on traffic signs immediately attracts the user's attention, as well as the reference to the letter "V" from Viana. Buttons and features are visible and easy to interpret and use, with a high comfort level. The arrangement of colors and elements on the screen also enhances the perception of the categories. Wheelchair users are attributed the color green; sensory impaired are orange and purple, temporarily impaired are pink and blue; and autists are attributed the color yellow.

The first screen of the app introduces the Viana + Acessível program, displaying the app logo or icon, as well as the logo of the Viana do Castelo City Hall (institution to which it is connected). Subsequently, the first part of the user interaction is presented. Figure 2a) shows the screen where the user may choose his condition/category. It should be noted that this choice is important, since it affects all contents available in subsequent interactions with the app, including the colors. Once the condition is chosen, the user is taken to the next screen where he can start the interaction with the rest of the app. This way, UX Design allows discovering how a structure or geometry works, translating it into a more emotional decision. UX Design allows anticipating user decisions while navigating the platform. The purpose of the digital product is to present elements and components that are easy to access and use, turning urban obstacles into disabled-accessible cities. All the elements that make up the interface should be distributed harmoniously so that users can easily absorb information from the screen and interact with the digital product. The app Viana + Acessível thus resulted in an appealing aesthetically pleasing product, allowing comfortable navigation and easy information retrieving, fostering user engagement and emotional connection, bridging urban obstacles and user needs, connecting with users' emotions in a positive way, towards a disabled-accessible city.

3.5. Final prototype

Figure 2 shows the main screens of the app development. Figure 2a) shows the initial screen where the user can choose his condition. Based on this information, navigation will be optimized. In Figure 2b) we can see the first screen of the app where there is a marker for each reference point. Pressing it shows some information and allows the user to select to navigate there. Figure 2c) shows the navigation screen where a non-optimized route is shown. The caption shows information regarding the sub-segments of the route: non-optimized, advised, moderate and avoidable parts. Figure 2d) shows all routes of the chosen segment so the user can freely use to navigate through the city and see which are the most recommended routes. In this case, the user does not need to choose a destination. He simply activates the routes and navigates at his own will. Figure 2e) shows all taxi points. By pressing in a marker, the number of available places is shown as well as an option to navigate there. The screen for parking points is not shown as is very similar to the one regarding taxi points.

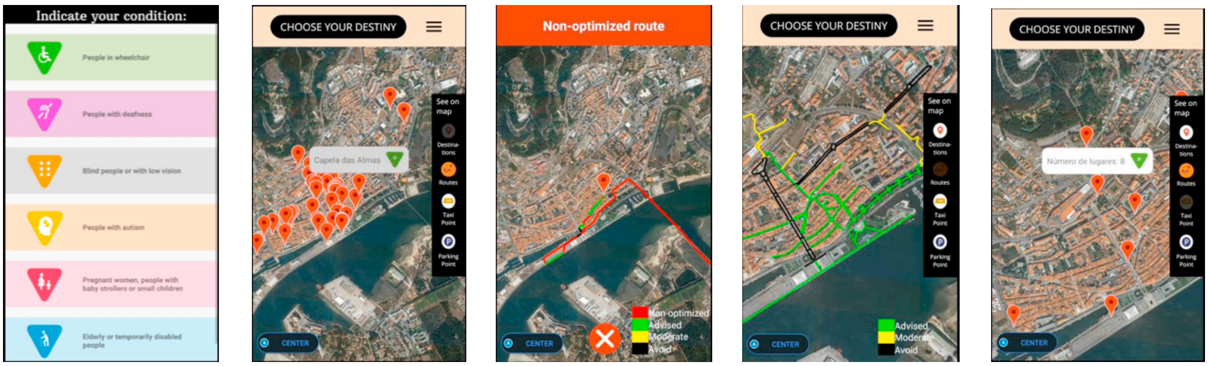

Fig. 2. (a) screen for the user to choose his condition; (b) main screen with all destinations; (c) navigation screen; (d) all routes to a given segment; (e) taxi points

4. Conclusions and Future Work

In this paper, we present a case study developed in the city of Viana do Castelo, together with the City Hall, in order to develop an app with the goal of helping people with reduced mobility (temporary or permanent), which include: people in wheelchairs, deaf people, blind and partially sighted people, people with autism, pregnant women or people with children and the elderly. The goal is to inform app users about taxi points, parking spaces and landmarks in the city, with additional information on the best navigation route to the desired location, optimized for the type of user segment. For this, there was a joint work with the associations of each of the segments, in order to define, for the historical center of the city, the best routes. Based on this information, a set of services was created by the city council, so that the app can obtain the best route, given a source, destination and segment. The navigation system used the Dijkstra algorithm for its implementation. In this paper the implementation phase was presented in detail, as well as the final layout of the application, practically finished. The next steps include, as soon as possible and after the isolation season is over due to COVID-19, tests with users from each of the segments in order to make usability tests.

Acknowledgments

This project was developed in partnership with the Viana do Castelo City Hall to whom we appreciate for all cooperation throughout the entire duration of the project.

References

[1] Paiva, S. (2018) Architecture and Specification of a Solution to Calculate Optimized Routes within a City for People with Reduced Mobility, International Journal of Advances in Electronics and Computer Science (IJAECS)-IJAECS, ISSN 2394-2835, Volume-5, Issue-12.

[2] A. Luschi, A. Belardinelli, L. Marzi, F. Frosini, R. Miniati and E. Iadanza, "Careggi Smart hospital: A mobile app for patients, citizens and healthcare staff," IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI), Valencia, 2014, pp. 125-128. doi: 10.1109/BHI.2014.6864320.

[3] Hsiao-Hui Li, Chih-Tsan Chang and Yuan-Hsun Liao, "Using mobile application for Long-Term Care system," 2015 Eighth International Conference on Mobile Computing and Ubiquitous Networking (ICMU), Hakodate, 2015, pp. 62-63. doi: 10.1109/ICMU.2015.7061030.

[4] H. Sasaki, "A smartphone app provides preventive care for the elderly with dementia," 2016 IEEE 32nd International Conference on Data Engineering Workshops (ICDEW), Helsinki, 2016, pp. 50-53. doi: 10.1109/ICDEW.2016.7495615.

[5] C. Lins, A. Hein, L. Halder and P. Gronotte, "Still in flow — long-term usage of an activity motivating app for seniors," 2016 IEEE 18th International Conference on e-Health Networking, Applications and Services (Healthcom), Munich, 2016, pp. 1-4. doi: 10.1109/HealthCom.2016.7749476

[6] L. Li and M. N. Ulaganathan, "Design and development of a crowdsourcing mobile app for disaster response," 2017 25th International Conference on Geoinformatics, Buffalo, NY, 2017, pp. 1-4. doi: 10.1109/GEOINFORMATICS.2017.8090943.

[7] J. Disney, D. Bailey, A. Farrell, A. Taylor and B. McGreavy, "Anecdata.org: An online citizen science platform for Building Climate Resilient Communities," OCEANS 2018 MTS/IEEE Charleston, Charleston, SC, 2018, pp. 1-4. doi: 10.1109/OCEANS.2018.8604515

[8] S. Cabral, M. Mónica, J. Metrôlho and F. Ribeiro, "App for More Inclusive Urban Mobility a Prototype in Development," 2019 14th Iberian Conference on Information Systems and Technologies (CISTI), Coimbra, Portugal, 2019, pp. 1-4. doi: 10.23919/CISTI.2019.8760871

[9] Citymapper, «Citymapper», Citymapper making cities usable, 2019. [Em linha]. Disponível em: https://citymapper.com. [Acedido: 24-Mar-2020].

[10] H. Technologies, «Here», Wego, 2019. [Em linha]. Disponível em: https://wego.here.com. [Acedido: 24-Mar-2020].

[11] S. Foell, G. Kortuem, R. Rawassizadeh, M. Handte, U. Iqbal, e P. Marrón, «Micro-navigation for Urban Bus Passengers: Using the Internet of Things to Improve the Public Transport Experience», em Proceedings of the First International Conference on IoT in Urban Space, 2014, pp. 1–6.

[12] S. Ram, Y. Wang, F. Currim, F. Dong, E. Dantas, e L. A. Sabóia, «SMARTBUS: A Web Application for Smart Urban Mobility and Transportation», em Proceedings of the 25th International Conference Companion on World Wide Web, 2016, pp. 363–368.

[13] M. De Marchi, J. Eriksson, e A. G. Forbes, «TransitTrace: Route Planning Using Ambient Displays», em Proceedings of the 23rd SIGSPATIAL International Conference on Advances in Geographic Information Systems, 2015, p. 67:1--67:4.

[14] H. Shen, K.-Y. Chan, J. Coughlan, and J. Brabyn, "A Mo- bile Phone System to Find Crosswalks for Visually Impaired Pedestrians," Technology and Disability, vol. 20, no. 3, pp. 217–224, 2008.

[15] V. Ivanchenko, J. Coughlan, and H. Shen, "Staying in the Crosswalk: A System for Guiding Visually Impaired Pedes- trians at Traffic Intersections," in AAATE, Florence, Italy, 2009.

[16] D. Ahmetovic, C. Bernareggi, and S. Mascetti, "Zebralocal- izer: identification and localization of pedestrian crossings," in MobileHCI. Stockholm, Sweden: ACM, 2011, pp. 275– 284.

[17] Korkishko, I. (2019) UI/UX design guide with terms, explanations, tips and trends. Retrieved August 9, 2019 from https://medium.com/swlh/ui-ux-design-guide-with-terms-explanations-tips- and-trends-754b9356d914.

[18] Garrett, J. (2011) The elements of user experience: user-centered design for the web and beyond. Berkeley: New Riders.