VibraMaps: Haptic navigation App for Visual Impaired People

- Android and iPhone app for high precision navigation with haptic feedback for blind people -

Internship report

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Logo of VibraMaps has been designed taking into account Apple guidelines found in [21] for color contrast.

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Preface

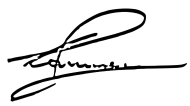
In the same line of study of some of my master projects [28] regarding people with some type of impairment, in this report a new app for navigation with haptic feedback (but not limited to) for people with visual impairment (PIV) is proposed. Some devices have been proposed to aid visual impaired people navigation using haptics, however, not a standalone app for smartphone of this kind can be found yet, which is something PIV demand for an easy accessibility as barely never these devices are available to buy or reproduce.

The idea of the app came first after my first "blind" walk using other available apps for smartphones where I nearly crashed myself several times, as I cannot interpret how much right is "turn slightly to the right". After discussing few times with my counselor of ONCE, this turned out to be not only a personal concern, but rather an issue PIV deal with everyday.

Some other concerns were that, apps that require an active listening are limiting the "vision" of PIV; having one ear dedicated (even with bone conduction earphones) to listening to an app is like watching the world without an eye for sighted people. And that becomes quite tricky when out there there are a lot of risky situations (car suddenly appears in the street, people walking quickly, unpredicted object on the sidewalk etc) that may harm you.

After an exhaustive research 1 and counselling by ONCE (National organization of Spanish blind people), vibraMaps is the proposed app to solve the found not already satisfied necessities of PIV.

Aalborg University, May 28, 2021



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Chapter 1

Initial research

Prior to developing and coding the actual app, a profound research is carried out in order to get a clearer idea of what are the true general problems and necessities visual impaired people have (from now on, people with impaired vision will be referred as "PIV"), and what technologies (focusing on external hardware and smartphone apps) have been developed towards it. Additionally, haptic current technologies regarding PIV are also studied.

1.1 Studies regarding PIV necessities/appeals/design considerations

One of the main goals when designing an app for blind people or any particular sector of the population, is to know certainly what their necessities are. In a research study [11], 88 blind people are asked about what they want. One of their main frustrations is having to ask continuously what things in front of them are. In their research project, an object recognizing app poared by AI is developed to tackle this issue sight-impaired people have. In [7], 5.329 blind people are asked to make questions about photographs they made with their iPhone. In particular, it is found out that most of the questions PIV made are about "Identification" (73 %) and it is also remarkable that they want also to know subjective information such as "how the sky looks like" or "the attractiveness of people", showing that social perception is often ignored in the nowadays technology design.

A certainly related book about the developed technologies for PIV is "Assistive Technology for Visually Impaired and Blind People" [19]. This book contains several PIV projects and problems are analyzed and followed by a descriptive solution. Nonetheless, the book is a little out of date (2008).

In [52], an extensive survey is conducted extracting relevant information regarding PIV and technologies, such as blind people most popular used smartphone is the iPhone. Flick and numeric keypad is most used by low vision people while voice as input is most used by fully blind people. Drawbacks consider problems in output speech for blind people. The survey reflects that a 20.9 percent of the smartphone usage is dedicated towards geographical information and a 62.8 percent used voice input compared to other input types. Also, this research asked a "wish list" for PIV in which GPS navigation app are the most desired. This supports the utility of the goal of this project: facilitating navigation is a demand many PIV have and its right functioning will facilitate its dairy life.

Further researches [4, 5] study the needs of PIV conducted by formative studies and a clear evaluation approach of a future system of auditory augmented reality to augment the natural elements in open spaces is presented. Results show that PIV tend to use apps at home, before going to public transport or nature, but not much inside the parks. In [12], some techniques are suggested for facilitating app usage to blind users without proper evaluation.

In [46], an extensive detailed research tackles the whole picture starting by a formative study to understand the demands of PIV where the findings are the ones leading the resolutions or design. In their feedback, PIV related that a hands-free technology is desired as not to disrupt them from navigating the world. Moreover, holding a phone is not such a good idea due to safety reasons as well as hampering the use of their primary mobility tool. Another really important remark from the work, is that not all PIV should be treated equally as they do not present equal capabilities/impairments. So as, adapting the technology for the variety of PIV is critical. Besides, some PIV would like to keep incoming information related to their task or context, while other prefer a full description of the environment to create their own mental map. This will influence the configuration possibilities of vibraMaps.

In paper [33], findings to guide future researchers and developers and the importance of user feedback is drafted and will be taken into account for this project. In volume [17], the principles and techniques used in assistive technology and good design practice are explained, where a categorisation of travel aids is proposed. When it comes to design, more guidelines and approaches towards technologies for PIV are available, such as [42, 45]. One remarks towards design, is that not enough information have been actually gathered from the starting point of the project. One way to avoid prone errors when designing for a concrete part of the society is participatory design. Participatory design and co-design is a part of human-centered design where the design is developed *with* the users, rather than the traditional approach *for* the users. In this approach people are considered more than a mere source of information. Users are active participants in the design process, achieving outcomes that in other ways will not be possible [45]. A common type of activities for this design process are workshops or participatory events, such as a Wizard Of Oz approach. Nevertheless, due to the current

Covid-19 situation, this path which involves mostly people gathered together is avoided.

Notwithstanding, personal contact to visual impaired person belonging to the ONCE (national organization for the Spanish blind people) (see figure 1.1) for this internship is established from the very beginning to better guide the design of the project although not fulfilling completely these recommendation of co-design approach. In this case, the involvement of the end user is regarded as a research participant [18] who also provides advise but not considered as a consultant due to the fact that one person is not representative of a population.

Figure 1.1: The author of vibraMaps with counsellor Rosa, at ONCE office

Involvement of PIV as end-users requires consideration of the diversity of the population of blind people on factors including age, gender, race/ethnicity, education, employment, O&M training and skills among others characteristics [42]. Following the great extension of Pissaloux and Ramiro work, the next statements about the *Stages of the Design Process* [42] will be taken into account for the development of this project:

1. *Learning about the users and their activities as early as possible, preferably right at the start.*

2. *Applying this knowledge about the users to inform the design.*

3. *Repeatedly presenting the users with early prototypes for evaluation.*

4. *An iterative cycle of design, (end-user) testing, measurement and redesign, which is repeated as often as necessary, to identify and take account of any issues identified in end-user testing and resolve the associated problems.*

1.2 About apps for PIV

There are many apps already built for smartphones with different purposes and success. Regarding that, an extensive app review is carried out in [2] which will be taken into account for filling table 1.2 with all found PIV apps.

Apart from the final goal of an app for PIV, the in-app navigation is also quite important. In [34], the research studies the use of different gestures types as input is designed for guidance inside an app aided by sounds.

The recent developments in audio and tactile feedback based assistive technologies targeting the blind community are summarized in [10]. Important related-to-the-field words are defined within their work, such as "auditory icons", "earcons" or "sonification". It shows that although some successful haptic devices are developed, comfort is high appreciated by users, and till some level is reached, success will be delayed. This work [10] also talks about some iOS apps, such as Ariadne GPS, which is promised to be able to "announce stops on the bus or train". However, when reading the app manual [8], it says it can bookmark bus stops, or concrete locations, which the user will be warned when approaching them, however, that is not exactly announcing each bus stops the user is at nearby.

In [16], a smartphone app enables blind people to gain route knowledge and familiarize with the environment before visiting a particular location. It is a way so that PIV transfer their route knowledge to the real-world and reach the destination unassisted. In [43], different aiding PIV navigation systems are conveyed using different feedback while doing jogging: Wizard of Oz, wrist vibration and head beat. In wrist vibration participants had the best opportunity to listen to their surroundings (not aurally distracting). However, several participants felt that these two vibrating watches are socially unacceptable (would get some sort of criticism). The mentioned alternative is to have only one watch but with different vibration locations, which would steeper the learning curve for localization. In their research, it is recommended for future designers that the use of vibrations is pronounced so that a person can use their cane or guide dog and still feel the vibrations. They also found that wind and loud noises reduces the perceived audio cues (but non verbal), so louder and high frequency sounds are recommended for open spaces. The study also highlights *"someone's turn status while in motion is a challenging research problem."* Social acceptance is also mentioned in [50], where it is underlined that many specialized devices attracted undesirabled attention, making situations in public spaces uncomfortable and marking PIV as "different" reinforcing their differences [48].

Designing and defining a helpful assistance for PIV is [50] is crucial. Keeping in mind that the provided information must not disrupt the on-going action, that this information must be adapted to the user and moreover it should be accommodated to the actual social context an issue to keep in mind for this project. As an example of these situation, a PIV who is using the phone speaker reported:

"I have my cane in my right hand... and then my phone in my left and basically I'm just listening to the directions... I get the look of why is this guy blind and he's looking at his phone? Is he texting? That type of look... There's a couple of times that you just want to walk and you want to concentrate and the app's kind of you have to look down or listen to it and you're like, "Why, do I need to do that?" [23].

Some PIV also use earphones (stereo or mono) for navigation and to avoid holding a phone in the hand. However, these disrupt anyway the cues they get from the environment [23] (participants in this study are totally blind or legally blind). It is recommended that apps had a trigger phrase or a single button press on the phone or on a headset, a particular notification when the phone is tucked away. Context to locations, landmarks, POIs (point of interest) are recommended for any navigation app.

After this brief analysis of the found studies regarding app, a table 1.2 is designed to better visualize the PIV app current panorama.

1.3 About devices in combination or not with smartphones for PIV. The "inaccessibility" of accessible devices

Apart from smartphone apps, widely available, it can be found other research projects which enhance the experience by using external devices (in combination or not with smartphones) which are not so available nor accessible as it will be concluded at the of this section (see table 1.3).

In [9], a 3D spatial guidance system that helps a blind user find a specific location of interest on an object using CamIO, an audio-based AR system.

Also, in [25], an avoiding collision suitcase, which it is social accepted by PIV, is designed for navigating in crowded spaces in places such as airports. Although the good results, there is not much written about if it is possible to buy it, the final expected cost, or how to build it. Although these new devices and proposals show great results, the truth is that PIV in general, cannot access them. Either due to price or for inaccessibility (cannot buy them/it is not produced), the final user would not be able to make use of it.

There are also some apps that combine an external device intercommunicated with the phone. This is the case of Blind's Mate, [32] which presents a smart stick that alerts of obstacle and water pits providing audio feeds to the user. The stick is promised to have a low price. However, no price is stated nor evaluation is carried out over VIP, leading to a non-trustable conclusion.

In comparison, other researches have a more extensive evaluation, such as [20], where evaluation period comprises 2 years. In this research, a providing assistance in home environment is developed. It provides blind people offers assistance

App Title	Additional HW	Uses Smartphone	Exp. Phone	Android/iOS	Latest release	OS version	Map Model	Haptic location feedback*	Haptic signal type	Body part involved	Cost	Comments	Current availability
FAR Vision	No	Yes	-	Android	2020	Android 11	-	-	-	-	free	Uses beacons installed in partner businesses for navigation	Yes
RightHear	No	Yes	-	Android	2020	Android 11	OpenStreetMap	-	-	-	free	Uses beacons installed in partner businesses for navigation	Yes
Lazarillo GPS	No	Yes	-	Android	2021	Android 11	GoogleMaps	-	Simple vibrations	Hand	free	Navigation GPS for the blind	Yes
Eye-D Pro	No	Yes	-	Android	2019	Android 10	-	-	-	-	~8$	Navigation, read text, and identify objects	Yes
GetThere GPS	No	Yes	-	Android	2019	Android 10	-	-	-	-	free	Voice navigation and location alarm	Yes
Talking Location	No	Yes	-	iOS	2010	3.1.3	-	-	-	-	free	Very basic navigation	Yes
WalkyTalky	No	Yes	-	iOS	-	-	-	-	-	-	-	Not found	Not found
vOICe	No	Yes	-	iOS	2013	5.1.1	-	-	-	-	-	Augmented reality based navigation support	Not found
Ariadne GPS	No	Yes	-	iOS	2019	10.3.4	GoogleMaps	-	-	-	~5$	Navigation GPS for the blind	Yes
GPS Lookaround	No	Yes	-	iOS	2020	10.3.4	-	-	-	-	-	Not found	Not found
BlindSquare	No	Yes	-	iOS	-	-	-	-	-	-	~40$	Navigation GPS for the blind	Yes
POI Explorer	Yes	Yes	-	Android	2013	KitKat	-	-	-	-	-	Not found	No
GuideBeacon	Yes	Yes	-	-	2017	-	-	Unknown (not accessible information)	-	-	-	Allows users to interact with low cost Bluetooth-based beacons	No
EyeMate	Yes	Yes	-	Android	2015	Marshmallow	GoogleMaps	No	Simple vibrations	Finger and head	-	User is navigated through a avooiding-obstacle spectacle	No
Voice Maps	Yes	Yes	Nokia n97 (JavaME), Motorola MileStone and T-Mobile G1	Android	2011	Honeycomb	OpenStreetMap	No	Simple vibrations	Hand	-	tem is capable of finding the route obtained with the use of DGPS rece	No
Loadstone GPS	No	Yes	-	iOS	2019	10.3.4	OpenStreetMap	-	-	-	free	POI are obtained from OpenStreetMap	Yes
Soundscape	No	Yes	-	iOS	2019	10.3.4	-	-	-	-	free	Place audio cues and labels in 3D space such that they sound like they are coming from the direction of POI	No
Seeing Eye GPS	No	Yes	-	iOS	2019	10.3.4	-	-	-	-	free	ser can select three choices for POI data (Apple, Foursquare, and OSI	Yes

Haptic location feedback*: is feedback beyond just "vibrating at an intersection"   - : not applicable or information not available

Figure 1.2: Summary of found PIV Apps and their characteristics

with work on a computer, including writing in Braille on a regular keyboard and specialized work in IT and electronics.

Table 1.3 summarizes the found projects for PIV navigation and their characteristics, highlighting the accessibility/availability so PIV can make use of them or not. Out of 21 projects, only two are available and are designated for PIV (and do not require additional hardware). In [22], a review of quite a lot projects for PIV are reviewed. Only 15 out of 112 references are referred to smartphone applications.

This clearly suggest that although developing and researching external hardware for enhancing PIV navigation could be an interesting idea, final end-user may not have the opportunity to try it out. Furthermore, we currently live within a pandemic, a handicap which will harden an evaluation of a hypothetically developed device for this project. Switching therefore the paradigm to an app over a smartphone which mostly every PIV have, seems a good starting point if the goal in mind considers PIV making straight forward use of this project and not delegating the discovered findings to be left on the back burner.

1.4 State Of The Art regarding haptics over smartphones and other devices

Recently, modern smartphones haptic technology have relevantly developed [15, 53], making haptics a rich source of information possibilities for the user, who can obtains this output information privately, only perceived by the person (broadens socially accepted situations).

In [15], concrete vibration patterns can be assigned to metaphors, such as "heartbeats" vibrations if a partner is calling, or a "knocking on door" if it is a neighbor. To communicate complex information, the vibrotactile stimuli need to be associated with some concrete meaning. This stimuli scale a tacton (tactile icon) or haptic icon. The possible variables to alter when using haptic icons are frequency, amplitude, waveform and duration [39]. In the proposed alerts app in [15], the following used patterns can be visualized in figure 1.4. However, while developing this report app, it is wistfully discovered that no smartphone is capable of reproducing amplitude variations in vibrations.

Most of these examples involve the use of a computer for the haptic device to work, and they are not thought as a wearable that PIV would carry on when in the outside. In [14], a haptic interface to give navigational cues is developed concluding that directional haptic cues are sufficient and effective for navigational guidance. However, the handheld device is not available or accessible currently to use on a dairy basis in a combination with a smartphone. Other works also demand a special hardware still not accessible to the public, but with high expectancies of their future possibilities, such as in [1], where a vibrotactile interface is designed

Reference #	Additional HW	Uses Smartphone	Experiment phone model	Android/iOS	Year	Map model	Haptic feedback for navigation	Haptic signal type	Body part involved	For PIV	Results*	Cost	Comments	Availability
[1]	Y	Y	-	A	2011	-	Y	Matrix of tactile actuators	Back	Y	Not finalized	-	Has not been finalized	No
[2]	Y	Y	Motorola	A	2011	Unknown	Y	Vibration patterns	Hand	N	Good	Not available	Presents 3 different location methods	No
[13]	Y	N	-	-	2013	Unknown	N	Vibrations on concrete points	One finger	N	Good	Not available	Not mobile (need PC)	No
[14]	N	Y	-	A	2019	-	Y	Vibration patterns	Hand	Y	Good	Free	Vibration patterns assigned to app icons	Yes
[15]	N	Y	-	ios	2019	OpenStreetMap	N	Simple vibrations	Hand	Y	Good	Free	Vibration to indicate user has completed turning	Yes
[24]	Y	N	-	-	2018	-	Y	Vibrations	Belly	Y	Good	Expensive	Some participants would not be up to wear it	No
[25]	Y	N	-	-	2019	-	N	-	-	Y	Good	Expensive	A suitcase mounted device to alert sighted people	No
[31]	N	Y	-	A	2010	-	Y	Vibration patterns	Hand	Y	Good	Not available	Pointing and scanning with a navigation device could potentially augment the reality	No
[32]	Y	Y	-	A	2019	-	N	-	-	Y	Without Evaluation	Not available	To avoid obstacles	No
[33]	N	Y	Lenovo Phab 2 Pro	A	2020	Floor plans	N	Simple vibrations	Hand	Y	Good	Not available	Indoor navigation	No
[34]	N	Y	PPO A57 Smartphone ColorO	A	2018	-	N	-	-	Y	Good	Not available	Aids navigating an existing module (web)	No
[35]	Y	Y	-	-	2012	-	N	Vibration patterns	Wrist	Y	Good	Not available	Vibrations to tell the time	No
[37]	Y	Y	P20 lite, Huawei	A	2020	-	N	Pressure	One finger	N	Good	Not available	AR manipulation of virtual objects	No
[38]	N	Y	-	A	2010	OpenStreetMap	Y	Vibration patterns	Hand	N	Good	Free	Navigation through haptics not designed for PIV	Yes
[43]	Y	Y		A	2018	Other person feedback	Y	Simple vibrations	Wrist	Y	Good	Not available	Wrist vibration to keep on a jogging track	No
[44]	Y	Y	-	A	2009	Personal	Y	Vibration patterns	Back	N	Good	Not available	Discovery of geo-located information	No
[45]	Y	Y	Nokia N95	-	2014	Personal	Y	Raw vibration	Hand	N	Good	Not available	Vibrations towards any correct direction to final goal	No
[47]	N	Y	-	A	2019	-	N	-	-	Y	Good	Not available	Vision-based system for last-few-meters wayfinding problem	No
[48]	N	Y	NexusOne	A	2013	-	N	Vibration patterns	pants pocket	N	Good	Not available	ıone users perceive the urgency of ten simple vibration	No
[50]	N	Y	-	A	2012	OpenStreetMap	Y	Simple vibrations	Hand	N	Good	Not available	audio- tactile interactive tourist guide	No
[52]	Y	Y	-	-	2015	-	N	-	-	N	Without Evaluation	Not available	-	No

* Good: expected initial goals are accomplished - : not applicable or information not available

Figure 1.3: Summary of found devices/projects and their characteristics

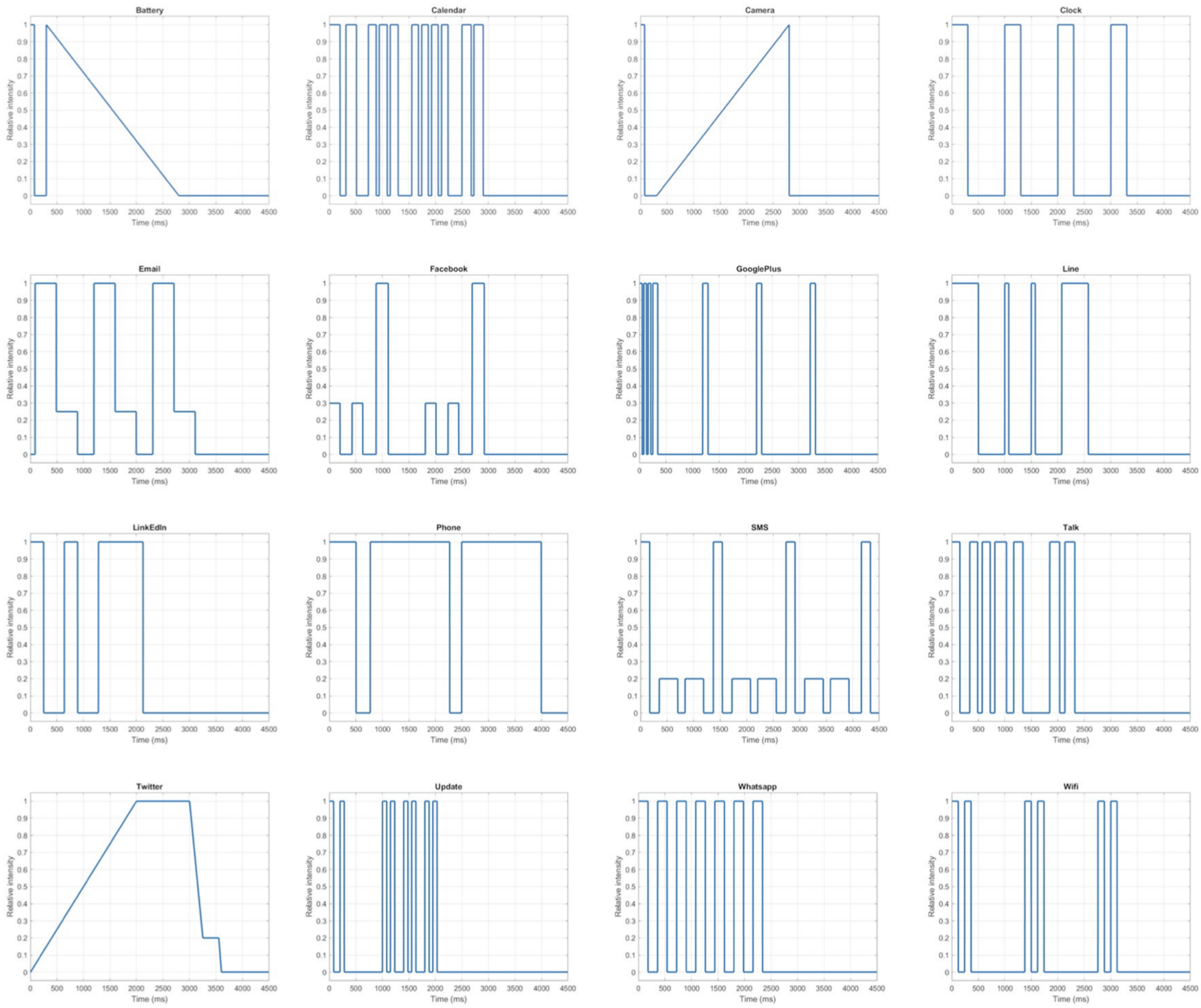


Figure 1.4: Vibrating patterns associated with the haptic icons used by the HAPP application. X-axis represents the time in milliseconds and the Y-axis represents the relative intensity of the vibration. A zero value denotes no vibration meanwhile a one value is the maximum vibration intensity.

to increase the spatial awareness of PIV or in [37], where a wristband display and wearable haptics are used for Augmented Reality. Many more related examples can be found in [27].

In [24], a distance sensitive belt and a haptic belt are presented. It is considered to be a discreet device that costs around $1k. From the beginning, the research is designed with blind people. The main research goal is: *"Our objective is to create a contactless, intuitive, hands-free, and discreet wearable local navigation solution that allows users to sense both low- and high-hanging obstacles as well as physical boundaries in their immediate environment for local navigation"*. The (sort of) question: *"Would. You use it on a daily basis"* or *"Would you pay the price to use it"* is not mentioned. This highly differs from this project, where accessibility to the final result of what developed is a must.

In combination with a smartphone (to be attached on it), it can be found SPIDAR-S [51], which is small, cheap and simple haptic device. It is cconnected to the phone through an earphone jack and provides force feedback by the image information got from the camera. However, no further explanation on how the response behaves when a particular image is recorded neither an evaluation is performed. In [35], when using a vibration watch, it is difficult for PIV to recognize five vibration or more to recognize the current time (the numbers of vibrations represent the hour number). Using long vibration is found to lower PIV errors for getting the correct time. Also, in [47] vibration patterns on smartphone are studied, finding that the vibration pattern designs should be kept as simple as possible and with the least number of on-off pairs during the full pattern.

Related to the aforementioned but using only a smartphone, Shiri Azenkot *et al* developed in [3] a smartphone app for navigation using haptics. The authors compared one already implemented method (Pattern method) [39] for navigation using haptics and two new proposed methods (Wand and ScreenEdge):

1. ***Pattern****: uses input of pressing physical phone buttons. The smartphone vibrates 1 to 4 pulses to indicate which way the user must turn at the nearest intersection. The phone vibrates when the user presses one of the physical keys on the phone.*

2. ***ScreenEdge****: uses touch input. The phone will vibrate when the user touches close to the edge that corresponds to the direction she or he must walk. It does not use the internal smartphone compass (direction indicated is relative the previous log of the route) which can lead to a wrong estimation and therefore, be risky for a PIV.*

3. ***Wand****: uses directional input from the user. The user must point the top of the phone (like a wand sweeping all directions) and it will vibrate when approaching the direction she or he must walk. The built-in compass is used.*

Accuracy is high and the preferred method is *Pattern* followed by *ScreenEdge*. The main issues found by the study participant are induced by the reliability of the phone compass. Navigation did not cause much cognitive load for the users and neither it demands auditory attention.

About smartphone vibrations in [27], we can find a comparative study of how frequency and amplitude of vibration, surface texture, battery level, physical size may affect the perception of a smartphone alert. In general, the higher frequency and amplitude of the acceleration would come out as a stronger vibration perception.

Smartphones vibrations are used in [49] to convey information about distance and direction in a tourist guide, apart from speech sounds with information about the place. In [31], a navigational app that combines audio and haptics is presented. The user may scan the surroundings by using the phone as a laser-ray pointing to the different directions. When "hits" a POI, the phone will vibrate and read aloud its name. To get to a POI, turn right/left and different directions are indicated by different vibration patterns. Evaluation is positive and performed in a park (not really on the streets where most POI are).

Similar to the presented concept in [31], in [44], a mobile device (not a smartphone) is being swept to browse for interesting information about geo-tagged POIs by providing directional vibrotactile feedback. Evaluation is carried over only sighted persons.

A research on the influence of the scanning angle interval on navigation performance is studied in [30]. It is concluded that an interval of 30º to 60º degrees is suggested while if low cognitive load is important an interval of 60º to 120º may be more suitable. Observations confirmed that pointing gesture for navigation is intuitive and easy to use.

In [38], an Android App (year 2010) is presented to navigate maps getting feedback exclusively from vibrations. It is not evaluated over PIV and does not use Apple Maps or Google Maps, so user can choose to go only where she can "tap" on the map (no concrete names as shops or pharmacies) and no searching box to search for a place or street to go. An analysis on the recorded data of the app is presented one year later in [40].

In chapter [41] of “Mobility of Visually Impaired People” book, it is explained what smartphone sensors can do and how to possibly, extract verifiable information from them. Although until not getting into the actual "coding", this are just mere references, as each manufacturer and smartphone is a world itself and the possibilities are limited even if explicitly APIs allow control over some parameters which turn out to be not tunable finally during the research of this project as we can see in table 1.5. Neither of them are capable to reprodue differnet vibration intensities.

Phone / Feature	Android version	Able to get facing angle?	Comments on vibratior	Comments on angle na	Vibrations noticeability	Min interval time between vibrations	Min vibration time
Sony xperia xz1	9	Yes	-		High	50	50
Xiaomi A1	9	No, only gets the true facingAngle if staying still horizontally	-	Gets facingAngle wrongly	Medium	500	500
Huawei P9 Lite	7	Yes, but must be completely horizontal to get the facingAngle	-	-	Medium	50	50
Samsung J3 (2016)	5.1.1	No, it is running very dump in general this phone	-	-	Super Low	50	50
Moto G rooted	7.1.2	Yes	-	-	High	50	50
Moto G Play	7.1.2	No, google services must be updated but wifi phone does not worl	-	-	Super Low	50	50
Moto C	7	No	-	-	Medium	50	50
Moto G XT1032 (old mam‹	5.1	No	-	-	High	50	50
Iphone 6	12.5.2	Yes	-	-	High	-	500
moto g 6 plus (papa new)	9	Yes	-	-	Medium	50	50
Xiaomi Mi A2 (mama new)	10	No, sets the North each time differently	-	-			
Iphone SE	13.5.1	Yes	Does not vibrate	Current location is wrong			

Figure 1.5: Tested smartphones and their corresponding found vibration features

Chapter 2

Implementation of the app

VibraMaps has undergone several iterations since it first version. This chapter reviews its design, functionalities, old versions and further considerations.

2.1 Design of the app interface

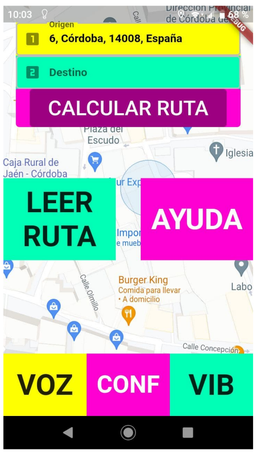


Figure 2.1: Main screen of vibraMaps

The design is desired to have a really simple interface and to offer "ready-to-go" for navigation. Refer to figure 2.1 for the final design of the main app screen.

As we can see from figure 2.1, GUI is kept basic with as few buttons as possible. Although PIV people may use Talk-Back to place the different items on the screen without hassle, the placement of the buttons is on purpose at the top, left, right and bottom. This facilitates remembering where the buttons are and therefore navigation through the app. Also, bold and uppercase text is used in combination with high contrast colors [21] are used as this facilitates navigation for people with low vision [36], yet not totally blind. Besides, the current map, current location and calculated route (comprised of red lines) can be regarded in the background under the other items as it can be seen from figure 2.3. This aids the programming flow in real time when examining what the app is calculating and how navigation behaves, as this accelerates the app troubleshooting.

2.1.1 Main screen

In the main screen 2.1 we can observe different items. In order of appearance, from top-left to bottom-right:

- **Origin field**: it is automatically filled the current location if possible. Is the place of origin of the route.
- **Destination field**: is the place of destination of the route.
- **Calculate route button (CALCULAR RUTA)**: used to calculate the route. If conditions further discussed in 2.2.1 are satisfied, navigation starts automatically when pressed.
- **Read route button (LEER RUTA)**: if route is successfully calculated, speaks the route to walk.
- **Help button (AYUDA)**: if navigation has started, speaks the cardinal coordinate and the angle you are looking, where you should look to and how much to walk naming the street that must be crossed.
- **Voice navigation button (VOZ)**: it is a switch that activates or deactivates voice navigation.
- **Configuration menu button (CONF)**: opens configuration menu to change the possible app variables further discussed in 2.1.2.
- **Vibration navigation button (VIB)**: it is a switch that activates or deactivates voice navigation.

2.1.2 Configuration menu screen

When configuration menu button is pressed, a secondary screen (see figure 2.2) is shown with a list of configurable parameters. If any parameter is touched, a brief explanation about it is spoken. In order of appearance from left to right, top to bottom, they are:

- **Voice navigation information**: speaks information of how voice navigation works.
- **Navigation tutorial**: speaks information of how navigation in general works.
- **Vibration navigation information**: speaks information of how vibration navigation works.

Figure 2.2: Configuration menu screen of vibraMaps with default parameters

- **Radar range in angles**: imaginary range angle that "shoots" your phone. If the next turning point is at 100º and you radar angle is 30º, then you should look between 85º and 115º so as the smartphone does not vibrate (that means you are in the correct path).
- **Preadvice distance**: distance (greater than advice distance) where vibraMaps notifies the user that a turning point is proximate, if voice navigation is active 2.1.1.
- **Advice distance**: distance where vibraMaps alerts the user that a turning point is near, if voice navigation is active 2.1.1.
- **Refreshing time**: period of time that vibraMaps retrieves the user location.
- **Vibration in advice**: when vibration navigation is active 2.1.1, makes the phone vibrate 4 times in a row when advice distance 2.1.2 is reached. Each vibration lasts 1 second.
- **Vibration in preadvice**: when vibration navigation is active 2.1.1, makes the phone vibrate 2 times in a row when advice distance 2.1.2 is reached. Each vibration lasts 1 second.
- **Vibration in advice**: same that *Vibration in preadvice* but at Advice distance.

- **Turning vibration in advice**: when vibration navigation is active 2.1.1, it produces a vibration pattern according to the turning angle to make. Long vibrations corresponds to right while short vibrations too the left. One vibration indicates a turning of 0º-30º, two vibrations indicates a turning of 30º-60º, three between 60º-90º and so on.
- **Back button**: goes back to main app screen and saves the configuration preferences.

2.2 Functionalities and behaviour of the app

When vibraMaps is opened, a non-disturbing characteristic "pip" sound is played. When it is the very first time that user opens vibraMaps, a short message is played so user knows where tutorial and information buttons are located if she/he wants to know more about. Also, it is warned that YouTube video [29] of a real example of voice navigation is available. Either way, if user feel confident to use the app without tutorials, he/she can continue straight away. In fact, vibraMaps design is thought to be as intuitive as possible so as these tutorials are not truly needed to start a successful navigation.

2.2.1 Calculate route button

When pressed, there are three different outcome options:

1. **Route distance is extreme**: when total distance of the route is higher than 5 km, this is notified to the user with an informative message where he/she is told that sometimes, to include the city in the address or introducing a nearby place may solve the problem of getting such a extreme (and highly wrong) route. This route information is retrieved by Google Maps API. Automatic navigation will not start.
2. **Route start is far from user location**: route distance is spoken and user is warned that his/her current location is far (more than 10 metres) to the actual starting point of the calculated route and to extreme caution if user starts route right now (see figure 2.3 for a real app route example). Automatic navigation will start.
3. **Route start is near enough to the user**: after speaking the route distance, navigation starts automatically telling the user which coordinate and angle is facing the phone, where it should be looking to, how much to walk, and which street/address must be crossed.

2.2.2 Read route button

When pressed and route has not and extreme distance, for each direction of the route speaks: the cardinal coordinate and angle to look, how much to walk and the address/street to cross. This is repeated for each "line" that comprises the route. For example, the route that can be seen on figure 2.3 is comprised of two lines (one long red line joint to a short one) and therefore two directions.

Figure 2.3: Short route calculated after pressing read route button consisting on two directions. Calculated initial point of the route is far from user current location and warning message is played 2.2.1.

2.2.3 Help button

When pressed, it speaks the cardinal coordinate and angle you are looking (from 0° (North) to 360° clockwise), where the user should look (also in cardinal coordinates and angle), how much to walk and the address/street to be crossed.

2.2.4 Voice navigation button

Activates or deactivates voice navigation. When activates, when reaching preadvice distance or advice distance 2.1.2, the user will be warned about the distance left to reach to the next turning point and which direction to turn in angles to the right or the left. Example: *"There are 15 meters left to the next turning point, 60° to the left*".

2.2.5 Vibration navigation button

Activates or deactivates vibration navigation. Depending on the established configuration 2.2.6, different notifications will be triggered. By default, vibrations navigation is OFF. Short vibrations (100 ms) are triggered if user is not looking to the next turning point within the selected radar angle range from configuration menu.

2.2.6 Configuration menu button

The different parameters that appear in this menu (see figure 2.1.1) are elected as personalization of the app is crucial to enhance PIV user experience [33]. For example, personally, I like vibraMaps with *voice navigation* OFF, *vibration navigation ON* and with *vibration advice in preadvice* and *advice distance* turned ON. I use just vibrations to guide me and when I am notified that I have arrived advice distance, I just press help button to re-orientate myself till I get no vibrations and I keep on walking. But when designing for a wide range of population, the more personalization, the better the app can adapt to each individual, as my counsellor Rosa from ONCE firmly states.

2.3 Old design versions and considerations

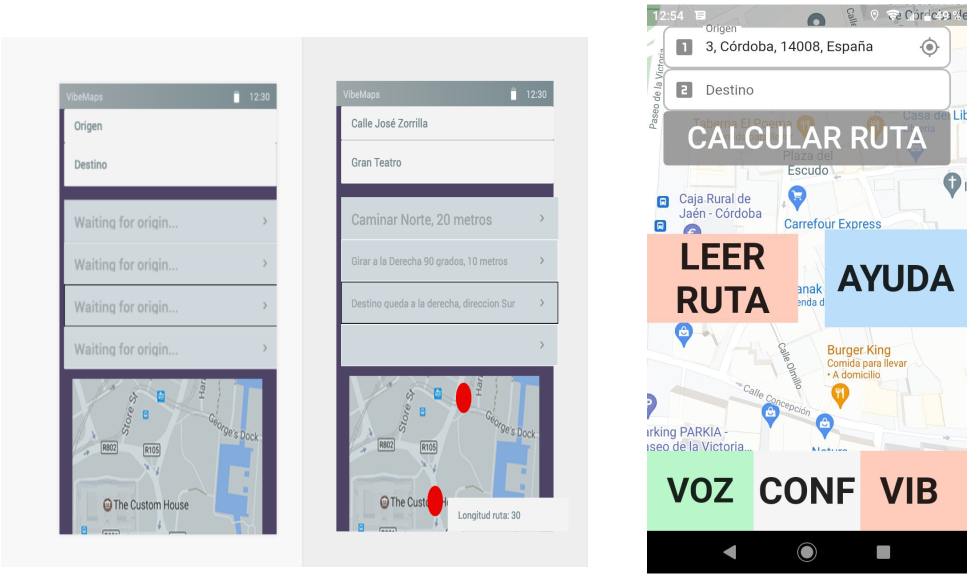
In the very first moments of the project (before coding), FLUID UI [13] is used for designing the screens of the app (see figure 2.4a for the very first design).

Figure 2.5: Version 5 main screen of vibraMaps

Regarding version 3 (refer to figure 2.4b) light colors are used for buttons and all directions information is given in angles. In earlier versions of the app, these two buttons of version 3 ("LEER RUTA" and "AYUDA") are not even included as regarded as "not-so-important" for navigation in the beginning. After counselling, to have them is regarded as compulsory for a satisfactory navigation experience.

Too many buttons are shown in version 5 (see figure 2.5) offering nearly same functionality but in a different way (e.g. "AYUDA CARD" speaks help by using cardinal coordinates while "AYUDA ÁNG" speaks help by using angles).

This is first considered because some people may prefer to listen only to one data type rather the other and not to lose time listening to more not needed info. However, it is determined that the time consumed in the full spoken audio if to speak both data (angle and



(a) First designed screen of vibraMaps

(b) VibraMaps in early stages of development. Precisely, version 3

Figure 2.4: First draft of vibraMaps screen and version 3 screen, respectively

cardinal coordinate) is minimal and will take out one not needed button that makes things more dense. Same conclusion is presumed for route calculation buttons placed at the left in the screen ("RUTA CARD", "RUTA ÁNG", "RUTA CALLES") (see figure 2.5).

Tutorials get updated carefully with each new found mishap (e.g: restarting app may improve sometimes compass, some devices need to turn ON *Vibration on buttons* in Settings for vibraMaps vibration navigation to work out, sometimes adding your current city to the address allows vibraMaps to calculate successfully the route, etc).

This type of information I also would like to receive when navigating with other PIV apps, such as Lazarillo [26] as I do not know what to do or how to proceed when being confused during navigation.

Configuration parameters get also shaped within each app iteration as we can see in figure 2.6 of an old app version. As we can see in context, with each new version vibraMaps is evolving and improving after receiving constant counselling feedback.

It is worthy to say that, in an attempt to change PIV standard of using Text To Speech human synthesizers, human voice was recorded for some items of vibraMaps, which shares Text To Speech and human voice. In the very beginning, all was programmed only using real voice, until finding some unavoidable obstacles that have moved the project towards the use of Text To Speech.

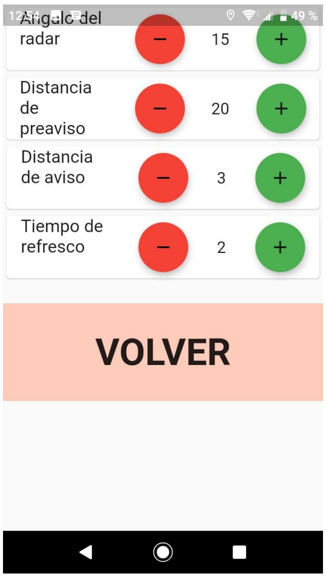


Figure 2.6: Configuration menu parameters in version 3.

2.4 iPhone implementation issues

Regarding the app implementation in iPhone, many difficulties are encountered although flutter exportability to iOS. Firstly, the minimal working example is ran on iPhone without hassle. Also, when it comes to exporting to other iPhones in situ it works quite nice. However, PIV tend to use last software updates (even Beta versions) and that becomes a problem if last version of Xcode (which is used to install the app) does not allow a target software greater than the version of the PIV available iPhones. So, I am not able to install vibraMaps in the available iPhones in ONCE. Moreover, although Aalborg University offers the possibility of having an Apple developer account being an student, neither me or other professors managed to get an app uploaded to the Apple Connect Store correctly so it can be delivered to team members. Besides, TestFlight (necessary to send an invitation to test the app remotely) is not provided within the university account, so testing on PIV iPhones is not duable at the end.

Chapter 3

Evaluation and Results

For the app evaluation, Google form is chosen as the best tool as it provides a pretty accessible experience for PIV. It is is a brief questionnaire (5-10 minutes, short as recommended also by the ONCE counsellor) with questions regarding personal and smartphone information, appearance of the app (location and distributions of items), app functionalities, offered information (app tutorials), street navigation, configuration menu and general considerations.

Additionally, more informally, personal valuable comments during the app use and while its development are also gathered.

3.1 Google form survey results

6 people have participated in the study (2 PIV, other are blindfolded), 5 used Android OS and 1 iOS.

The survey reflects that the majority of participants value the appearance and distribution of the app items as pretty adequate. With respect to routes calculations, around a third of the participants states that some routes are not found by the app. Only one participant think that when "Read Route" button is pressed, too much/redundant information is spoken. To enhance the performance of this button it is suggested that "speeding up somehow the directions spoken" would be a good idea. All participants agree that the information offered by vibraMaps about voice navigation is nice and complete. One participant (PIV) affirms that vibration navigation is not useful for him. Nevertheless, if there existed any connection of vibraMaps to an external device to feel the vibration not on the phone, would be perfect. One tester (PIV) claims that information about vibration navigation could be more complete as this is the first app in this vibration category that she uses.

Regarding in-app navigation, in general, participants think that is easy to navigate within. All participants agree or highly agree that is really easy and quick to learn how the app works. The majority of participants believe that is easy to navigate through the streets with vibraMaps and that it is precise giving indications.

A third of participants affirms that, when navigating in the street is confusing, help buttons aids in this. A majority of participants think that is useful or very useful to have voice and vibration navigation available on the app. A majority of participants believes that vibration navigation is very useful in order to not being continuously listening to what the phone is speaking, so attention can be directed over other streets events. All participants disagree with regarding vibration navigation as confusing. A third of participants states that, sometimes, vibraMaps gets wrong directions over the street.

Regarding configuration menu, most participants agree that the menu parameters are good and adequate. Also, it is suggested that better explanations about configuration parameters are provided. Regarding changing the parameters values, one participant (PIV) states that sliders could be better than using the plus and minus buttons. Also affirms that this is her *"personal preference"* and not probably the best fit for everyone. Also, changing parameters using just voice could be another enhancement. The rest of the participants state that would leave configuration menu untouched.

Regarding the tutorial and information offered, most of participants agree that the given advice is adequate. One participant states that it could be more complete. There is not a really homogeneous opinion about if it is preferred to use human voice or robotic voice, either for sighted not sighted testers.

In general, valuation of vibraMaps is quite positive as few extracts from participants comments show:

"Vibration navigation is God", "This could make a real difference for PIV users, still need more development", "It is an app where it is noticeable the code sign with PIV and not treating them as just a mere end-user", "very configurable and offers a lot of possibilities."

All participants would like to see this app in the market. Its price is thought to be in 4€-10€ range or free, subsidizes by authorities.

3.2 General comments

For some PIV, although not expected, find vibration navigation uncomfortable. In contrast, others find vibration navigation extremely useful as the they do not have to be with one one hand occupied as with the other they are used to have a guiding dog or a cane and then will not have any free hand if any unlucky event happens.

The possibility of vibraMaps to have a similar places discovery functionality such as BlindSquare [6] or Lazarillo [26] do, is suggested, as a way to "bypass" having to know the name of the place in order to get there. Also, it is suggested that vibraMaps allow routes where public transport is needed. The high-contrast items of vibraMaps for low vision are very well received, as in contrast other popular apps for PIV ([6, 26]) do not.

Some PIV affirm that vibration navigation is not useful really useful in this state, although, if there would be an external device to feel the vibration instead of using the phone would be impressive and achieve a milestone regarding navigation for PIV. Regarding the tutorials, one participant (PIV) states that, due to the novelty of the haptic feedback, vibration information should be more further explained, as no market app shares this functionality. Other (PIV) thinks that Text To Speech option should be available always (instead of human voice). Other participant, thinks that when a button is pressed, it should “shine” or to be highlighted somehow, so low vision people can get subtle feedback.

One tester comments during street navigation: *"The placement of help button is quite affordable to reach for my thumb, which is a comfortable design. It is a well-thought design".*

Chapter 4

Disccussion

The general agreement on the app items distribution shows that keeping a simple and minimalist approach for the design as recommended in the different general read guidelines reviewed in 1.1 has been a success. This supports the decision of discarding more dense versions (see 2.5).

For those which are not comfortable with feeling the vibrations on their phones, the use of an external gadget is recommended, which would not be a big hassle (in theory) to develop. For example, a little ring or wristband that uses Bluetooth to receive phone information and vibrate. Even it could be somehow attached to watch strap to be more comfortable to wear and undress everyday. It must not be forgotten that to simplify is always a good path in facilitating everyday actions for people with impairments of any kind. Likewise, if developed, it to had be also accessible; either this device could be bought or should be relatively easy to be reproduced or built for a sighted person.

Sometimes, when route is big, it can be tedious to listen to the full text read by "Read Route" button, as one participant states. VibraMaps offers high precision indications, so, if there is a big curve in the path turns slightly to the right, directions may seem like:

"3, look to 180º south, and walk 3 metres crossing street King Carlos III,

"4, look to 185º south, and walk 5 metres crossing street King Carlos III,

"5, look to 190º south, and walk 7 metres crossing street King Carlos III."

Maybe pressing this button again can skip the direction that is being told and skip to the next to accelerate the reading if route is more or less familiar. In contrast, other PIV firmly states that this "Read Route" button, with the precision it offers, is the *"absolute king of this app"*, as nothing similar exists up to date.

The majority of testers agree that is easy to learn to navigate the app along with navigating with precision the streets. Moreover, they find vibration navigation quite useful. In contrast, a third of the participants declare that vibraMaps gets wrong directions over the streets. Often, this is due to GPS not being quite accurate due to battery, others app opened, phone model, etc. This is mostly the main issue found during navigation (see figure 6.2).

Configuration parameters are considered as satisfactory as confirmed by the results, but a better explanation of them could be provided. Regarding the tutorials comments, a new configuration parameter could be implemented to set all app spoken info to Text To Speech or use Human Voice when possible.

In general, comments are remarkably positive and the app is desired to be available in the market, with a price ranging from 4€ to 10€.

Chapter 5

Conclusion

VibraMaps changes the traditional paradigm of PIV (people with impaired vision) navigation apps. It offers the highest precision regarding instructions available in the market for walking a route while offering a navigation guided by voice and/or vibrations. This allows users to have their hands free and ears free (no listening is required) which enhances the liberty degree.

VibraMaps has a minimalist design where in-app navigation and street navigation is designed to be quite accessible, which steeps up the learning curve of how the app works to start playing with it as soon as possible, so user does not leave it in the back burner and be forgotten.

VibraMaps, being enhanced by a future possible combination to transfer the vibrations to other external wearable devices such Apple Watch, could change the current paradigm in facilitating PIV navigation in such way that no other application has achieved right now. Notwithstanding, further development is required, avoiding wrong direction estimations (GPS unstable), suiting tutorials and app information better, selecting the more accessible routes, creating a list of saved routes, etc.

Altogether, results show that vibraMaps is in the right track to set a new milestone in traditional navigation in conjunction with making life easier for people with visual impairments.

Chapter 6

Future work

Comments and experiences regarding the novelty of the app, value the high precision offered navigation information and its the vibration navigation possibility. However, there are many possible future improvements.

Figure 6.1: The author this report walking a route with vibraMaps while unfortunate packets are placed in the middle of the path that would lead to a collision.

A more advanced notification system, such as alerting the user that his location is unstable (refer to figure 6.2) or his/her compass is erratic or it has become again stabilized, an in-app study of how other parameters (many other apps opened, battery under a percentage, phone model, etc) affect this and communicates it to the user, or in-route object detection (see figure 6.1 for an example) could be implemented as a future work.

Besides, many PIV walk periodically same routes (for work, pleasure, visiting relatives...). Being able to save a route to a list, so user just may go to a "routes list", select it, and start straight away navigation would be also a good improvement which is suggested on counselling but yet not implement due to time limits. Additionally, calculating a better route, taking into account the bars/pub to avoid these usually crowded streets (with tables placed nearly on the sidewalks, at least in Spain) could be also an enhancement. Besides, voice input possibility could facilitate the app navigation.

A participant of the study firmly believes that vibraMaps in combination with an external gadget that can be wore without, such as the Apple Watch would change the paradigm for PIV forever, as such a thing still does not exist.

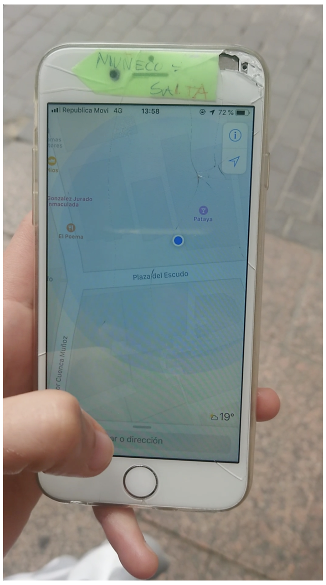


Figure 6.2: User is "flying" over the buildings as calculated by Google Maps in the street.

Chapter 7

About work experience and progress

This is the first remote working experience I have in cooperation with a company and a non-lucrative organization; and it has been real different from other job experiences I have had.

The starting weeks of this internship are comprised with a considerable essential initial research load 1 before right getting hands on work. After these 2-3 weeks and discussing the research conclusions with counsellors, vibraMaps idea is initiated. Flutter framework is elected to develop the app, exportable to android and iPhone; interesting characteristic as a considerable part of PIV uses this OS.

First month is dedicated mostly to understand the basics and the philosophy of Flutter and to develop a minimal working example app.

The following months are committed to get an operative app and to enhance last made version. The beginning is devoted to develop the mathematical functions to calculate the precise angles to turn through the route. After meetings with my ONCE counsellor, the app and its functionalities are redefined and shaped until its last version. Sometimes, where counselling is not straight-away available, I keep on developing and asking myself how this app can be regarded and accessed in a new way, what is still failing and I am not able to see so it is even more accessible and reliable.

This is the working trend during the most time of the internship which is illustrated in figure 7.1, which shares certainly similarities with [42] cited in 1.

Certainly, difficulties arise as the app is developed in the form of undetermined errors, back-end updates that breaks the coding program and simulator, things turning out to not work in a concrete moment, smartphone models performing in distinct ways with same app version... Indubitably, persistence in these moments is forged and even more in a remote context. That has turned me into a more resilient programmer. Little steps are celebrated by all parts and encourage me to keep on going despite of the adversities.

Around the middle of the internship, I keep a working journal to write what

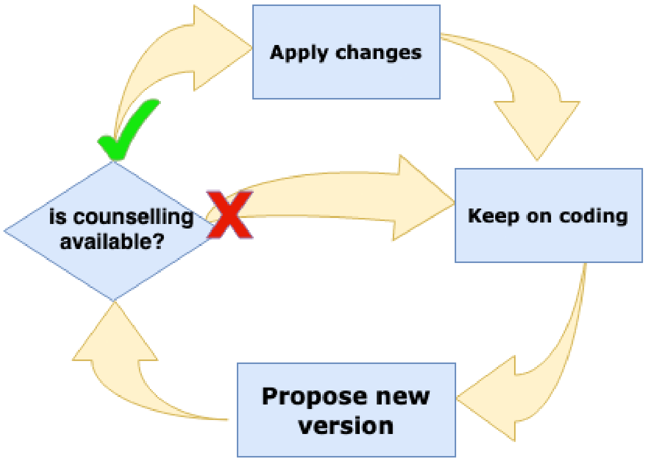


Figure 7.1: Work trend/flow during internship

are the objectives of the day, how I felt the day (goo, bad, neutral, etc) and what I can do the day after to perform better during the day. It turns out that at least, I should do an activity to clear up my mind which does not not involve screen (as I spent 8 hours or more during the day in front of them). Also, when I enter into "flow" state, it is preferable that I keep no working. Nevertheless, if I'm stuck, it is preferred that I stop, have a break with a different activity and then I get back to work or even the day after. This turns out to increase efficiency when code is just not compiling or I cannot see a way to achieve what I want that works out.

Conjointly, I keep a written dairy update of what I have managed to achieve during the day, and what is for tomorrow. To observe the development of my work in words (as app digital appearance may remain the same at first sight and progress null) satisfies me and encourage me to go further. Actually, I started this working diary on digital, but it turns out that this is not the most adequate nor appealing platform for me to write. Moreover, a handy notebook is more accessible personally than an excel document in some folder of another folder somewhere in my PC.

In last weeks of the internship, an app evaluation is carried out. Hard efforts are made too to be able to send iPhone invitations and installing the app on iOS PIV devices without success. The .apk is shared within a Telegram group in conjunction with the Google form to be filled up after the app is tested on the street. Thereupon, this report is written.

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