Czech Technical University in Prague

Faculty of Electrical Engineering

Department of Computer Graphics and Interaction

Description of Route Alternatives in Multimodal Transport for Blind Travelers

MASTER'S THESIS

2020 BC. VICTORIA USAN

ZADÁNÍ DIPLOMOVÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

Příjmení: **Usan** Jméno: **Victoria** Osobní číslo: **423590**

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Studijní obor: **Interakce člověka s počítačem**

II. ÚDAJE K DIPLOMOVÉ PRÁCI

Název diplomové práce:

Popis alternativních tras v multimodální dopravě pro nevidomé cestovatele

Název diplomové práce anglicky:

Description of route alternatives in multimodal transport for blind travelers

Pokyny pro vypracování:

Proveďte analýzu literatury a aplikací dostupných na trhu zabývající se orientací a pohybem nevidomých osob. Zaměřte se na metody prezentace tras v navigaci. Na základě výsledků analýzy vytvořte prototypy metod pro popis alternativních tras (text, artefakt, zvuk, apod.) a otestujte s účastníky z cílové skupiny. Implementujte prototyp vybrané metody generování popisu tras. Proveďte testování použitelnosti s účastníky z cílové skupiny v laboratorních podmínkách zaměřené na znalost trasy (route-knowledge).

Seznam doporučené literatury:

1) Ungar, Simon. "13 Cognitive mapping without." Cognitive mapping: past, present, and future 4 (2000): 221.
2) Sammer, Gerd, et al. "Identification of mobility-impaired persons and analysis of their travel behavior and needs." Transportation Research Record 2320.1 (2012): 46-54.
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III. PŘEVZETÍ ZADÁNÍ

Diplomantka bere na vědomí, že je povinna vypracovat diplomovou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací. Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v diplomové práci.

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Datum převzetí zadání	Podpis studentky

Declaration

I hereby declare that I have written this master's thesis independently and quoted all the sources of information used in accordance with methodological instructions on ethical principles for writing an academic thesis. Moreover, I state that this thesis has neither been submitted nor accepted for any other degree.

In Prague, January 2020

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Bc. Victoria Usan

Abstract

This master's thesis focuses on supporting independent travelling of blind people. Although many applications offer navigation functions for unsighted users, they are not often asked whether the offered route is the most suitable for them. The main objective is to create a concept of route summaries from which people can receive information about the oncoming journey. In order to design a solution, literature and existing applications were analysed. Set of templates was created for providing information on both global and local levels. During the two testing sessions, workable improvements in the route representation were discovered. Also, possible extensions and recommendations were offered, which improves the future concept and the prototype itself.

Key words: blind people, wayfinding, public transport

Abstrakt

Překlad titulu: Popis alternativních tras v multimodální dopravě pro nevidomé cestovatele

Tato diplomová práce se zaměřuje na podporu nezávislého cestování pro nevidomé lidi. Přestože množství aplikace nabízí navigační funkce pro nevidomé uživatele, nejsou často dotazování, zda nabídnutá trasa je pro ně ta nejvhodnější. Hlavním cílem je vytvořit koncept přehledů tras, ze kterých mohou lidé získat informace o nadcházející cestě. Pro návrh řešení byly analyzovány literatura a existující aplikace. Byla vytvořena sada šablon pro poskytování informací na globální i místní úrovni. Během dvou testování bylo objeveno proveditelné vylepšení reprezentace tras. Rovněž byla nabídnuta možná rozšíření a doporučení, která vylepší budoucí koncept a samotný prototyp.

Klíčová slova: nevídomí lidé, wayfinding, městská doprava

Acknowledgements

In the first place, I would like to thank my supervisor Ing. Jan Balata, Ph.D. for his valuable advice and recommendations, but, most of all, for the most precious part of the life, time that he shared with me.

Also, I would like to thank my parents for the all-year-round support despite being so far from me.

My special thanks also go to all my testers, who spent their own time for testing and made my work even more international and multicultural.

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Chapter 1

Introduction

While looking for an appropriate route from A to B, most of the map applications will be able to offer more than one route. It could differ in such criteria as time, price, or which type of transport the person will use. However, what might matter, especially for blind people, is the accessibility of offered routes, whether they can use a particular route independently, with the help of a white cane or a guide dog. They could be interested in how many transfers they will do or how long they will have to walk to the stop, where their route starts.

This master's thesis will deal with the issues of the orientation of blind people and their locomotion in public space. It will mainly focus on creating text summaries of possible routes from point A to point B for blind people, so they can choose the route, which is the most suitable for them.

Chapter 2 captures the analysis of the literature, which describes not only the blindness and psychological side of the space understanding but also mentions the urban environment and its accessibility. Besides, it contains route presentation methods and the description of blind people's needs, which are necessary for the application design. Also, it is dedicated to applications that are connected to the navigation of not only blind people. Chapter 3 describes the design process, which goes from the design principles to the prototype. Chapter 4 follows up with the implementation of the application, and Chapter 5 provides the results of the evaluation sessions. Finally, Chapter 6 concludes the results of the master's thesis and offers possible future work.

Chapter 2

Related Work

2.1 Literature Review

In order to propose a rational approach for a route summary, which will meet the needs of sightless people, it is needed to explain essential definitions regarding blindness, the psychology of blind people's behavior, and the orientation of blind people in public space. It is also useful to learn the aspects of the city presentation, which will lead to a suitable route summary principle. Another interesting part of this section is a description of solutions that improve the outdoor accessibility all over the world. Last bot not least, there are route presentation methods and investigation of blind people's needs given. Certainly, many information sources do not take into account concerns about the visual impairments, therefore, it is needed to be careful and cautious with data received.

2.1.1 Blindness

When starting research about blind people, it is essential to explain, what blindness is and what impacts it brings to blind people's lives, when the topic of their traveling is discussed.

There are many definitions of blindness, depending on the cause of the impairment or the extent of disability [22]. However, general definition of the blindness could be loss of sight. It is also clear that the severity of the disability is measured by visual acuity.

Being cut from the sense of vision, a person faces the problems of several aspects of life: from non-verbal communication to education and employment. It is also an issue of mobility: traveling in an unfamiliar environment, where unexpected hazards, obstacles, and danger are present, causes stress and fear [36]. During the journey, the blind could collide with newly started constructions, tables in the sidewalk in front of the restaurants or cafés, or half-opened doors [18]. Sometimes, problems could be caused by unregulated crossings, crossings at roundabouts [16], and crossings overall [35], and most often by changes in the space the blind user already knows [29].

2.1.2 Wayfinding and Navigation

The definitions that also have to be explained are wayfinding and navigation. Golledge [19] describes wayfinding as a directed and motivated activity of finding and following a path or a route from an origin to a destination. It also could involve an ability to choose between alternative routes or to modify the route along the journey. On the other hand, navigation is the processing of spatial information, which is later summarised as a course to be followed.

According to Tverksy [32], for navigation, a traveler needs some spatial knowledge, and there are three levels of knowledge: overview (global level), view (local level), and action (turn-by-turn) knowledge. For the purpose of the master thesis, it is essential to work with an overview knowledge as it is a representation of a route summary, and also a view level as it still can give a traveler some details to understand the route. The essentials of the overview knowledge are to provide a representation of the route, not giving many details, but at the same time providing such details, which could later influence the future decision. The view knowledge can already present critical information along the route, and it does not go deep into the details like local surroundings: such a route is created by turn-by-turn knowledge.

2.1.3 Presentation of the City

The process of the route descriptions creation requires an understanding of how to present the city within a simple approach. Therefore, an essential part of it is to do a research about urban planning. Every human is unique, so is the image of the city. Thus, it is necessary to create such a description of the city, which will be recognizable and repeatable.

To create an image of the city for a future traveler, it is necessary to introduce the following elements as Lynch suggests [26]:

- paths (streets, walkways, transit lines, etc.). Other environmental elements are mostly arranged along the paths and are related to them. Paths are considered to be a dominant element;
- edges (shores, railroad cuts, walls, etc.). This type of element could create a barrier, however, it is considered as an organizing feature;
- districts (relatively large sections of the city). Most people use these elements to create an overview image of the city;
- nodes (crossings, junctions, places of a break in transportation, etc.). This element is related to a path and a district concept;
- landmarks (mountains, stores, signs, etc.). These are outstanding points of reference used as clues along the journey.

All these elements help people to "read" the route and to recall its details. In the case of sighted people, there is nothing to criticize. However, in the case of navigation of people with the absence of vision, these elements have a different character. For example, it will not work if someone addresses a blind person that his destination lies just in front of the 10-floor department store with a big sign on the roof (a usual landmark for a person). It could help if the person knows this area and the location of the store, otherwise, it is unuseful information (unless the person has no concerns about asking the people around). Thus, the key feature of the route summary should be an appropriate presentation of these elements.

2.1.4 Cognitive Mapping

When navigating, people are using their sight to orientate in space. When vision cannot be used, other senses should be applied. In any case, a traveler needs to develop a cognitive map.

In [20], Golledge et al. define a cognitive map as "the internal representation of experienced external environments, including the spatial relations among features and objects." Objects could be the elements discussed in Subsection 2.1.3. Those elements are encoded to specific place cells, which, in turn, may be randomly distributed in the brain. Thus, it is possible to define cognitive mapping as a process of creating, keeping, and later on, working with cognitive maps, namely geo-referenced information.

Regarding the ability of a blind person to create a cognitive map, there are three theories presented in [15], [23] and [33]:

- deficiency theory - congenitally blind individuals lack the ability to develop a general spatial understanding;
- inefficiency theory - people with visual impairments can understand and mentally manipulate spatial concepts, but their ability is less efficient than the ability of sighted people;
- difference theory - visually impaired individuals possess the same abilities to process and understand spatial concepts. Those abilities are qualitatively different from, but functionally equivalent to the abilities of sighted people.

From the description above, it is clear that all three theories propose that blind people do not have the skills to use cognitive map knowledge properly, or it is even impossible.

2.1.5 The Accessible Journey Chain

Before the user starts to travel, it is necessary to create a plan. Zhang [38] offers a four-phase concept of the accessible journey chain in the following way:

- Information: gathering information about barrier-free facilities, timetables, and other useful information;
- Departure (out-of-a-vehicle): walking from the origin to a start point of traveling in a vehicle;

- Traveling (in-a-vehicle): waiting, boarding, traveling in a vehicle, and leaving a vehicle;
- Arrival (out-of-a-vehicle): walking from the final point of the previous phase to the destination.

With the concept above and information about spatial knowledge, it is already possible to make a draft of route summaries. The first phase, information, could be a representation of a route summary, and it is a global level of spatial knowledge. It is an opportunity for a traveler to choose the most suitable route before the journey. The last three phases could represent the local level of spatial knowledge and help deepen the knowledge about the upcoming journey.

Building the navigating plan based on this journey chain will help to provide sufficient information about the trip, putting the descriptions of each of the phases in its own information cell.

2.1.6 Solutions on Accessibility in Transport

Generally, sighted people accomplish around 3.7 trips per working day [31], while blind people have a slightly lower number, 3.3 trips per working day. Those trips consist of traveling by car as a passenger (19%), traveling on foot (34%), and traveling by public transport (47%). As public transport traveling presents almost half of the traveling routine, it is necessary to know what opportunities public transport companies can offer for mobility-impaired groups.

Different companies decide on the accessibility of their transport differently. Below, there are only several different approaches on how to ease the traveling routine for blind people:

- in Moscow, Russia, there is a different voice in metro trains, which announces the stations. When the train goes in the way of the center, travelers hear a man's voice; when traveling out of the center, a woman's voice announces the stations. In the case of the Circle line, a man's voice is used when traveling clockwise, and when anticlockwise - a woman's voice;
- in Seoul, South Korea, the approaching train is announced by a signal, which differs, depending on the platform;
- in Seoul, South Korea, there are walls on the platform. Their main aim is preventing a falling on the rails; however, the walls are also used for signs, which describe in Braille the number of the coach, the number of the doors in the coach and the direction of the train (see Figure 2.1);
- in Seoul, South Korea, all following exits are announced, both to the left and to the right. On the other hand, for example, in Prague,

Czechia, or Moscow, Russia, exit to the left is a default exit, and only exits to the right are announced.

Figure 2.1: Braille description of the metro train coach in Konkuk University Station, Seoul, South Korea. 6 stands for the number of the coach, 2 stands for the number of the doors in the coach, the title in Korean stands for Naksongdae direction. Photo by the author

Despite the differences, there is a common trend in improving traveling:

- increasing the number of low-floor buses and trams;
- increasing the number of elevators for access to the platform in metro;
- increasing numbers of ramps and special lifts and similar solutions.

Although most of the improvements seem to be for wheelchair travelers, it also eases the journey for blind people as there are fewer obstacles on their way.

To give an overview of particular solutions, the source of Prague Public Transport Company was studied [13]. To find out the number and direction of the bus or tram arriving, people can use a transmitter for blind people ["VPN, Vysílačka pro nevidomé" in Czech]. The transmitter turns on the acoustic output, which is located right on the vehicle. Sometimes, the stops have the beacons installed, which provide the same output about the next vehicle. With the help of the same transmitter, blind travelers can announce their presence to the vehicle drivers and also to the other passengers: they will hear the phrase "the entrance of the blind traveler" ["Nástup nevidomého" in Czech]. Transmitters are also located near the entrances to metro station vestibules, so blind people can have a navigation signal or receive detailed information. Also, there are transmitters near the escalators, elevators, and toilets. When the blind person wants to let the driver know about his/her presence, he/she can also use the transmitter, and also other passengers will hear the phrases (the doors' opening is activated [Otevření dveří aktivováno in Czech]). Also, stops and stations have tactile paths and railings (especially on island types of the stops).

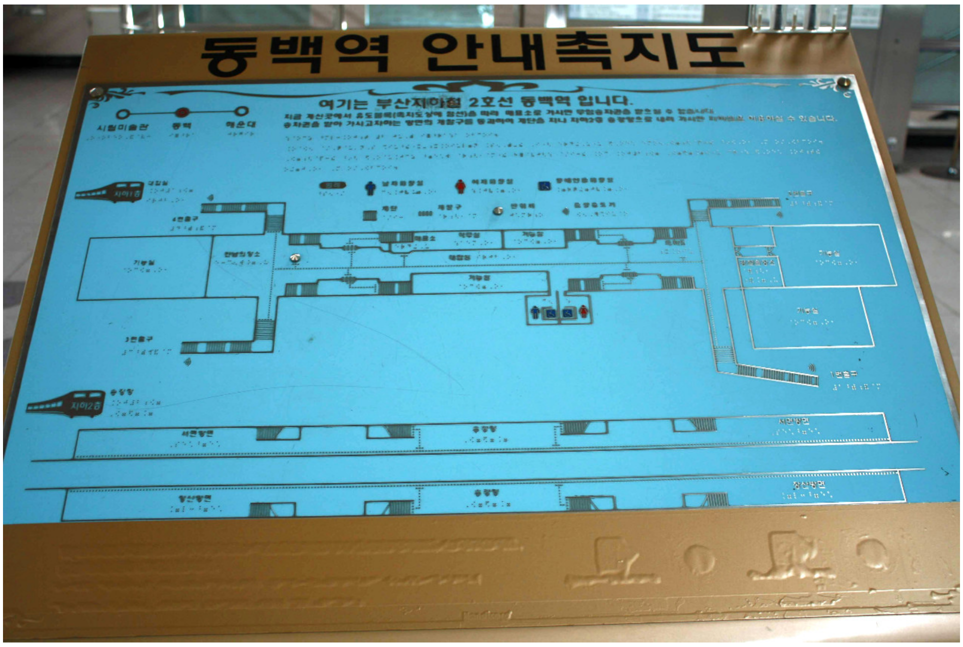

Figure 2.2: Metro station plan in Braille in Busan, South Korea. Photo by the author

2.1.7 Route Presentation Methods

Human beings mostly have five senses: vision, touch, hearing, smell, and taste. Within the subject of wayfinding, the last one is probably the most useless: it is not possible to describe an intersection or any landmark with a particular flavor. Addressing wayfinding for blind people, the vision should be crossed out too. There are last three senses, smell, hearing, and touch, which could be worth working with. The further paragraphs discuss not only how to present the parts of the route summary, but also through which senses bring the information to the user.

When presenting the route summary to the user, the smell is not a useful sense. It is not yet possible to describe the whole route with the sense of smell. However, the smell could work for directions for blind people. Here are some examples: bakery, brewery, café, or another smelly place; the smell of the asphalt after the rain; the smell of the hot metal of the tram rails (for a tram, the sense of hearing will work even better) - everything could be a landmark on the route.

When discussing touching, in the case of blind users, people probably often recall Braille letters. Doubtlessly, with the help of Braille writing system, it is possible to describe the routes. Recently, LEGO company started to develop special LEGO Braille bricks for blind children [11]. It is an effort to encourage them to study Braille letters despite the outnumbered amount of audio content. This could be an example of gamification in struggling the barriers. Fortunately, progress does not stand still, and new perspectives and innovations are found in the field of touching sense. For example, ELIA Life Technology PBC started to develop tactile reading system ELIA Frames claimed to be "the most intuitive" [6]. ELIA Frames are based on the Roman alphabet, and every letter stands in its own frame, so people with full sight could also read the text written in this font, while blind people could read it by touching - this approach should erase borders between people, and help them easily cooperate together.

Discussing the route summary, it seems possible to include haptic sense as a way to mark a landmark in the description. It is possible to set particular objects - such as a lamp near the intersection of the streets or trees along the path - as milestones along the route, so later, the user can touch a lamp or a tree on his on her route. On the contrary, there could be a problem to find such data from map applications as these details are not useful for the majority of the users.

Regardless of the extensive use of touching sense in the accessibility for the blind, it is not easy to create a description of the route just with the help of this sense. Definitely, it could be used in the descriptions of directions when the route is already chosen under the condition that the route will not be changed. Such a description is not easy to generate on-the-go, and, during the trip, the information could be changed very fast, even in little details like late transport or unexpected situations in transport functioning. There are some other examples in accessibility by touching for navigation like relief printed maps, touching guide dog's head to understand the relief of the ground, and much hardware intended for blind people is provided with relief buttons to distinguish them, but this is basically it. In such an unpredictable space like transport, it is not possible to create cheap and fast dynamic solution controlled by touching sense.

Thus, the sense of hearing is the only candidate for the route descriptions. In comparison to an artifact created to be discovered by touching, the textual description of the route could be newly generated in seconds in any device, and then transformed to the audio content. Technical giants (e.g., Google, IBM, or Microsoft) already have text-to-speech applications, and although they are in different stages of development, they can provide the basics of transforming a text to audio. The only thing that could be designed, and which is essentially needed for a transformation, is the text basis, i.e., the route summary. The potential drawback is that it is not possible to provide 100% verified data.

2.1.8 Investigation of Blind People's Needs

The most critical issue of the prototype design is the awareness about the needs of target users. Being developed by people with vision, the details and perception of the future use of the application are often lost.

According to [31], there are four main groups of obstacles presented for mobility-impaired people:

- problems with third persons who are inconsiderate to help;
- problems caused by the public transport offer;
- problems with the physical environment (stairs, curbs, etc.);
- problems with quality and availability of information.

The biggest problems for blind people are problems with third persons (16% of blind people experienced it) and problems with the physical environment (24% met those problems).

In the case study [37], there are some implications from the discussion with blind people about GPS based applications are presented. Participants were considering that applications are not always accurate. In that case, they were relying on their Orientation and Mobility skills they received during their training, or they asked passersby. Mentioning the last comment, some of the participants have considered a concern of safety while interacting with strangers. This issue was also found in [18] when people complained about being robbed in the streets. Studying the outdoor navigation of blind people, the research concluded that "device should be robust to changing weather and light conditions, and should provide multiple possible routes in case the primary route is unavailable."

In [21], the study shows that the participants were making their routes before traveling sitting at home. The task is to gather information about the route: check the schedules and accessibility features, look for the directions (the first phase of the accessible journey chain - see Subsection 2.1.5). These steps are a must, especially for traveling to a new place.

A blind person overall is not a target user yet, and the future prototype should be intended for the use of persona. Several personas were created in [37], and they could be sample users of the future solution. They meet assumptions regarding personality attributes such as attitude towards technologies, exploration attitude, ability to ask for help, and choice of mobility aid. A future user is a person who is not afraid of independent traveling and is ready to use a mobile application for the movements around. However, the information is not always accurate, so the user is not afraid to ask a passerby for advice (in certain areas in big cities, it could be harder to stop a person, though).

Considering the investigation above, the aim is to let the blind people feel free while travelling and feel not to be restricted to a few routes that are familiar to them.

2.2 Application Review

Nowadays, people have a variety of possibilities which applications to use during their trips. Users can use pre-installed applications of a technical giant like Google, or they may prefer local map applications provided by the search engine corporations in their countries. There are also some tools intended specifically for visually impaired and/or blind people. The development of navigation aids for them starts with non-technological tools like white canes, guide dogs or human assistants, and continues now to a higher technological level. As time goes on, there are more and more opportunities to support mobility using new technologies like Bluetooth, GPS, or the Internet. In any case, the user wants to use an application that can provide the most accurate information about the journey.

This chapter analyses tools intended for blind people as well as the most popular mobile applications for navigation and discusses their advantages and disadvantages. The aim is to find inspiration for the non-visual route descriptions and to find and try to avoid the drawbacks in the future prototype.

2.2.1 Trekker Breeze

Trekker Breeze is standalone hardware for navigation [10]. Created as an orientation aid, it is designed as a talking GPS. The navigation is based on the system of names of the streets, intersections, and landmarks. All the information is saved in the electronic maps on the SD card.

When the user inputs the desirable destination, the device starts to navigate right away. While traveling, it can provide information about the next intersection and points of interest around the user: shops, restaurants, or other landmarks. Also, it is possible to record the route during the journey and later use it to get back to a starting point.

As maps for the navigation are stored on the SD card, it is not possible to track essential information for traveling by public transport such as transport delays or accidents on the road. Also, the card space is restricted, and maps must be uploaded in advance, so when the user by accident comes to a place, which is not saved on the maps in the device, the user becomes "blind" and cannot orientate in the public space anymore.

2.2.2 BlindSquare

BlindSquare is one of the most popular applications for blind and visually impaired users [4]. Running only on iOS, for now, this application uses FourSquare and Open Street Map API for its content. When planning a complex route (i.e., when it is not possible to create a walking route and taking public transport is needed), the application offers to use a third-party map application.

As BlindSquare is a paid application, it is not possible to explore the application the other way than to listen to podcasts or to read an article, eventually to watch a video where the users talk about their experience. From a tutorial [28], it is seen that the application offers just one route, taken by default as the best possible. The author mentioned that sometimes the user has several options to choose from, and depending on the application, the route can also vary. As BlindSquare uses third-party map applications, all the route descriptions belong to them.

2.2.3 Google

Google Maps

Google Maps application is probably the most used navigation application. It is not used only as a web application, but it is also a pre-installed application for all Android mobile phones. Being the corporation, which wants to gain more users, Google made a step forward towards travelers with disabilities and introduced "wheelchair accessible" routes on March 15, 2018 [14]. Despite the title reserved for wheelchair users (at least, in most of the languages; e.g., in Polish, it was translated as routes for disabled, in Czech - barrier-free accessible routes), there could be a chance that it could be also helpful for people with other impairments including blind people.

Google Maps seems to be a perfect candidate for gathering information for future route summaries as it provides much information in the application. Also, it gathers information from local companies, so it is possible to get to know the timetables and ticket prices before stepping out of the house. In the following paragraphs, the possible use case of the Google Maps application is made and discussed.

Example: the user wants to go from Prague castle to Wenceslas Square. It is a typical tourist trail, and it is hilly and full of obstacles. To access a wheelchair accessible route, the user needs to type departure and arrival points in the Directions section first. Then in the Routes section in the section Options, the user chooses a wheelchair accessible route.

As it is seen in Figure 2.3, at first glance, the route seems to be ideal with no transfers. Nevertheless, it is not possible to clearly say whether this is the best possible route for a blind person. According to the application, within 29 minutes of the whole travel, 13 minutes are dedicated to walking. The last

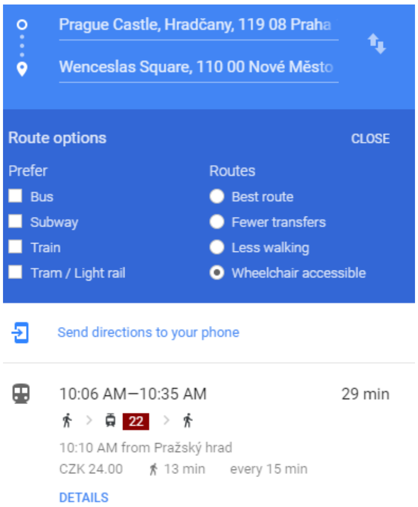

Figure 2.3: Wheelchair accessible route from Prague Castle to Wenceslas Square

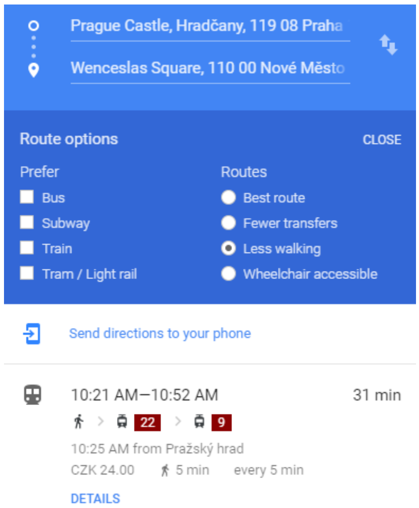

Figure 2.4: Less walking route from Prague Castle to Wenceslas Square

but not the least point is that the center of Prague is not disabled-friendly as there is almost no presence of tactile paths, and the majority of pedestrian zones are paved with cobblestones, not to mention crowds of tourists, cars or trees that could be a distraction for a traveler. In case of assistance, there might not be a big effort as the assistant could lead a person through all the barriers. However, in the case of independent traveling, this could be a problem.

Figure 2.4 shows a description for the route in the case of less walking option. The less walking part is already presented in the route as the walking decreased from 13 to 5 minutes. On the other hand, the number of transfers increased to one. Fortunately, in this case, the user does not have to go to the other stop. However, depending on the layouts of the city and familiarity with the surroundings, making a transfer could be quite a task for the user.

Besides the discussion, which particular route is the best for a blind person, it is necessary to focus on the route description itself. Some descriptions were already seen in Figures 2.3 and 2.4. The icon of a train shows that the user is in a mode of public transport (transit) traveling. To the right from the icon, there are times for departure and arrival, and on the right of the box, there is total time of the suggested journey. Under the departure and arrival time, there is a chain of icons for the route. Referring to Figure 2.3, the first icon is a person indicating a walking part of the journey; the next is an icon of the tram and the number of the tram (red color is reserved to tram connections in Prague; the color depends on the transport companies in different countries), which is followed again by a walking icon. The next row is the time of the departure of the first vehicle. The rest of the information displayed is a ticket price for the route, the total time of the walking part of the route, and how often the first vehicle goes. The detailed information on directions is hidden under the Details button.

Figure 2.5: Be My Eyes - initial page

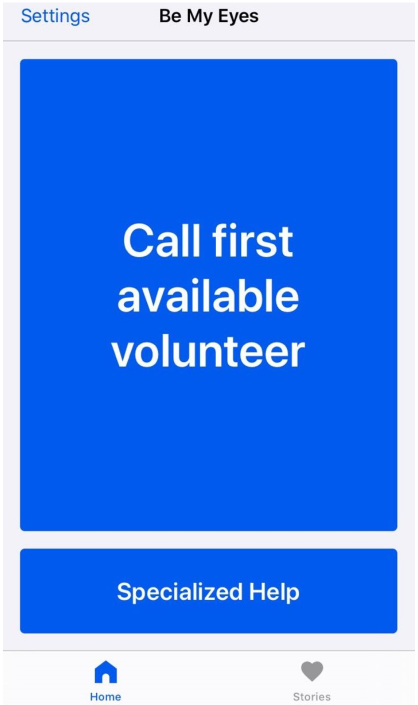

Figure 2.6: Be My Eyes, homepage for blind and visually impaired users

Be My Eyes application

It is not only the Google Maps application, where the company continues to create an inclusive traveling. Its next initiative is launching cooperation with Be My Eyes application [3]. The feature of Specialized Help is supported by the Google Disability Support team - the team of volunteers the user can call to at any time and ask for visual guidance pointing the camera at a problem in front of the user. Among many possible ways of using the application, there are also "Familiarizing yourself with new places" which could be useful while traveling to a new place, and "Finding out when public transportation (buses, trains, etc.) are departing or arriving" which helps to travel more comfortable.

2.2.4 Naver Map

Naver is a search engine corporation in South Korea, and it is also a provider of map service. The web application is not provided in English and even does not support search in the English language. Furthermore, the route description is quite close to Google descriptions. In comparison to Google Maps, it offers total distance in kilometers. Fortunately, the mobile application supports the English language (and unfortunately, the searching for a particular place is not always successful though), and it looks user-friendly, unlike the desktop application. Moreover, it offers one more feature, a stacked bar on which values and times for each segment of the traveling are placed, one by one. The total value of the bar is then the whole duration of the journey. As it is seen in Figure 2.7, the grey color corresponds to walking parts of the route, whereas green color matches up with a color of the subway (in the same way as Google Maps have, colors are correlated to the color of subway and bus lines and the companies). The idea of one stacked bar graph seems to be a great tool as the perception of the visual information is faster. However, it is not an appropriate information channel for a blind user.

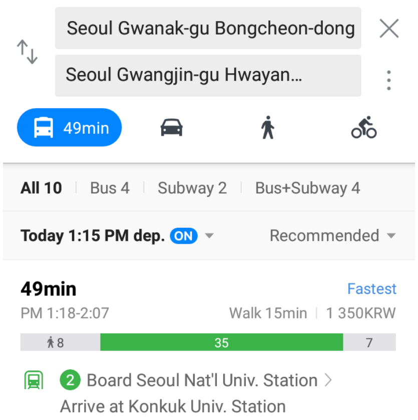

Figure 2.7: Directions function in Naver Map mobile application

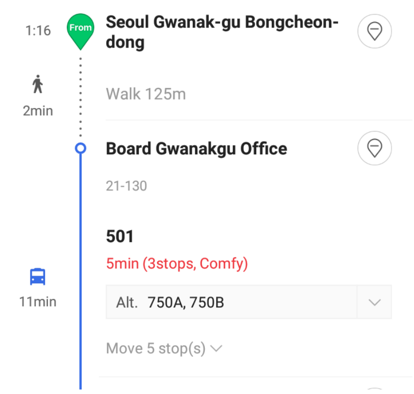

Figure 2.8: Details of one of the routes in Naver Map application

Another useful feature is an offer of alternative buses on the route (see Figure 2.8). In case of a late bus, the user does not have to rebuild the whole route, which could be a stressful situation, especially for a blind user, and he or she has just to wait for the next bus.

The next feature that can also be found in Figure 2.8 is a description of the buses. Right next to the number of stops, there is a characteristic `Comfy`, which means that the user can find a seat while traveling. Otherwise, `Crwd` is shown, which means that it is a rush-hour now, and it will be hard to find a place to sit. This feature is useful in the case of any situation which does not depend on time, so the person does not push him- or herself in crowds hurrying to or from work unless the user has to go outside, e.g., to a doctor appointment.

2.2.5 Yandex.Maps

Another search engine corporation with its own map service is Russian Yandex. Again, the features provided are almost the same as in the applications mentioned before. One slight difference is that the distance to a transport stop or station is shown instead of time in a route summary, as seen in Figure 2.9[1]. In case of the blind user, on the one hand, it could be more relevant information in the process of evaluating the route; on the other hand, there is still no information about the obstacles which could be present on the route, and it is not possible to do an objective evaluation of how much time the user will need to accomplish the route. Another difference is when the user is looking for traveling points in any language, the application still shows the result in English.

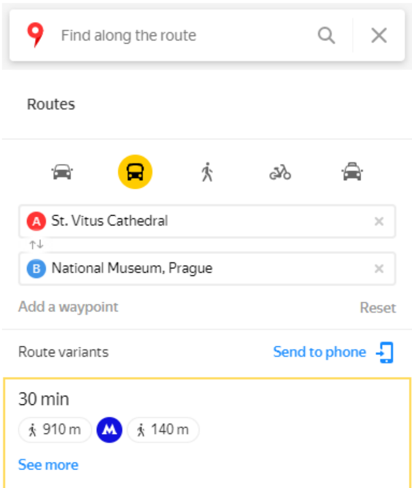

Figure 2.9: Yandex.Maps route planner before December 2019

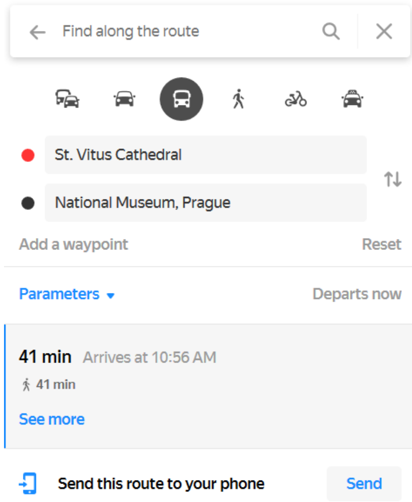

Figure 2.10: Yandex.Maps route planner after December 2019

2.3 Recommendations

The mobility is considered as an important prerequisite for social life and satisfaction of basic human needs. Therefore, it is essential to define the

[1]When the application was reviewed in December 2019, it was redesigned and could not offer the right journey anymore, offering only walking route instead (it is shown in Figure 2.10)

state of the future application, which could improve this characteristic of daily life:

- keep the levels of spatial knowledge, especially, overview and view, which could be responsible for route summaries;
- keep to a strategy of Lynch presentation of the city;
- keep the accessible journey chain within the text templates;
- consider the benefits and drawbacks of the applications reviewed and choose wisely their characteristics to add to the future applications;
- provide multiple routes.

Chapter 3

Design Process

This chapter proposes design essentials for the solution and discusses the process of creating the descriptions. Also, the prototypes, both lo-fi and hi-fi, are presented.

3.1 The Principles of Universal Design

The future approach for a route summary should offer such a solution which not only meets the needs of blind people but also encourages them not to be afraid of their independent travelling and to try to travel freely. There are no strict guidelines of how the solution should be presented, but it could be applied to principles that were proposed by the Center of Universal Design [5]. Despite that the principles were created for designs of products and environments, it is possible to apply them to the solutions intended for people with the loss of vision.

There are seven principles presented, and each of them could be associated with a need for a sightless user:

- Equitable Use. One of the guidelines says: "Provisions for... safety should be equally available to all users." It means that the information about safety should be provided in an appropriate format so that it could be used by any type of user. In the case of blind people, for example, the information should be prepared to be read by readers;
- Flexibility in Use. This principle talks about the choice in methods of use and adaptability to each user (right- or left-handed access, speech-to-speech or text-to-speech methods, and so on);
- Simple and Intuitive Use. One of the essential guidelines is to eliminate extra complexity, which means for the solution not to offer unnecessarily complex routes;
- Perceptible Information. In this case, the legibility, i.e., the ease of making a route known [19], should be maximized;
- Tolerance for Error. If a mistake was made by a blind person, he or she is not able to recover from it easily. Therefore, this principle is especially essential. In the case when a sightless user is traveling to an unknown place or goes through a complex route, the warnings or notifications should be provided. The other way is naturally to make the solution as easy as possible to eliminate even the space for the mistakes;

- Low Physical Effort. The solution should provide a journey that should be done comfortably and with minimal fatigue for a traveler;
- Size and Space for Approach and Use. Any facility that is located on the way of the journey should be comfortably accessed regardless of the mobility of the traveler.

Following these principles, it is possible to create a solution that will be not only user-friendly, but it will also suggest the best possible optimal route and lead the person to the final destination.

3.2 Design of the Route Summaries

The future description of the route should consist of the following parts (based on Zhang concept discussed in Literature Review - see Subsection 2.1.5):

- introduction;
- how to get to a start point;
- information about a process of travel (waiting times, transfers, etc.);
- how to get to the final point.

Section for traveling in a vehicle is logically separated from the other two out-of-a-vehicle sections because it is possible to let it contain less information than for out-of-a-vehicle phases. The reason is that it is mostly a straightforward process in comparison to out-of-a-vehicle phases where unexpected situations (reconstructions, change in timetables, and so on) can occur more often. Once the user is in the right transport, in most of the cases, he or she could probably start to think about the next section of traveling.

Unfortunately, this concept does not work well in a case when the final destination is within walking distance, and it makes no sense to force a user to use public transport. In this case, the journey chain reduces to one big out-of-a-vehicle phase. On the other hand, it could be essential trying to avoid walking-only routes as it is most likely to be influenced by unexpected situations.

It could be useful to add some information about the settings around, especially if the user is outside. The journey phase could be then divided into two parts as it is suggested in [19]: the first part is an environment that could be described by elements discussed in Subsection 2.1.3, and the second one is an action that prompts a user what to do.

Taking into account the principles of universal design discussed in the previous section and the division of route summary accordingly to the designed phases, it is also necessary to follow simple instructions offered by Passini [27] in order to create a cognitive map. Firstly, designed information should be easily perceived, selected, and understood within dense and stimulus-rich environments. The next part is that the characteristics of settings around and movements through them should be understandable. Finally, decisions in order to reach destinations, or an action plan, should be developed without any further problems. To sum up, these instructions should lead people to be able to represent themselves in the description given.

"The issue of choosing among various routes...is not central to wayfinding design", writes Passini in [27]. "Each major route to a destination should be wayfinding efficient and should display appropriate information." Also, there could be speculation that the routes could be similar in descriptions, i.e., to show appropriate information and use plain words that are not giving preferences to a particular route.

3.3 Objectives of the Prototype

The developed prototype is an effort to transform the graphical route description from popular navigation applications into a non-visual medium filled with information received from Google Maps API. The only task to resolve is how to represent the information within the sequence and what text template should be used in the route summary.

The caveat regarding the prototype is that it is not intended for a totally independent traveling as it is still not possible, even with all the technologies available. Also, it does not deal with the task of navigating a person, but it covers just the task of route summaries.

Future users, in the absence of vision, have to memorize information in sequential order. As blind people rely on serial strategies in memorizing, and they are excellent at it [30], it is necessary to create a memorable sequence. The text sequence for a prototype is based on the accessible journey chain (see Subsection 2.1.5). The in-a-vehicle phase is divided into more parts if transfers are expected. The out-of-a-vehicle phase is divided into environment and action descriptions, as it was suggested in Section 3.2. The information is also enhanced by accessibility features.

An independent traveling for blind people might be a stressful situation, and it is essential to create a plan B for them. Therefore, it could be nice to add a feature of requesting a taxi or an Uber to the application. It is not only a way to help them to get out of the hard situation, unsuccessfully struggling some barriers outside, but also a way to let them feel "like everybody," being able to call a car. The last but not least, plus is that this could be helpful in bad weather: e.g., in case of slippery ice in winter or other extreme weather conditions, the user calls a driver, and he or she will be sure that they are not going to be hurt outside.

3.4 Lo-Fi Prototype

The first prototype is limited to two different routes from which the user can choose; both are based on less walking and fewer transfers options in Google Maps. As a source of information for the lo-fi prototype, Google Maps in web version were used. Unfortunately, it does not provide any information about the environment outside, so it is not possible to include this information into templates. However, the desktop application has information about the platforms and accessibility of the transport. First, the user enters the departure and arrival points. Routes are presented one by one, starting with an introduction about the route and followed by more detailed descriptions of the route. In the end, the motivation and the space for errors are presented. To present the workflow of the prototype, the example usages were created (see Subsection 3.4.2).

3.4.1 Templates

For presenting the information about the route universally and plainly, it is necessary to create templates for the descriptions of each phase. In the walking only routes or walking parts of the route, it could be hard to construct the summary that does not turn in the end into turn-by-turn navigation (action knowledge which was mentioned in Subsection 2.1.2).

First level (for routes that include transport): The length of the {`n-th`} route is approximately {`duration of the route`} {`units: minutes and/or hours`}, including {`duration of walking`} {`units: minutes and/or hours`} of walking and {`number of transfers`} transfers. {`number of barrier-free accessible transport`} out of {`number of transfers + 1`} is barrier-free accessible;

First level (walking only routes): The length of the {`n-th`} route is approximately {`duration of the route`} {`units: minutes and/or hours`} of walking.

Out-of-a-vehicle phase (bus, tram):

- Action: Walk approximately {`distance of walking`} {`units: kilometers and/or meters`} to the stop of the {`bus X/tram Y`} {`name of the stop`} in the direction of {`last stop of the transport line`};
- Action (transfer without changing the stop): From the same stop, take {`bus X/tram Y`} in the direction of {`last stop of the transport line`};
- Action (transfer with changing the stop): Transfer to the stop of the {`bus X/tram Y`} {`name of the stop`} in the direction of {`last stop of the transport line`};

- Environment (barrier-free accessibility of the road transport, tram): {`Bus/Tram`} {`is/is not`} barrier-free accessible;

Out-of-a-vehicle phase (metro):

- Action: Walk approximately {`distance of walking`} {`units: kilometers and/or meters`} to the station {`name of the station`} of the line {`name of the line`}. Go to the {`name/number of the platform`} in the direction of {`last stop of the metro line`};
- Environment (barrier-free accessibility of the metro): Metro {`is/is not`} barrier-free accessible;

Out-of-a-vehicle phase (train):

- Action: Walk approximately {`distance of walking`} {`units: kilometers and/or meters`} to the train station {`name of the station`}. Go to the platform {`number of the platform`} in the direction of {`cardinal direction`};
- Environment (train description): Your train is {`number of the train`} {`name of the train if offered`} of the company {`name of the company`};
- Environment (barrier-free accessibility of the metro): Train {`is/is not`} barrier-free accessible;

In-a-vehicle phase (road transport, tram): Go {`number of stops`} stops to the stop {`name of the stop`};

In-a-vehicle phase (metro, train): Go {`number of stations`} stations to the station {`name of the station`}.

Closing information: The end of the description of the {`n-th`} route;

After the user chooses the route, he receives information about weather and motivation: The weather outside is {`temperature and conditions`}, {`there is no reason to be afraid of your journey today!/Be aware of {extreme weather condition}`}. However, if you are not sure you can make it, you can call your friend or call Uber to help you to get to the destination.

3.4.2 Use Case

The blind user Thomas lives in Prague, Czech Republic, close to the Anděl metro station, on the left bank of Vltava river (Plzeňská 1270/101). His friends asked him to join their gathering in the pub Zlý časy in the evening. He did not visit this place before, and he would love to go there. The pub is located on the right bank of the river; the area of the pub is not included in the city center, and there is no tourist spot around. Thomas took his phone and entered by his voice a departure point from his home and the pub as an arrival point. Unfortunately, there is no close metro station, and the only way to get there is by tram as the results told him:

First route (fewer transfers):

- Introduction: *The length of the first route is approximately 30 minutes, including 9 minutes of walking and one transfer. One out of 2 transport is barrier-free accessible*;
- Out-of-a-vehicle phase: *Go approximately 500 meters to the stop of the tram 15 U Zvonu in the direction of Olšanské hřbitovy*;
- Environment: *Tram 15 is barrier-free accessible*;
- In-a-vehicle phase:*Go two stops to the stop Anděl*;
- Out-of-a-vehicle phase: *Transfer to the stop of the tram 7 Anděl in the direction of Otakarova*;
- Environment: *Tram 7 is not barrier-free accessible*;
- In-a-vehicle phase: *Go nine stops to the stop Náměstí Bratří Synků*;
- Out-of-a-vehicle phase: *Go approximately 140 meters to the destination*;
- Closing information: *The end of the description of the first route.*

Second route (less walking):

- Description: *The length of the second route is 34 minutes, including 7 minutes of walking and one transfer. None out of 2 transport is barrier-free accessible*;
- Out-of-a-vehicle phase: *Go approximately 400 meters to the stop of the tram 10 Klamovka in the direction of Sídliště Ďáblice*;
- Environment: *Tram 10 is not barrier-free accessible*;
- In-a-vehicle phase:*Go four stops to the stop Zborovská*;
- Out-of-a-vehicle phase: *From the same stop, take the tram 7 in the direction of Otakarova*;
- Environment: *Tram 7 is not barrier-free accessible*;
- In-a-vehicle phase: *Go eight stops to the stop Náměstí Bratří Synků*;

- Out-of-a-vehicle phase: *Go approximately 140 meters to the destination*;
- Closing information: *The end of the description of the second route.*

After Thomas chose his route, he receives information about the weather and also some motivation: *The weather outside is +18 and cloudy, there is no reason to be afraid of your journey today! However, if you are not sure you can make it, you can call your friend or call Uber to help you to get to the destination.*

3.5 Hi-Fi Prototype

Below, the hi-fi prototype is presented, where all the data are provided by the JSON response from Google Maps API (more details on the implementation are in Chapter 4).

3.5.1 Design

As the application is intended for blind people usage, it is not necessary to create other designes than minimalistic one:

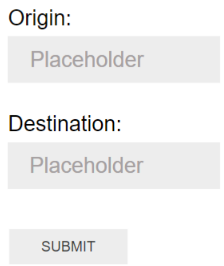

Figure 3.1: Design of the application - entering origin and destination

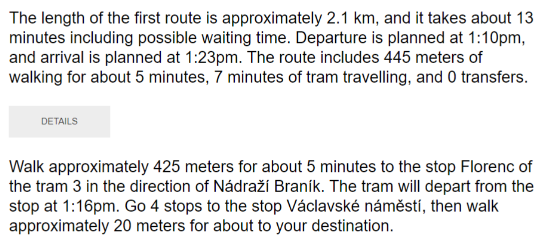

Figure 3.2: Design of the application - the results

3.5.2 Templates

After the analysis of the response (more details in Subsection 4.2.1), it is clear that some templates are not possible to fully implement, even though there are data in the Google Maps application. Also, there were some imperfections that could be improved, e.g. for transfers, approximations for durations, etc. (see Subsection 3.4.1). Below, the new templates are presented:

Introduction (destination and origin): Routes between {origin} and {destination}.

Introduction (weather): The temperature in the destination today is {number of degrees} degrees Celsius. The expected weather is currently {description of the weather} and {speed of the wind} km/h wind. {There is no reason to be afraid of your journey today!/Be aware of the weather conditions!}

First level (for routes that include transport): The length of the {nth} route is approximately {distance of the route} {units: kilometers and/or meters}, and it takes about {duration of the route} {units: minutes and/or hours} including possible waiting time. The departure is planned at {departure}, and the arrival is planned at {arrival}. The route includes {distance of walking} {units: kilometers and/or meters} of walking for about {duration of walking} {units: minutes and/or hours}, {duration of transport using} {units: minutes and/or hours} of {transport type} travelling and {number of transfers} transfer/-s;

First level (walking only routes): The length of the route is approximately {distance of the route} {units: kilometers and/or meters}, and it takes about {duration of the route} {units: minutes and/or hours} of walking. There is no transport connection between {origin} and {destination}.

Note: the phrase Be aware of the weather conditions! appears under the condition of showers, t-storms, rain, ice or when the speed of the wind is more 39 km/h (according to Beaufort scale, strong breeze or stronger wind).

Out-of-a-vehicle phase (part TRANSIT is the first; bus, tram):

- Action: Take the {bus X/tram Y} in the direction of {last stop of the transport line} from the stop {name of the stop};

Out-of-a-vehicle phase (part TRANSIT is the first; metro, train):

- Action: Take the {metro X/train Y} in the direction of {last station of the transport line} from the station {name of the station};

Out-of-a-vehicle phase (part WALKING; bus, tram):

- Action: Walk approximately {distance of walking} {units: kilometers and/or meters} for about {duration of walking} {units: minutes and/or hours} to the stop {name of the stop} of the {bus X/tram Y} in the direction of {last stop of the transport line};

Out-of-a-vehicle phase (part `WALKING`; metro):

- Action: Walk approximately {`distance of walking`} {`units: kilometers and/or meters`} for about {`duration of walking`} {`units: minutes and/or hours`} to the station {`name of the station`} of the metro {`name of the line`} in the direction of {`last station of the transport line`};

Out-of-a-vehicle phase (part `WALKING`; train):

- Action: Walk approximately {`distance of walking`} {`units: kilometers and/or meters`} for about {`duration of walking`} {`units: minutes and/or hours`} to the station {`name of the station`} of the train {`name of the train`} of the line {`name of the line`} in the direction of {`last station of the transport line`};

Out-of-a-vehicle phase (`TRANSIT`; bus, tram):

- Action (transfer without changing the stop): ...from the same stop take the {`bus X/tram Y`} in the direction of {`last stop of the transport line`};
- Environment (time of departure): The {`bus X/tram Y`} will depart from the stop at {`departure`};

Out-of-a-vehicle phase (`TRANSIT`; metro, train):

- Action (transfer without changing the stop): ...from the same station take the {`metro X/train Y`} in the direction of {`last station of the transport line`};
- Environment (time of departure): The {`metro X/train Y`} will depart from the station at {`departure`};

In-a-vehicle phase (road transport, tram): Go {`number of stops`} stops to the stop {`name of the stop`}, then...;

In-a-vehicle phase (metro, train): Go {`number of stations`} stations to the station {`name of the station`}, then...;

Closing information:

- last part of the route is `TRANSIT`: ...then you will be at your destination;
- last part of the route is `WALKING`: ...then walk ... to your destination;

3.5.3 Use Case

After the work with real data, which are provided by APIs, templates were considerably changed. Therefore, for a complete image of new routes' summaries, it is needed to provide a new use case along with comments on improvements.

The blind user Alicia lives in Stockholm, Sweden, and today she was at the museum Skansen. Now, she wants to get back home. She took her phone and entered by her voice a departure point from the museum and her home address as a finish point. There are different ways, how to get back home:

- First, she receives a description about points between which she wants to travel: *Routes between Skansen, Djurgårdsslätten 49-51, 115 21 Stockholm, Sweden & Studentbacken 15, 115 57 Stockholm, Sweden*;
- Then, she receives information about the weather: *The temperature in the destination today is 7.8 degrees. The expected weather is currently mostly cloudy and 16.7 km/h wind. There is no reason to be afraid of your journey today!*
- Her first option is to go home with a bus and a metro: *The length of the first route is approximately 3.2 km, and it takes about 26 minutes, including possible waiting time. The departure is planned at 11:21am, and the arrival is planned at 11:47am. The route includes 880 meters of walking for about 12 minutes, 4 minutes of bus traveling, 1 minute of subway traveling, and 1 transfer*;
- She decided to skip the first route as she did not want to go with metro and started to listen to the introduction about the second route: *The length of the second route is approximately 4.0 km, and it takes about 31 mins including possible waiting time. Departure is planned at 11:15am, and arrival is planned at 11:46am. The route includes 660 meters of walking for about 8 minutes, 5 minutes of tram traveling, 14 minutes of bus traveling, and 1 transfer*;
- This option was much more interesting for her, so she decided to listen to the details of the route: *Walk approximately 345 meters for about 4 minutes to the stop Nordiska Museet/Vasamuseet of the tram 7 in the direction of T-Centralen Spårv. The tram will depart from the stop at 11:19am. Go 3 stops to the stop Nybroplan, then from the same stop take bus 54 in the direction of Rindögatan. The bus will depart from the stop at 11:29am. Go 7 stops to the stop Rindögatan, then walk approximately 315 meters for about 4 minutes to your destination.*

As it is seen from the example, the routes summaries are now clearly divided into two levels of spatial knowledge, overview (introduction and the description of each route) and view (the details of each route).

Chapter 4

Implementation

4.1 Services for the Applications

As Google Maps seem to be the most commonly used application for navigation, it makes sense to use its APIs for creating summaries of the routes.

In the following implementation, several Google API are used:

- Places API - returns detailed information about places, including e.g. Place Search Autocomplete when searching for places [8];
- Directions API - returns the most efficient routes while calculating directions between locations [7]. Directions API allows the developers to work both on the client-side via Javascript and on the server-side via Java, Python, Go, or Node.js clients. For the purpose of the solution presented, it will be done via Javascript.

However, it has some drawbacks. Google Maps API do not offer detailed information about traffic (for example, intervals between transports). Also, there are no data about the transport accessibility in JSON response, although it could be found in the application, e.g., which entrance to use when entering the metro station.

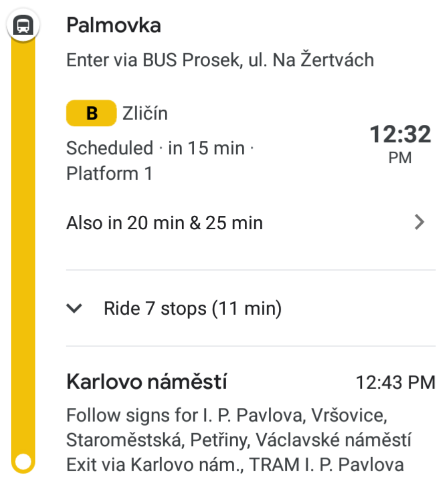

Figure 4.1: Information provided by official Google Maps application: description of the entrance and exit, intervals, number of the platform, etc.

The project backend was settled on two pillars, Google Cloud Platform and Firebase Platform. To start with a Javascript API, it is needed to create an API key as it is a crucial component of any request, and that was the task for Google Cloud Platform. For each of the services, it is necessary to enable the key separately. For using API, it is also needed to enable billing, although it has a free trial period which lasts 12 months, and the user is granted 300 USD to use (the project was set on the platform on September 28, 2019).

For the hosting of the web application, web, and mobile application development platform, Firebase was used. As Firebase belongs to Google, the application implementation, which is set on Google Cloud Platform, could be easily connected to the project hosting on the Firebase platform. To see the web application online, visit `https://alternative-routes-desc.firebaseapp.com/` till September 27, 2020. After this date, the application is available in the file attached and could be set in Firebase according to documentation in Appendix A.

The application stands on Javascript, and there were plenty of options, which template engine to use. In the end, Handlebars.js was chosen over its parent, Mustache.js. The main reason for the choice was that the Handlebars.js allows more customizability via helpers. It also allows working with more complex nested paths, which is essentially necessary as the values in JSON response are saved deep there (see more in Section 4.3). The data below will be described within the syntax of Handlebars.js if applied (documentation is available at [9]).

For the forecast data in templates, APIs from Accuweather were used, Locations API and Current Conditions API. Locations API searches for a key of the place, which is based on the latitude and longitude of the destination, and this key is used for finding particular data about the weather in Current Conditions API.

4.2 API Request Description

4.2.1 Google APIs

The following parameters are required for processing the request:

- `origin`: location from which the user starts the journey. It is needed to be inserted manually by the user. Options could be:
  - LatLng - place described with latitude and longitude, e.g. *41°24'12.2"N 2°10'26.5"E*;
  - String - the name of the place in a natural language, e.g., *Prague Main Station*;
  - google.maps.Place - special ID of the place, e.g. *ChIJrTLr-GyuEmsRBfy61i59si0*;

Information is processed by the server as a hash code regardless of input type.

- `destination`: location, where the user would like to finish the journey. It is needed to be inserted manually by the user. Options are the same as for `origin`;
- `travelMode`: mode of transport, which the user wants to use during the journey; within the project, it is limited to Transit Mode, which public transport;

Although the next parameters are optional for the request, some of them play an essential role in adapting travelling for blind travellers. Below, there are only used parameters described:

- `transitOptions`: applied only when the `travelMode` is set to the value `TRANSIT` meaning using transport for a route (which is the case of the project). When chosen, values for `waypoints[]`, `optimizeWaypoints`, `avoidHighways` and `avoidTolls` are ignored.
  - `arrivalTime`: time of arrival,
  - `departureTime`: time of departure,
  - `modes[]`: depends on the type of transport user wants to use: `BUS`, `RAIL`, `SUBWAY`, `TRAIN`, `TRAM`, `HEAVY_RAIL`,
  - `routingPreference`: defines special route preferences such as `FEWER_TRANSFERS` or `LESS_WALKING`,
- `unitSystem`: defines, whether to show the results in imperial or metric system (in application, set to metric system),
- `provideRouteAlternatives`: defines, whether API should provide more than one route to get user to the destination. It is the most important variable within this project as it designates the values that are used in the application implemented.

Below, the example request is presented:

Code 4.1: Example of the Google Maps API request

```
"origin":{
    "placeId":"ChIJVXA5GpWUC0cRGlazzn35Y7I"
},
"destination":{
    "placeId":"ChIJ8Xbv9zuVC0cR_-KZ3vG4tXU"
},
"travelMode":"TRANSIT",
```

```
"provideRouteAlternatives":true,
"transitOptions":{
    "routingPreference":"LESS_WALKING"
}
```

In origin and destination elements, places' hashcodes could be found. Both elements are filled manually by the user and processed for a server as hashcodes, while the next elements are pre-filled in the application. Travel mode is set to `TRANSIT` accessing routes including public transport, and `provideRouteAlternatives` is set to `true`, whose results provide more options, how to get from A to B. The element `routingPreference` equals to `LESS_WALKING`, which is a hypothese for the application that blind users will need the routes with less walking to avoid unexpected obstacles when in an out-of-a-vehicle phase.

To set a language to English (to show the results in unified language, not depending on the browser language), to make a call for Places and initialize a request itself, the script at the end of the file is used: `https://maps.googleapis.com/maps/api/js?key=API_key&language=en&libraries=places&callback=init`

4.2.2 Accuweather APIs

As it was mentioned previously, for the forecast templates, there are two APIs from Accuweather, Locations, and Current Conditions. Both are described below:

- Location API helps to receive a location key, which is used in the next API to retrieve weather data [1]. To get a location key, the latitude and longitude (inserted in parameter `q`) from the Google Maps API response along with API key are used for the Geoposition Search method;
- Current Conditions API shows weather data for a particular location [2]. For data, location key and API key are needed. Also, to get more detailed information about the weather, such as wind or rainfalls, the parameter `details` must be set to `true`.

4.3 API Response Description & Fitting the Templates with Data

4.3.1 Google APIs

After the user entered origin and destination, the application receives a response in JSON format, which should be processed in order to prepare template system. The core elements of the response that are used for templates are described below:

- `status`: specifies the metadata on the request. The best status for an application to work is to receive `OK` response for the request. In several occasions, the result could be `NOT_FOUND`, if at least one of the locations is not geocoded or `ZERO_RESULTS`, if there is no route between points. The worst situations though are `INVALID_REQUEST` in case there is an invalid parameter or value in the request, `REQUEST_DENIED` in case of bad cooperation between the service and the appication or even `UNKNOWN_ERROR` in case of problem on the server side;

- `geocoded_waypoints`: contain brief informations about the origin and destination such as `geocoder_status` (whether the place was found successfully), `place_id` (the same as google.maps.Place in Section 4.2) and `types` (the address type of the point, e.g. `country`, `intersection` or `natural_feature`);

- `routes`: possess four possible routes, which could differ in types of transport, number of transfers or just in departure time.

- `request`: contain the data about the journey sent by Javascript to a server: `origin`, `destination`, `travelMode`, etc.;

All of the elements above contain further subelements with detailed data, which are used to fill in the templates (according to Subsection 3.4.1):

- origin & destination: both elements are processed by server as hashcodes, though there is a value hidden in `routes.n.legs.0.start_address` & `routes.n.legs.0.end_address`, where `n` is the number of the route (`n` could be presented as a counter which is going through all the routes generated). Sometimes, however, it does not contain a specific name of the point, so it should be enriched by the data from autocompleted fields for start and end of the route;

- duration of the route: could be found in `routes.n.legs.0.duration.text` as a text value with minutes or `routes.n.legs.0.duration.value` as a integer value in seconds. When using the `.text` value, the result depends on the browser language, e.g. for one hour 5 minutes, in Danish, the result will be `1 time 5 min.`, for Czech - `1 hodin, 9 minut`, etc., unless it is firmly stated in the request to set language to English;

- duration of walking: as it is needed to present a sum of all the sections of walking, it is required to go through all the steps and find those ones, which contain the parameter `travel_mode` equal to `WALKING`, where `m` is the number of the step. All the values from `routes.n.legs.0.steps.m+ .duration.value` are summed up and presented as minutes;

- distance of walking: the values for distances could be found in `routes.n.legs+ .0.steps.m.distance.value` under the condition that `travel_mode` is equal to `WALKING`. The final value contains the distance of walking in meters;
- number of transfers: it is required to go through all the steps and find those ones, which contains the parameter `travel_mode` equal to `TRANSIT`, therefore the number of transfer is set to the number of transit steps minus one;
- bus V/tram W/train X/metro Y/rail Z: `routes.n.legs.0.steps.m+ .transit.line.vehicle.type` element contains the type of the vehicle and the relevant number is in `routes.n.legs.steps.m.transit.line+ .short_name`;
- name of the stop: is located in the element `routes.n.legs.0.steps.m+ .transit.departure_stop.name`;
- direction of the transport line: `routes.n.legs.0.steps.m.transit+ .headsign`;
- number of stops/stations: `routes.n.legs.0.steps.m.transit.line+ .num_stops`;
- Also, there is an in-a-vehicle phase "Go {`number of stops/stations`} to the station {`name of the stop/station`}". It could happen that the final destination of the transport and the stop/station, where the traveller is heading to, are the same stops/stations. Unfortunately, the element `routes.n.legs.0.steps.m.transit.headsign` is provided in local language, and it could confuse the user. For example, in the case of travelling from Smíchovské nádraží to Prague Main Station, the `headsign` of the train is Praha hl.n., which stands for Prague Main Station in Czech language;

For each step, it is also possible to use the value of `routes.n.legs.0.steps+ .m.instructions` with short description, however, it is still discussable, whether these instructions are to be needed in the summary descriptions and whether they are extractable.

Problem points are:

- to check whether transport and/or transport facilities are barrier-free (unfortunately, Google Maps do not provide the environment descriptions);
- to check whether it is a side/isle stop/platform;
- in which street, passage, etc. the stop/station is located;
- intervals, which are not the part of the response;
- only one transport on the route is presented, even if there is another transport, which goes to the same stop/station.

4.3.2 Accuweather APIs

- Locations API: in the response, a lot of geographical data are available, and for the weather forecast API, `response.Key` is needed;
- Current Conditions API: there are several elements, which are used later in the templates:
  - description of the weather: `response[0].WeatherText` contains text description about the weather. Accuweather provides 44 possible states: some of them appear in the day time, some - during the night, and some could be presented in both time slots;
  - current temperature: stored in the element `response[0].Temperature+.Metric.Value`, providing the temperature in Celsius degrees;
  - wind: located in `response[0].Wind.Speed.Metric.Value`, and retrieves the speed on the wind.

4.4 Customization of Templates and Custom Functionality

For creating the container with text templates, the `script` tag with the type `text/x-handlebars-template` was used. Within this tag, the text templates, all the functions, and cycles are inserted. For giving a unique description for each type of situation and providing more natural language in the templates, it is needed to create helpers to adapt the text.

- to iterate the values, the built-in helper `each` is used. Below, there is an example of iterating the routes:

Code 4.2: Iterating the routes within template via Handlebars.js

```
{{#each routes}}
...
{{/each}}
```

- weather response is added to the tag `div` with id `weatherResponse`.
- for origin & destination, it was decided not to use pure data from JSON response, but to use values both from the search request fields and the response. It makes a great difference, when announcing origin and destination points. For example, when looking for "Smíchovské nádraží", address will be "Smíchovské nádraží, 150 00 Praha-Praha 5, Czechia" in the response, and "Smíchovské nádraží, Smíchov, Prague 5, Czechia" will appear, when autocompleting the search request. In the case presented, it is possible to use both response value and value from the field as it both contains the name of the establishment and its address. However, there are worse cases, when it is not even possible to distinguish the establishment from the response. When searching for the Masarykova dormitory in Prague, the result in the response is "Thákurova 1, 160 41 Praha 6-Dejvice, Czechia". The name of the establishment is available only in the search request field when autocompleting. Accordingly, the helper `start` and `finish` were created, which get the values from the fields. For the purpose of showing, how to register a helper in Handlebars, the example is presented below:

Code 4.3: Registering the helper for displaying the origin (works analogously for the destination)

```
var str1 = document.getElementById('autocomplete_origin').value;
var str2 = str1.split(",")[0];
var str3 = response.routes[0].legs[0].start_address;
var str4 = str3.split(",")[0];
var str = '';
if (str2.toLowerCase() == str4.toLowerCase() ||
str2.toLowerCase().includes(str4.toLowerCase()) ||
str4.toLowerCase().includes(str2.toLowerCase())) {
str = str3;
} else {
str = str2 + ', ' + str3;
}
return str;
```

To call for the value only, three { are used. The example below shows the values of helpers `start` and `finish` in the text template:

Code 4.4: A call for values of `start` and `finish` helpers

```
Routes between {{{start}}} & {{{finish}}}.
```

- for adapting the templates according to the type of transport as in "stop" for bus and tram and "station" for metro, train, and rail, for adapting numbers to ordinal numbers, etc., the helper `if_eq` was implemented, which compares the value in the response with the given one in the template and add the appropriate text to the template. Opposite job is done by the helper `if_not_eq`;
- sometimes, it is needed to go only one stop or station, that is why it is not possible to add "go `{number of stops}` stops/stations" with a fixed plural. Because of this issue, adding of singulars and plurals should be dynamic and depends on the number:

Code 4.5: Adapting singulars and plurals according to a number of stations

```
{{#if_eq transit.num_stops '1'}}
station
{{else}}
stations
{{/if_eq}}
```

- for displaying ordinal numbers in the template (as first instead of 1, second instead of 2, etc.), it was necessary to follow two steps:
  - register the helper `offset`: as the variable `@index` is zero-based, it was needed to create a helper, which increments `@index` by 1 and therefore provides a base for creating "first", "second", etc. for templates;
  - add ordinal numbers: together with the helper `if_eq`, the set of conditions was added to the template:

Code 4.6: Adapting cardinal numbers to ordinal numbers

```
{{#if_eq (offset @index "+" 1) '1'}}
first
{{/if_eq}}
```

- as people perceive rounded numbers as more trustworthy numbers, and also they are processed more fluently [34], the distance could be rounded to the nearest multiple of 5. For this issue, the helper `round` was created;

- for a total duration of walking, the helper `walkingDuration` was implemented. It goes through `response.routes[index].legs[0].steps`, where `index` is the index of the route, and looks for elements `travel_mode` equal to `WALKING`, summing up durations of walking in seconds and rounding up to the minutes, changed to hours if needed;
- for a total distance of walking, the helper `walkingDistance` was implemented. Similarly to `walkingDuration`, it goes through all the steps with `travel_mode` equal to `WALKING`, summing up distances of walking in meters, changed to kilometers if needed;
- for a number of transfers, the helper `transferNumber` was created. It goes through `response.routes[index].legs[0].steps`, where index is the index of the route, and looks for elements `travel_mode` equal to `TRANSIT`. If their number is more than 1, the number of transfers is equal to the number of instances `TRANSIT` minus 1;
- in case, there are only walking routes between origin and destination, using the helper `walkingOnly`, template for only walking routes is shown;
- helper `hasNextTransit` checks, whether the transit step, with which template engine is working now, is followed by a step, which is also equal to `TRANSIT`. Opposite function is made by the helper `hasPreviousTransit`. Helpers check, whether there are two steps with the travel mode `TRANSIT` in a row, and if so, there is a transfer made at the same stop, otherwise, the user has to go to another stop or station in order to make a transfer. Both helpers are used to create appropriate text templates;
- to check whether the previous stop was walking, the helper `wasPreviousWalking` is created. As previous helpers, it helps to create a convenient template;
- the helper `transTotalDur` counts the total duration of traveling for the particular transport, which is used in the first level route description;
- the helper `round` rounds the numbers to the closest number, which is divided by 5;
- for the homogenous representation of time, the helper `replaceTime` was created. The helper counts the time from the `routes.n.legs.0.duration.value` and converts it to the hours and minutes;
- analogously, the helper `replaceDistance` converts meters to kilometers and meters.

Chapter 5

Evaluation

In this chapter, the results of two testing sessions are provided. Both of them were aiming to evaluate the proposed design of the routes summaries. In the first evaluation, the lo-fi prototype was tested, whereas, in the second evaluation, the hi-fi prototype was put to the test.

5.1 First Evaluation

One use case (provided in Subsection 3.4.2) is not enough, neither for evaluating the quality of templates nor for exploring, whether there are enough templates and whether they are created in an appropriate way, so for testing purposes, the exploratory method with elements of semi-interview was used. In the first testing session, the design of the lo-fi prototype was evaluated by a person who is not a target user. In the case of the prototype intended for blind people, the testing must be taken cautiously, when performed by people with sight; the assumptions and the context for an exploration of the application should be explicitly defined.

5.1.1 Procedure

The reviewer is supposed to go through a sample task, which should be successfully completed as a result was created on the go. The exploration method could be a great tool for testing in the early stages of application development. However, it can not replace the target audience. Its aim was mainly to improve the quality of templates themselves rather than to check how they are perceived by the users.

To start an exploratory process, it is needed to create a sample task (including the guidelines on how to perform actions to complete the task) and to provide the description of the interface. Data for the route summary were used from the Google Maps web application.

The testing, which lasted around one hour, includes one evaluator who received a task to travel from his home (Tobrucká 701/1, Prague 6) to the pub The Pub (Československé armády 785/22, Prague 6), which is approximately 3 km far. In the case of this route, there are more possibilities on how to arrive at the destination (in comparison to the use case created in Chapter 3.2). The evaluator is not aware of the surroundings of his destination. In the case that there was no template for a situation that appeared in summary, a template was created immediately. Also, if the template was not appropriate, it was changed by the interviewer.

After the evaluator entered the start point and the destination, the following routes were generated based on the information from Google Maps application (newly generated templates are in curly brackets):

First route (less walking): *The length of the first route is approximately 16 minutes, including 9 minutes of walking, {tram}, and no transfers. Walk approximately 240 meters to the stop Bořislavka of the tram 20 in the direction of Sídliště Barrandov {or tram 26 in the direction of Nádraží Hostivář}. Tram is not barrier-free accessible. {Tram goes every 5 minutes.} Go five stops to the stop Vítězné náměstí. Walk approximately 500 meters to your destination. The end of the description of the first route.*

Second route (fewer transfers): *The length of the 2nd route is approximately 13 minutes, including 11 minutes of walking, metro, and no transfers. Walk approximately 350 meters to the metro station Bořislavka of the line A. Go to the platform 2 in the direction of Skalka. {Metro goes every 3 minutes.} Go one station to the station Dejvická. Walk approximately 500 meters to your destination. The end of the description of the second route.*

The evaluator chose the first route as he supposed that dealing with stairs of only one tram is much easier for a blind person than dealing with escalators in Bořislavka and Dejvická stations to get to the vestibule. Also, he remembered about a roundabout in Vítězné náměstí, but it will be one crossing less. Shortly, it is less walking for the user.

After that, he received the last notification: *The weather outside is +14 and cloudy, there is no reason to be afraid of your journey today! However, if you are not sure you can make it, you can call your friend or call Uber to help you to get to the destination.*

5.1.2 Recommendations

After the procedure, the unstructured interview was held about possible changes and improvements. Also, the interviewer added some suggestions and recommendations about the process of generating the summary for future work:

R1: add which transport will be used in the route in the introduction:
The length of the {`n-th`} route is approximately {`duration of the route`}, including {`duration of walking`} of walking, {`types of transport used along the route`} and {`number of transfers`}...;

R2: add transport intervals to the environment description of out-of-a-vehicle phase:
{`Tram/Bus/Metro/Train`} goes every {`intervals`};

R3: add a description of the metro/train station where the blind user will arrive, whether there is an elevator to exit the station:
Metro station has {an/no} elevator to exit the station;

R4: analogically, add a description of the bus/tram stop where the blind user will arrive;

R5: delete a summary about barrier-free accessibility in the introduction of the route: it works in case of buses and trams, but not in case of metro stations. Instead, there will be a description of the accessibility when the transport or the station is mentioned;

R6: add to each of the transport its own final stop in case of more trams or buses on the stop, which the user can take. On the other hand, the fact is that it is the same platform anyway: it may be enough to say one tram or bus and then mention which trams or buses the user can take from there;

R7: not to mention final stop, in the case when the user can take any transport from the stop;

R8: add information about the accessibility of the destination if possible;

R9: think which voice input will be easier for the user, natural language processing (the user asks: "How to get from here to the hospital?") or keyword input (the application asks, "Enter the starting point," and the user answers, "From here," and so on);

R10: consider including wheelchair-accessible route as it probably combines both less walking and fewer transfers option to ease a route for wheelchair users.

Although there is plenty of details, it has to be evaluated by the target audience before working with it. Also, it is useful to consider which information is critical to the user and which is not (according to [32] discussed in Subsection 2.1.2) as well as to compare the heuristics discussed in Section 3.1. The last but not the least is that a significant part of the information is just not provided in a map application, and its implementation could be considered in the future.

5.1.3 Implementation of the Recommendations

After the consideration of the suggestions described in Subsection 5.1.2, only **R1** was implemented (added total durations of traveling by a particular transport). The response does not contain information about intervals (**R2**), accessibility of the transport (**R3**, **R4**, **R5**, **R8**) or whether there are more transports at the same time (**R6**, **R7**). As for **R9**, along with no voice implementation in the low-fidelity prototype, there are two fields for entering the origin and destination. Finally, **R10** seems to be irrelevant, because in most cases, wheelchair routes and less walking routes are similar.

5.2 Second Evaluation

The second evaluation was conducted with the data from the Google API response and improved templates as in with the hi-fi prototype. As the data are no more sampled from the real Google Maps, but from its API and templates went through some significant changes, it is a turn to consider whether changes were reasonable. Also, it is needed to discuss the level of the details of the summary as there are already two well visible levels of detailed information, whether something should be added, changed, or deleted.

5.2.1 Participants

Unfortunately, it was not possible to find a target group to test the templates, so it was decided to bet on finding and fixing usability problems and conduct testing with sighted people. Therefore, six non-visually impaired people took part in this experiment. The level of English was considered subjectively by the participants themselves on a Likert scale (Very Good, Good, Average, Bad, Very Bad). Although nobody was a native speaker of the English language, they considered themselves to be at least average in English. They were aged from 23 to 25 years old ($mean = 23.667$, $SD = 0.94$).

Index	Age	Gender	Country	English Level
P1	25	F	Czechia	Average
P2	23	M	Slovenia	Average
P3	23	M	Slovenia	Average
P4	23	M	Poland	Good
P5	25	M	Czechia	Very Good
P6	23	F	Czechia	Average

Table 5.1: Demographics of the participants of the second evaluation

5.2.2 Procedure

The testing was held as a one-to-one session with a structured interview divided into three parts. The main objective of the testing is to evaluate the quality of the presentation of the data about alternative routes.

Pre-test Interview

The first part of the evaluation was a pre-test interview: getting to know the user, his/her traveling habits, and stereotypes about the traveling of blind people:

Q1: How old are you?

Q2: How comfortable are you with English?

Q3: How often did you travel in the past month to known places?

Q4: How often did you travel in the past month to unknown places?

Q5: What do you think, how often do blind people travel to known places?

Q6: What do you think, how often do blind people travel to unknown places?

Q7: When traveling to unknown places, how do you prepare your journey? Which applications do you use for planning your journey?

Q8: When traveling to unknown places, what do you think, how do blind people prepare the journey? What applications do they use?

Q9: Which transports do you prefer for traveling?

Q10: What do you think, which transports do blind people prefer for traveling?

Main Testing

After the pre-test interview, the main part of the testing starts. The descriptions, which are prepared ahead of the testing, are read aloud by the moderator. They had no opportunity to take a look on the routes, only to ask to repeat the description if needed. For the first four tasks, routes are created with places, which are unknown for the participants. In the last fifth task, the route contains places, which are known for the traveler. Routes for tasks 1 to 4 were prepared in the way to test all the features: different modes of transport, transfers, the same stop description, only walking route, the last task is prepared on the go in the prototype running online. Original spellings for origin and destination in the introduction part of the route description are kept. Below, there are also questions to be answered during the experiment:

Task 1: Consideration of the introduction (for the purpose of the testing, the particular name of the restaurant was changed to a general type of the establishment):

Task 1.1: Route with the good weather forecast:

Route 1: Routes between Soukenická, 110 00 Praha-Nové Město, Czechia & Vietnamese Restaurant, Rybná 26, 110 00 Staré Město, Czechia. The temperature in the destination today is 5.5 degrees Celsius. The expected weather is currently mostly cloudy and 12 km/h wind. There is no reason to be afraid of your journey today!

Task 1.2: Route with the bad weather forecast:

Route 2: Routes between Soukenická, 110 00 Praha-Nové Město, Czechia & Vietnamese Restaurant, Rybná 26, 110 00 Staré Město, Czechia. The temperature in the destination today is 13.9 degrees Celsius. The expected weather is currently drizzle and 11.1 km/h wind. Be aware of the weather conditions!

Questions: Are origin and destination clear enough to understand where the journey starts and ends? Does the weather forecast make any sense in the decision process?

Task 2: Consideration of the first level description (only first level description is presented):

Task 2.1: Consideration of the first level description of the route with transport modes:

Route 3: The length of the route is approximately 3.6 km, and it takes about 19 minutes, including possible waiting time. The departure is planned at 4:09pm, and the arrival is planned at 4:28pm. The route includes 575 meters of walking for about 7 minutes, 12 minutes of tram traveling, and 0 transfers.

Task 2.2: Consideration of the first level description for the only walking route:

Route 4: The length of the route is approximately 0.3 km, and it takes about 4 minutes of walking. There is no transport connection between origin and destination.

Questions: How extensive is the description of the first level? Which information is missing, which information is excessive? Please, explain the route in your own words;

Task 3: Consideration of the second level (both first and second level descriptions are presented):

Route 5: Walk approximately 435 meters for about 5 minutes to the stop Hlavní nádraží of the tram 26 in the direction of Divoká Šárka. Tram will depart from the stop at 4:26pm. Go 8 stops to the stop Sparta, then from the same stop take tram 25 in the direction of Bílá Hora. Tram will depart from the stop at 4:43pm. Go 2 stops to the stop Prašný most, then walk approximately 160 meters for about 2 minutes to your destination.

Questions: How extensive is the description of the second level? Which information is missing, which information is excessive? Do you understand the difference between the first and second level? How comfortable are the participants with the problem points in the description, absence of barrier-free accessibility, side/isle stops/stations descriptions, etc. in two levels of the descriptions? Please, explain the second level description of the route in your own words;

Task 4: Comparison of different first level and second level descriptions. The participant is considered to work with the descriptions as a real user; he/she listens to the introduction and the global levels of the routes. If some of the routes sound interesting, he/she can ask for more details (local level):

Route 6: Routes between SMÍCHOFF, Moulíkova 2240/5, Smíchov, 150 00 Praha-Smíchov-Praha 5, Czechia & Kodaňská, Praha 10-Vršovice, Czechia. The temperature in the destination today is 4.7 degrees Celsius. The expected weather is currently cloudy and 3 km/h wind. There is no reason to be afraid of your journey today!

The length of the first route is approximately 6.0 km, and it takes about 31 minutes, including possible waiting time. The departure is planned at 4:36pm, and the arrival is planned at 5:08pm. The route includes 160 meters of walking for about 2 minutes, 18 minutes of tram traveling, 6 minutes of bus traveling, and 1 transfer.

[Here, the participant can ask for more details]

Walk approximately 160 meters for about 2 minutes to the stop Smíchovské nádraží of the tram 4 in the direction of Čechovo náměstí. Tram will depart from the stop at 4:39pm. Go 9 stops to the stop Náměstí Míru, then from the same stop take bus 135 in the direction of Chodov. The bus will depart from the stop at 5:02pm. Go 3 stops to the stop Slovinská, then you will be at your destination.

[Here, the participant can ask for the next route or chose the current one]

The length of the second route is approximately 6.4 km, and it takes about 32 minutes, including possible waiting time. The departure is planned at 4:36pm, and the arrival is planned at 5:09pm. The route includes 490 meters of walking for about 7 minutes, 25 minutes of tram traveling, and 0 transfers.

[Here, the participant can ask for more details]

Walk approximately 160 meters for about 2 minutes to the stop Smíchovské nádraží of the tram 4 in the direction of Čechovo náměstí. Tram will depart from the stop at 4:39pm. Go 14 stops to the stop Čechovo náměstí, then walk approximately 330 meters for about 5 mins to your destination.

[Here, the participant can ask for the next route or chose the current one]

The length of the third route is approximately 6.0 km, and it takes about 30 minutes, including possible waiting time. The departure is planned at 4:44pm, and the arrival is planned at 5:15pm. The route includes 160 meters of walking for about 2 minutes, 18 minutes of tram traveling, 6 minutes of bus traveling, and 1 transfer.

[Here, the participant can ask for more details]

Walk approximately 160 meters for about 2 minutes to the stop Smíchovské nádraží of the tram 4 in the direction of Čechovo náměstí. Tram will depart from the stop at 4:47pm. Go 9 stops to the stop Náměstí Míru, then from the same stop take bus 135 in the direction of Chodov. The bus will depart from the stop at 5:09pm. Go 3 stops to the stop Slovinská, then you will be at your destination.

[Here, the participant can ask for the next route or chose the current one]

The length of the fourth route is approximately 9.9 km, and it takes about 47 minutes, including possible waiting time. The departure is planned at 4:32pm, and the arrival is planned at 5:20pm. The route includes 265 meters of walking for about 4 minutes, 31 minutes of tram traveling, 6 minutes of bus traveling, and 1 transfer.

[Here, the participant can ask for more details]

Walk approximately 160 meters for about 2 minutes to the stop Smíchovské nádraží of the tram 5 in the direction of Ústřední dílny DP. Tram will depart from the stop at 4:35pm. Go 18 stops to the stop Želivského, then walk approximately 105 meters for about 1 minute to the stop Želivského of the bus 139 in the direction of Komořany. The bus will depart from the stop at 5:14pm. Go 4 stops to the stop Kodaňská, then you will be at your destination.

Questions: How comfortable are you with two levels of the descriptions? Is the flow of using the application understandable? Which information is missing, which information is excessive? Decide, which route you will use and why, use think-aloud protocol;

Task 5: Creation of the route description from the participant's home address to their favorite place;

- How comfortable are the participants with two levels of the descriptions? Decide, which route you will use and why, use think-aloud protocol;

Post-test Interview

Finally, the post-test interview was held:

- What do you think about the presence of two levels? Do you think it is helpful for travelers?
- Do you feel confident that you understand the route, and you are able to understand the difference between the routes?
- Do you think, it is enough information to consider, what route is more appropriate to take?

5.2.3 Results of Testing

In the following paragraphs, the results of the second evaluation are presented. Some information can also be found in Subsection 5.2.1.

Pre-test Interview Results

Travelling habits of sighted participants: sighted participants travel to known places literally almost every day (most of the time during working days), to the university, to work, to the gym, etc. When talking about the unknown places, it varies from several times per week (P4) to once in two weeks (P2, P3): on some trips or just to check out a new place in the town. For planning their journey, all the participants choose Google Maps and also special travel applications such as TripAdvisor, Booking, and other related applications. P6 also says that he is trying to use applications that are in possession of local timetables, as in IDOS in Prague or Yahoo in Japan. When choosing how to get to a place, participants are not very selective and named almost all the variety of transport. The interesting point was that some of the participants were taking into consideration more factors, especially the trend of being eco-friendly, than only the transport convenience, e.g., better public transport than car or taxi or better train than plane.

Stereotypes about the traveling of blind people: The answers for the question *What do you think, how often do blind people travel to unknown places* were very varied, from several times per week (P5, P6) to 3 times a year (P1). P6 also mentioned that it could depend on the accessibility of the destination or whether dogs are allowed to enter in their destinations. "*If they have somebody to accompany them, they are happy to travel,*" P6 added. As for transport usage, mostly metro, bus, and tram were considered to be adequate transport for blind people. P1 considered that long-distance transport might not be suitable for blind travelers, "*I don't know, whether they have ambitions to fly somewhere.*" In the further part of the evaluation, however, some of the participants mentioned that in case of the bad weather they could probably call a car. According to sighted participants, sightless people prepare the journey with the help of some special audio navigation applications or just ask somebody to go with them. The applications must have voice-over functions or allow to convert text to sound or Braille, some of the participants mention. When stuck at some point during independent traveling, they will ask people around to help.

Main Testing Results

Task 1: Introduction
Origin and destination: None of the participants noticed that the origin has only street without house number and that there was no name of the Vietnamese restaurant. P4 offered that the origin and destinations are too long, "*district could be important for the traveler, but postcode no.*"
Weather: Some of the participants (P1, P4) were asking about the source of weather information. P1 was interested in the weather also at the beginning of the route. P3 supposed that, in case of bad weather, the traveler could call a car, P6 generalized, "*they will find another transport.*" P1 and P6 noticed that e.g., in case of the slippery outside, the blind traveler would think, whether he or she has to go outside. P4 also considered that the phrase "There is no reason to be afraid of your journey today!" is not needed, it is more necessary to notify the travelers that there could be some problems rather than that there are no problems.

Task 2: First level of the route description
Usual route: P1 mentioned that intervals between transport are missing and the overall number of the route alternatives. Most of the users remembered only some parts of the last sentence of the description (that the route included walking, tram, and no transfers). When trying to repeat the numbers that were describing the route, participants tended to round the numbers (instead of 575 meters, say 500 or 570, instead of 19 minutes, say 20, etc.) This observation also repeats in the following tasks. For some of the participants, zero transfers were the key property of the route. P6 was

considering that accessibility would be necessary for this description as well.
Walking only route: Overall, participants were satisfied with the description (it was the shortest description presented in the evaluation). Some of them were hoping that later on, they will receive the turn-by-turn navigation.

Task 3: Second level of the route description
P1 was asking for the time to change the transport in case of transfer, the delay of the transport, crowdedness of the transport and accessibility. P1 and P6 were interested in the possible dangerous factors in the surroundings. It was hard to remember how many stops to go with which tram, and it was easy to remember, to which stops to go and how far is the stop from the origin and from the destination. In comparison to P6 in Task 2, P2 and P3 were expecting accessibility of transport here in the second level of the route description. P4 supposed that the user would not remember the information which was said at the beginning of the description. P6 was complaining that there are no supportive technologies for blind people while transferring: the user can get in the tram, but neither direction nor the number is announced in the tram, only the next stop.

Task 4:
The standard flow for all the participants was to listen to all the first level descriptions, then choose one of them, and ask for details of the route, the second level, to be sure that they made the right choice. Participants were given a choice of four different routes. The opinions divided into three groups: to choose the second route, to choose the third route, or not to choose anything. The first opinion was based on zero transfers on the route and absence of the necessity to look for the next stop or station. The second opinion focused on the small amount of walking and the shortest time of the whole route. The third opinion took place because some of the participants were not aware, which priorities blind people could have for their journeys, and they did not want to decide on the process.

Task 5: When participants were asked to name any origin and destination to create a route, most of the participants were saying names of the metro stations as Nové Butovice - Hradčanská or Dejvická - Karlovo náměstí and not naming the particular addresses. On the one hand, a couple of the participants were curious why there are no more suggestions for the subway during the journey as it could be easier to travel with the metro. On the other hand, some of the participants considered the metro more difficult way to travel as there are many stairs, escalators, or long passages for transfers.

Post-test Interview Results

Participants considered different levels of the descriptions helpful as they can focus on basic descriptions first and later on ask for more details. Some participants also offered to make an order in the presentation of the routes: by the number of transfers, by the distance of walking and by the whole distance of the route. P4 also offered to shorten the first level description as there are a lot of numbers. Overall, they liked the descriptions.

5.2.4 Recommendations

After the analysis of the results, the following recommendations are stated for the consideration:

R1: to shorten the origin and destination to the name of the establishment if applied and address;

R2: leave only the phrase "Be aware of the weather conditions!" in case of the bad weather, otherwise not to say anything;

R3: mention the number of route alternatives;

R4: tell the time between transports while transferring;

R5: order the route by some criteria, e.g., number of transfers or walking distance.

Some reasonable recommendations as accessibility, crowdedness of the transport, and delay are not presented in Google Maps API, and it makes to think about other API to add to the application or even change Google Maps API in favor of exploring different API, e.g. OpenStreetMap API.

Chapter 6

Conclusion

6.1 Introduction

In the Introduction, the research problem is defined. It is followed by the Chapter Related Work that consists of two sections. In the first one, Literature Review, the definitions regarding the orientation of blind people are explained. Also, the insight on the accessible journey chain and presentation of the city is taken as well as solutions on accessibility in transport. Also, the route presentation methods are showed and the investigation of blind people's needs is provided. In the second Section Application Review, many applications related to navigation are reviewed. They differ in approaches, target audiences, or devices; it is done in order to find an inspiration or an innovation, bigger or smaller, for creating a route itinerary.

The Chapter Design Process is dedicated to the principles of product design overall and later, more specifically, to the summaries' design. There are the objectives of the prototype, and the prototypes itself are presented, including use cases.

The Chapter Implementation shows the process of creating the system for route summaries, later on, tested in the following Chapter Evaluation.

In the following paragraphs, conclusions about the prototypes are made, and future work is proposed. Also, possible future extensions are presented.

6.2 The Prototype and Future Work

During the evaluation, several discoveries were made. Although they seem to be coherent, they were made by people with vision, which means that further work demands testing by the target audience. Qualitative studies with blind users will lead the prototype to a better design, better presentation of information, and give an insight into what blind users expect from the application. Later, quantitative studies will help to evaluate the implementation created. A set of various methods to measure route knowledge, which could be used, has been processed in [17].

Also, it would be appropriate to start an application with an onboarding feature. For first-time users, it is necessary to describe how the application works and how it could be controlled.

To improve hi-fi prototype even more, it is needed to discover the requirements of the text-to-speech application, which will be used and adjust the prototype to them. The next issue could be gathering information about the accessibility of walking routes or gathering information about the obstacles outdoor. For example, it could be useful to present information about the density of people outside or traffic density in the streets, although it could be a hard task to find real-time information.

6.3 Possible Extensions

An interesting point in making a summary is offered in [25]. Although the application created is intended for drivers, the system could also be useful for blind people. One of the possible changes in the route summary can be an exchange of some parts of a detailed description of the route to the pointing to the landmark the user already knows. The application will not have to find the best route to a certain place, but rather offer the user to use his or her usual route to get to a place the user already knows and from there continue to a destination. Example: the user wants to get from point A to point B, and there is the point C on the route which the user already knows how to get to. Instead of the description, *Go from A to the closest bus stop, take the bus number 1, transfer at D, take the bus number 2, take off at E, go to B*, the user can receive the description *Go from A to C, take the bus number 2, take off at E, go to B.* This approach requires a preset of landmarks the user already knows (transport stops, shops, sightseeing places, etc.). Otherwise, the application should construct a usual route summary. Such behavior was already shown in the results of the second evaluation when people were naming metro stations as their origin and destination: they already know the route to the closest station from where they are and how to get to the destination from the destination metro stop. In the case of blind people, it is also necessary to double-check the offered route and not let the person go by the usual route when there is any hazard there (reconstruction, accident, etc.).

The possibility is also to use points of interest from maps and to assume an awareness of blind people where these places are. It could be possible to mine data from maps using the popular routes, or trajectories, of people moving around the place. Unfortunately, data could be noised by tourists, drivers, etc., and scraping exact data being sure that these users are blind seems to be challenging, and, overall, it requires more mathematical knowledge.

An interesting idea is presented in the project Virtualna Warszawa [12], which is based on an outdoor beacon system, small transmitters that could introduce information about the place to the user through the mobile phone. Beacons could be placed on different landmarks: institutions, transport stops and stations, crossings. Beacons use Bluetooth low energy technology to connect to the user's mobile phone.

Chapter 7

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Appendix A

Setting the Application Online

The process of setting the application on the Google Cloud Platform and Firebase as of December 2019.

1. Go to Cloud Platform `https://cloud.google.com/`, click on "Get started for free" and login to Google Account ;
2. Choose the country and agree to the Terms of Service, click on "Continue";
3. Choose Account Type as Individual, fill in Name and address form and the payment method, start a free trial;
4. Proceed to Verification if needed;
5. Go to `https://console.cloud.google.com/`, choose "Select a project" → "New Project";
6. Fill the name of the project and its location, click on "Create";
7. Click on "Navigation Menu" → "API & Services" → "Library";
8. Enable following APIs: Places API, Directions API;
9. Go to "Navigation Menu" → "API & Services" → "Credentials" to create an API Key;
10. Go to `https://console.firebase.google.com/`, click on "Create a Project";
11. Choose the project from Google Cloud when choosing the name of the project, confirm Firebase billing;
12. Continue through step 2, add Google Analytics if needed in step 3, proceed;
13. Go to "Hosting," click on "Get Started";
14. Set up Firebase Hosting according to the steps;
15. Replace the files in the directory created with the files from the .zip archive attached to this thesis, deploy the project.

Appendix B

Content of the Attached .zip File

```
/
├── .firebase
│   └── hosting.cHVibGlj.cache
├── public
│   ├── 404
│   └── index
├── .firebaserc
└── firebase
```