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Hospital waiting room management system for visually impaired people

Master's thesis

Albert Vilalta Riera

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CTU in Prague supervisor
Ing. Miroslav Macík

UPC BarcelonaTech supervisor
Ing. Antoni Elias, Ph.D.

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In Prague on 6th of May 2016

Foreword

I would like to thank my CTU supervisor Ing. Miroslav Macík for his useful and always ready advice, his help with the interviews, his patience and for the time spent during consultations and meetings.
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Albert Vilalta Riera

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Abstract

Navigating inside large buildings such as government offices or hospitals is often confusing even for people with no orientation difficulties. Imagine how hard can it be for visually impaired people: the lack of adapted presentation of information and the frequent obstacles on the way are true challenges for them. In a hospital environment, where stress and unpleasant circumstances appear, navigation can be even more challenging.

The aim of this thesis is to study visually impaired people's needs within that environment, concretely regarding hospital waiting rooms, and design a management system for it. The designed system will be part of a complex in-hospital navigation system that expects to satisfy people with orientation difficulties' needs. The methodology we follow is the common one for any engineering process: study the needs, design a prototype and evaluate it.

This thesis reaches its end after the evaluation of the high fidelity prototype is completed. The proposed prototype is able to perform like a real waiting room kiosk from a visual impaired person's perspective: it informs patients out loud about their turn number, waiting time and doctor's office. It also helps them to find a free seat in the waiting room, to navigate to specific locations such as toilet or cafeteria and to ask for assistance if needed. Participants of the evaluation session are able to use the prototype for their purposes successfully and the proposed solution can be easily assimilated by the complex in-hospital navigation system.

Keywords

Hospital, in-hospital navigation system, navigation, orientation difficulties, visually impaired, waiting room.

Resum

La navegació dins d'edificis grans, com ara oficines de l'Administració o hospitals, és sovint confusa fins i tot per a persones sense problemes d'orientació. Imagineu com de difícil pot arribar a ser per a persones amb discapacitat visual: la manca d'informació adaptada i els freqüents obstacles en el camí són veritables desafiaments per a ells. En un entorn hospitalari, on les circumstàncies no acostumen a ser agradables i on apareix l'estrès, la navegació pot ser una tasca encara més complicada.

L'objectiu d'aquesta tesi és estudiar les necessitats de les persones amb discapacitat visual dins d'aquest entorn, concretament pel que fa a les sales d'espera d'hospital, i dissenyar un sistema per a gestionar-les. El sistema dissenyat formarà part d'un sistema de navegació dins d'hospitals complex que s'espera que satisfaci les necessitats de les persones amb dificultats d'orientació. La metodologia que seguim és l'habitual en qualsevol procés d'enginyeria: estudi de les necessitats, disseny d'un prototip i avaluació del prototip.

L'abast d'aquesta tesi és, per tant, l'avaluació d'un prototip d'alta fidelitat. El prototip que finalment es proposa és capaç de funcionar realment com el quiosc d'una sala d'espera d'hospital des de la perspectiva d'una persona amb discapacitat visual: informa els pacients en veu alta sobre el seu número de torn, el temps d'espera i sobre quina és la consulta del seu metge. També els ajuda a trobar un seient lliure, a desplaçar-se fins a indrets específics, com ara lavabos o cafeteria, i a demanar ajuda si cal. Els participants de la sessió d'avaluació són capaços de fer servir el prototip per als seus propòsits amb èxit i la solució proposada és fàcilment integrable en el complex sistema de navegació dins d'hospitals.

Paraules clau

Hospital, sistema de navegació dins d'hospitals, navegació, dificultats d'orientació, discapacitat visual, sala d'espera.

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List of abbreviations and symbols

VI Visual impairment
VIP Visually impaired person
SP Senior person
WR Waiting room
FR Functional requirement
NFR Non-functional requirement
CTU Czech Technical University in Prague

Chapter 1: Introduction

Visiting a hospital is usually a stressful experience. Often, reasons for going to a hospital are connected to negative events. In addition to that, it is quite common to get confused with the directions and signs. If we add long waiting times and the usual lack of proper information about them to this, frustration among patients and visitors is perfectly understandable.

Clearly, one of the user groups that are challenged the most all these issues are the visually impaired people. They have additional problems with orientation and they are specially challenged with the lack of adapted presentation of information.

According to Grote et al. [1], "*Patients and physicians are more and more likely to base their choice of hospital on nonclinical aspects of a visit –like convenience and amenities*". Nevertheless, "*few hospitals act systematically to understand what patients value in the nonclinical aspects of their hospital visits or how and when hospitals should invest to meet their expectations. Most hospital executives believe that it is enough to address the experience of patients by measuring and raising their satisfaction and resolving their complaints. Hospitals need to do more*."

In this context, this work attempts to improve the hospital visiting experience while paying special attention to people with orientation difficulties such as visually impaired people or seniors. This general objective is too complex and indistinct to address it as subject of a single Master's thesis. Our efforts are joining a bigger project whose goal is to design a complex hospital navigation system for people with orientation difficulties. In the particular case of the present work, we put the focus on the waiting room experience when it concerns to visually impaired people. We want this user group to be able to visit a hospital with complete independence and self-confidence.

Motivation and goals

Imagine that a visually impaired patient is visiting the hospital. He or she might have several orientation problems. Firstly, the path throughout the hospital can be really confusing. Secondly, once in a waiting room with a queue management system, the patient might be unable to read the screen and know when his or her turn arrives. Thirdly, the patient might have some problems in order to find a free seat to wait for his or her turn. And lastly, the hospital staff might have some troubles while trying to identify those patients with special needs. Our system is going to solve these kind of problems by installing navigation kiosks with facial recognition all around the hospital.

In order to achieve our goals, it is needed to establish a set of objectives that will guide our path throughout the search of a solution to the problem. These established objectives can be listed as follows:

1. To study and understand the state of the art in hospital navigation systems.
2. To analyse the user needs.
3. To state the system requirements according to these needs.
4. To propose a design fulfilling the stated requirements.
5. To implement and evaluate a high-fidelity prototype of the solution.
6. To state future developer documentation.

These goals are the essentially the same for any engineering process and they are important in order to follow a scientific methodology. But we need to state goals more closely related to our particular subject if we want to define the purpose of this thesis:

7. To help visually impaired people to understand information displayed in a hospital waiting room.
8. To improve visually impaired people's experience in a hospital waiting room by, for example, helping them to find a free seat or navigating them to specific locations such as toilet or cafeteria.
9. To make visually impaired people independent from other people while they are in their way to the waiting room and in there.
10. To design a waiting room management solution integrated in the complex in-hospital navigation system.

Structure of the thesis

This thesis is formed by four parts that represent the four stages of any engineering process.

The first part is the analysis, in which the problem and its environment is defined in order to state the needs that our solution will try to satisfy. It is formed by two chapters called *Hospital navigation system* and *User research*. The first one includes an overview of the state of the art in navigation systems (goal 1) and a contextualisation of this thesis in the framework of a complex system. The second one is a study of our user group formed by field study with interviews, statistical data and the creation of a persona that comes up with the statement of the user needs (goal 2).

The second part of the thesis is the design, where the solution is proposed. This part is formed by two more chapters. *Scenarios and HTA* is the first one and exposes all the situations a user may face. The second one, called *Solution design*, starts by stating the requirements of the system (goal 3) and continues by proposing the initial solution that expects to satisfy the requirements (goal 4).

The third part is the implementation. This third part is formed by only one chapter called *Solution implementation*. There, the system previously designed in the second part is now implemented in a high-fidelity prototype capable of representing the solution in a realistic testing environment (goal 5).

The fourth and final part is the evaluative one, in which the designed solution is tested with real users in order to check its functionality and improve it. This part is formed by a single chapter called *Usability testing*, which is carried out with real users (goal 6).

After these four main parts, the thesis ends with the habitual sections: conclusions and future work (goal 7), appendices and bibliography.

Part I: Analysis

The first part of this thesis focuses on the analysis. As for other engineering projects, it is necessary to carefully analyse external factors that might influence a particular solution that is being proposed. In case of this thesis, we will primarily focus on analysis of the target environment and analysis of needs and preferences of the target user audience. On the basis of complex analysis described in this part we were able to propose a useable solution that meets needs and requirements of our target users.

In order to achieve this goal, the first part is divided in two chapters. The first one studies the existing solutions of hospital navigation issues and explains the role of this thesis in the framework of the complex navigation system that is going to be designed (see section 2.2). The second one contains the user research carried out in order to understand the problems and identify the user needs.

Chapter 2: Hospital navigation system

This chapter starts with an overview of the state of the art related to hospital navigation problems. After that, it briefly introduces the solution currently developed at the CTU to address issues of current navigation systems: *In-hospital navigation system for individuals with specific navigation and orientation needs*.

2.1 State of the art

This section is a quick look to the related technologies applied to deal with navigation issues in hospitals.

2.1.1 Navigation systems

Navigating inside a big building like a hospital can be really confusing even for people with no impairments, as we see when we visit the main hospital in Prague (section 3.1). Therefore, it is understandable that many projects before this very one have been focused in solving those problems. Most of the collection of the following technologies was made by K. Fixová [2].

I. Panasonic In-hospital Navigation System for Outpatients

Panasonic proposed its so-called *In-hospital Navigation System for Outpatients*, where every outpatient is given a wireless pager (Figure 1). According to Panasonic [3], the system "*delivers the examination room details and time to patients (...) through handheld paging receivers. And it has achieved reduction of the complaints from patients due to long waiting time as well as increases privacy*." Panasonic also points out that "*as well as the benefits for outpatients, the system will take over the receptionists' paperwork to register for outpatients, tell them the time and location of examination room as well as when to pay for their medical fees*."

This means that hospitals can significantly decrease noise distractions such as verbal announcements and, at the same time, adapt the environment by making full use of waiting rooms.

The main issue that arise from the Panasonic solution is basically that those pagers are expensive and liable to be stolen or damaged by the users.

Figure 1: Panasonic wireless pager, from [3]

II. 3D Communication Navi System

The Japans' Kanazawa Medical University Hospital is using a navigation system in which the routes are displayed in 3D [4]. It uses a 3D visualisation of the hospital layout, connected to a touchscreen monitor (Figure 2). The creators of the 3D Communication Navi System (Ableseed and Metabirds) explain that "*a virtual version is easier than assembling video footage for every possible Point A-to-Point B request. Using 3D digital world, we can create navigation to any place when we want. A 3D simulation is easier to 'read' than real world video of the same location, since the virtual version can be visually streamlined to show only the most essential aspects*."

The main problem with this very solution is that 3D visualisation of the route is not an option for users with limited orientation capabilities or visually impaired people.

Figure 2: 3D Communication Navi System, from [4]

III. Logic Junction

Logic Junction [5] is a navigation system they have in some US hospitals like the Cleveland Clinic, ranked as one of the best hospitals in the world [6], which provides staff-assisted and self-service way finding. Self-service touch-controlled kiosks (Figure 3) are located at entries and, as its name suggests, at junctions that might be confusing. By interacting with those kiosks, visitors can obtain a printed map or send it to their mobile phone (part of the system is also a mobile application, which allows users to get directions by scanning QR codes). Moreover, the system provides audio descriptions if requested.

This solution is closer to fulfil our needs than the previous ones, but the almost imperative use of mobile phones and printed papers is far from our idea of a good solution.

Figure 3: Logic Junction kiosk, from [5]

IV. 3D navigation system for buildings in the Alice Hospital in Darmstadt

Alice Hospital in Darmstadt (Germany) provides a 3D navigation system that can be used from any location via internet access [7]. Patients can select a starting point and an end destination. Then, the system highlights the target building in a 3D model and starts the navigation presentation with an arrow moving through the hospital (Figure 4).

The main problem of this solution is that the system does not know where the user is, so it can be confusing for people who have orientation difficulties or problems remembering the route. In addition to that, this solution requires permanent Internet connection.

Figure 4: Alice Hospital's 3D Navigation System, from [7]

V. Kyoto University Hospital Navigation System

The Kyoto University Hospital introduced a navigation system [8] in which all patients have their own Bluetooth terminal with a proximity sensor (Figure 5). Furthermore, all patient's positions are tracked by the system and the system helps them to go to any waiting room at the appropriate time. This means a significant reduction of the waiting time and prevents patients and doctors from time wasting.

The main issue this solution has is similar to the one arisen from the Panasonic solution: those terminals are expensive considering that they can be stolen or damaged by the users.

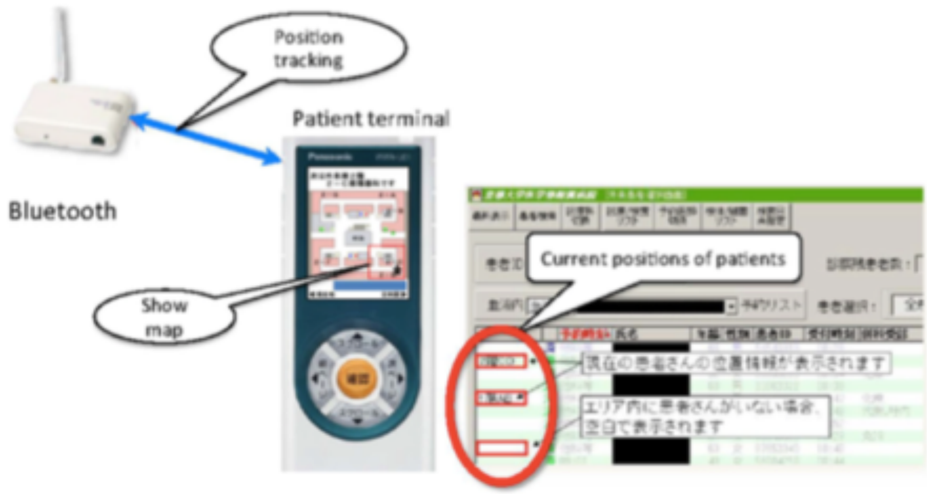

Figure 5: Conceptual design of the KU Hospital Navigation System, from [8]

VI. Mayo Clinic Patient Application

The prestigious Mayo Clinic in Minnesota (USA), developed a smartphone app in 2012 called Mayo Clinic Patient Application that helps users to navigate through the hospital. Mike Plotnick [9], from the *Healthcare Facilities Today*, explains that "*Mayo developed the tool in-house, using existing resources. They* (the IT team) *worked closely with the facilities team to conceive and build the application, which also includes secure access to personal medical records, messaging capabilities, hospital news and videos about the facilities.*" (Figure 6).

The app uses sophisticated interior mapping developed by Google to provide step-by-step navigation in the patient's smartphone. Furthermore, beyond way finding within the clinic, the apps also help visitors to find accommodations in the surroundings. This solution is very interesting from a budget point of view because it uses existing technology and patients' devices. Its main issue is, obviously, that not all hospital visitors have a smartphone, especially old and visually impaired people.

Figure 6: Mayo Clinic Patients App, from [9]

VII. Spreo's Wayfinding, Navigation & Mapping solutions for Hospitals

Spreo is a company that provides indoor location solutions. According to their website [10], their mobile wayfinding technology uses Bluetooth, Wi-Fi, GPS, gyroscope, accelerometer, and compass sensors on any smartphone to identify the location of a user. Although they base their technology on smartphones (Figure 7), they have also the so-called Self-Service Interactive Digital Displays & Kiosks. According to Spreo's website "*utilizing the interactive maps and directories found in SPREO's Cloud CMS, the kiosks provide an intuitive self-service touchscreen experience on high-tech yet surprisingly affordable hardware.* (...) *Each kiosk features an easy to use touch screen interface that emulates the Android version of the mobile app. With just* *a few taps, a visitor can locate their destination on the map and view the complete step-by-step directions and approximate walking time to any location in the venue."*

This solution is very interesting and fits many of our needs, but it is still not visually impaired user-friendly mainly because of the touchscreens.

Figure 7: Spreo's Navigation App, from [10]

Conclusions

In order to gather together and compare the exposed solutions, we are putting them all in a table to discuss the pros and cons of them from our point of view:

System	Pros	Cons
Panasonic In-hospital Navigation System for Outpatients	- Delivers examination room details and time. - Increases privacy. - Reduces noise. - Reduces paperwork to register outpatients.	- Wireless pager needed.
3D Communication Navi System	- Provides navigation directions.	- Touchscreen monitor. - 3D visualisation of the route.
Logic Junction	- Provides staff-assisted and self-service way finding. - Provides audio description of the route. - Provides a map (printed or on the mobile phone). - Users can get directions by scanning QR codes.	- Touch-controlled kiosks. - Works better with smartphones.
3D navigation system for buildings in the Alice Hospital in Darmstadt	- Provides 3D navigation model that can be used from any location via internet access.	- Location of the user not tracked. - Internet connection needed.
Kyoto University Hospital Navigation System	- Location of the user tracked. - Reduces time wasting.	- Bluetooth terminal with a proximity sensor needed.
Mayo Clinic Patient Application	- Uses existing resources. - Includes secure access to personal medical records, messaging capabilities, hospital news and videos about the facilities.	- Smartphone needed.
Spreo's Wayfinding, Navigation & Mapping solutions for Hospitals	- Location of the user tracked. - Intuitive self-service experience. - Provides complete step-by-step directions and approximate walking time to any location.	- Touchscreen or smartphone needed.

Table 1: Pros and cons of the existing navigation technologies

The studied solutions are good approaches to in-hospital navigation issues for most of the visitors a hospital receives. We can take some good ideas from them: users need to be tracked during their way, the system must be intuitive and provide step-by-step audio description of the route and it can include other features related to hospital's surroundings and facilities. This analysis also reminds us some important topics to take into account when we design our solution, such as users' privacy and noise pollution. Nevertheless, none of the existing solutions is visually impaired user-friendly due to the use of special devices, touchscreens or smartphones.

2.1.2 Authentication technologies

In order to identify the patients in an easy way while respecting their privacy, we think about a biometric authentication method. Jain et al. [11] define biometric recognition, or simply biometrics, as "*the science of establishing the identity of a person based on physical or behavioral attributes*." The Biometrics Research Group from the Michigan State University [12] adds that "*The word 'biometrics' is also used to denote biometric recognition methods. For example, fingerprint, face, or iris biometric features are sometimes described as single biometrics. Biometric technology can prevent fraud, enhance security, and curtail identity theft.*"

Therefore, biometric authentication is a better and safer way of identifying users than passwords or personal cards. The question is: what biometric way of authentication is the best one for our design?

Pruthi et al. [13] list the biometric solutions distinguishing between physical and behavioural ones as follows:

"*Physical biometrics*

- *a) Fingerprint scan*
- *b) Facial recognition*
- *c) Iris scan*
- *d) Hand geometry*
- *e) Retina scan*
- *f) DNA analysis*
- *g) Vascular patterns recognition*

Behavioral biometrics

- *a) Speaker/voice recognition*
- *b) Keystroke patterning*
- *c) Handwriting/signature analysis*"

Considering a hospital environment, we can dismiss some of these options: DNA analysis and vascular patterns recognition are too complex and expensive methods. Voice recognition might be imprecise in noisy areas. Fingerprint scan, hand geometry and keystroke patterning are insanitary methods in a hospital. Moreover, considering our target group, we can dismiss some more options such as iris and retina scan and the handwriting analysis. In conclusion, and by a process of elimination, the best biometric solution would be facial recognition. Pruthi et al. emphasize that, even though this technology is cheap and non-intrusive, the major drawback of it is that people do change their face over time. That is true but, in our system, the face will be recognized every time the users arrive to the hospital and used only during that single visit.

2.2 In-hospital navigation system

As we explained before, the current work is part of a complex project that intents to satisfy our target group's needs throughout their visit to the hospital. The system should support visitors' activities from the preparation of the visit until they leave the facilities after it. Obviously, the whole extent of the topic is far too complex to address it directly with one single thesis. This is the reason why the navigation system was divided into several different parts and projects. Currently, there are being developed the following components: a web application to prepare the visit, a main entrance kiosk to log in the system and start the navigation process and a waiting room kiosk to manage the waiting time and the users that wait in there (Figure 8). The primary aim of this thesis is development of the waiting room management kiosk, but, in order to contextualize it, it is important to briefly summarize the purpose of other components of the system.

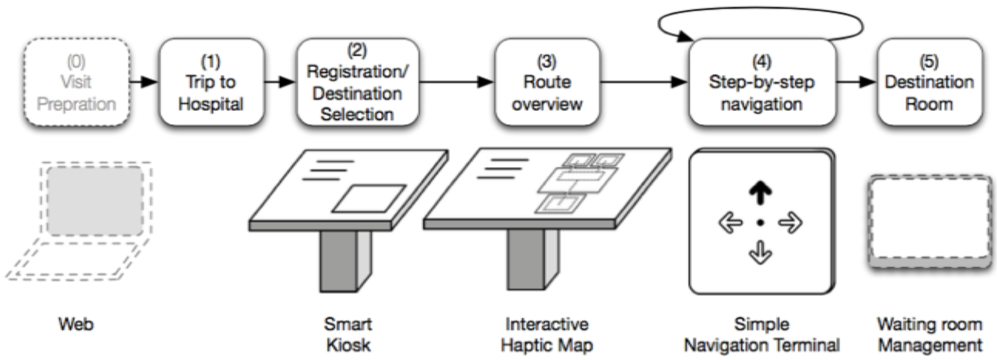

Figure 8: Navigation procedure with proposed system, from [14]

2.2.1 Web application for visit preparation

CTU student Flek, T. is developing the web application[1] that allows the users to prepare their visits to the hospital. When asked about his design after the user testing, he explains that, through the web application:

- Users can read or listen an overview of the functionality of the system and they are told about the face recognition.
- Users can make an appointment with a doctor or for a specific examination.

[1] A functional prototype of the website is available (only in Czech) at http://hospital-flektoma.rhcloud.com/, retrieved April 24, 2016.

- Users can also prepare navigation to a specific ward, to a doctor, to the cafeteria, etc. with the possibility to search for connections from home to the hospital (using idos.cz and naviterier.cz for visually impaired people).
- The system asks the users about their personal data (name, surname, date of birth, insurance company, phone number and optional email address) and needs (level of visual, motor or hearing impairment). For those users who do not want to fill in personal data to their account, the system allows them to access their appointment via phone number (which is a unique identifier) and SMS code.
- Users have the option to add tasks and notes to an appointment (e.g. "take results of the blood exam with me" or "don't forget the insurance company card").

Flek also explains that, in the future, he is planning to implement a simple forum where users could write tips and tricks about the system and the hospital itself.

2.2.2 Main entrance kiosk

CTU student Lorencová, E. is developing the main entrance kiosk that allows the users to sign in the system when they arrive to the hospital. When asked about her design after the user testing, she explains that:

- The main entrance kiosk is situated in the hallway, next to the main entrance.
- Users are identified by using their insurance card. Data is read via OCR and compared to the personal data retrieved on the website or on the medical history is important.
- Users can select their destination at the kiosk if it was not defined previously on the website application.
- If the visit was scheduled and the user is identified, the system provides directly the list of scheduled visits.
- User face is recognized in order that the step-by-step navigation by the simple navigation terminals can start.

2.2.4 Interactive haptic map

CTU team composed by Macik et al. [14] designed an Interactive tactile map that "*provides topological information about large parts of the hospital*." Users can explore the map in a visual way or in a haptic way: "*The actual route is visually highlighted. For the visually-impaired, there are touch sensors that help them to follow their planned route on the tactile map*."

2.2.4 Simple navigation terminal

Macik et al. [14] define the Simple navigation terminal (Figure 9) as "*the basic building block of our navigation system. The primary aim of it is to provide simple directional instructions at the corridor junctions*." The interaction procedure (Figure 10) begins by detecting the motion of a user. After that, "*a fast face detection algorithm* *is performed on the captured image. If a face is present in the image, the frame is sent to the server that performs advanced face recognition, resulting in the identification of a particular person. After successful user recognition, personalized navigation instructions are provided. However, the visual form is non-intrusive and is adequate for most users. Instructions for visually-impaired users are provided in the form of voice instructions.*"

Figure 9: Simple navigation terminal prototype

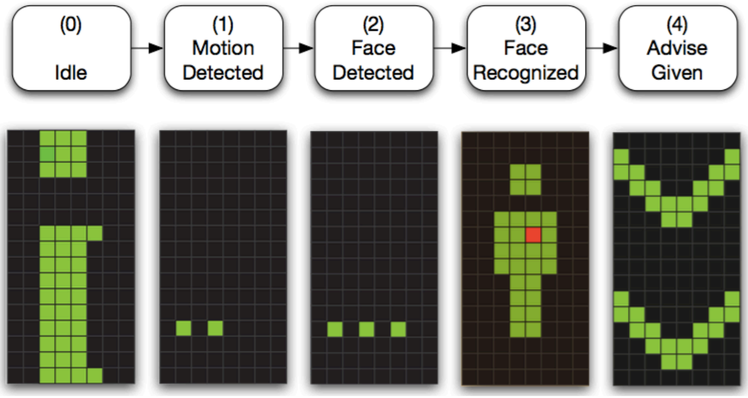

Figure 10: Interaction procedure with Simple Navigation Terminal, from [14]

2.3 Conclusions

This chapter has been useful to have a whole picture of the state of the art and, particularly, of the place our system is going to adopt in it. Although we took some ideas from them, we dismissed the existing solutions because they are not satisfying entirely what we need them to. After that, we considered the different technological ways of identifying people and we decided that facial recognition is the best authentication solution for a hospital environment. The last section has been useful to contextualise and understand the unified parts of the complex system.

Chapter 3: User research

This chapter gathers together all the user research done in order to analyse the problem and state the user needs. Only after listening to the users in such a study, one can think about the start design to provide a proper solution to the problem.

The user research starts with a report of the current situation of the main hospital in Prague focusing on navigation issues. It continues with three interviews with potential users (from this point on called "participants"). After that, the chapter introduces a teamwork experience map analysis of the results and states statistical data. The user research continues with the creation of a persona which brings together the main characteristics of the participants and allows us to get a better picture of the situations they face. Finally, the chapter ends by stating the user needs our solution must fulfil.

3.1 Hospital field study report: Fakultní Nemocnice[2] Motol

When designing a solution to navigation problems that visually impaired people may have inside a hospital, to visit and analyse a big hospital seems a good start point.

3.1.1 FN Motol's description

FN Motol is the biggest hospital in the Czech Republic. According to its website [15], the hospital:

- "*Provides basic, specialized and super specialized health care and services in medical fields in form of outpatient and in-patient care for children, adults and elderly patients.*
- *The biggest health care facility in the Czech Republic.*
- *Is built in two single blocks that are connected together as well as few separate pavilions – has 2,410 beds.*
- *More than 860,000 people per year are treated as outpatients.*
- *More than 70,000 people are treated as in patients.*
- *Has more than 5,000 employees*."

3.1.2 Navigation through hospital

Our visit to FN Motol starts getting off the metro. Although the metro station was recently built, it has no guidelines on the floor. It might be confusing for a visually impaired person to get to the hospital main entrance.

[2] "Nemocnice" is the Czech word for "hospital".

Once at the main entrance, the first map you can find has several problems (Figure 11): it has no braille indications, it is upside down from the observer's point of view (this is because the map is orientated following the cardinal points while the observer is towards the South), it has no English translations, the letters A-E are not explained in the legend and the legend lines are not following the alphabetical order. Furthermore, some buildings are extremely difficult to find following the map, according to our own experience and some nurses we asked for help (e.g. building number 16).

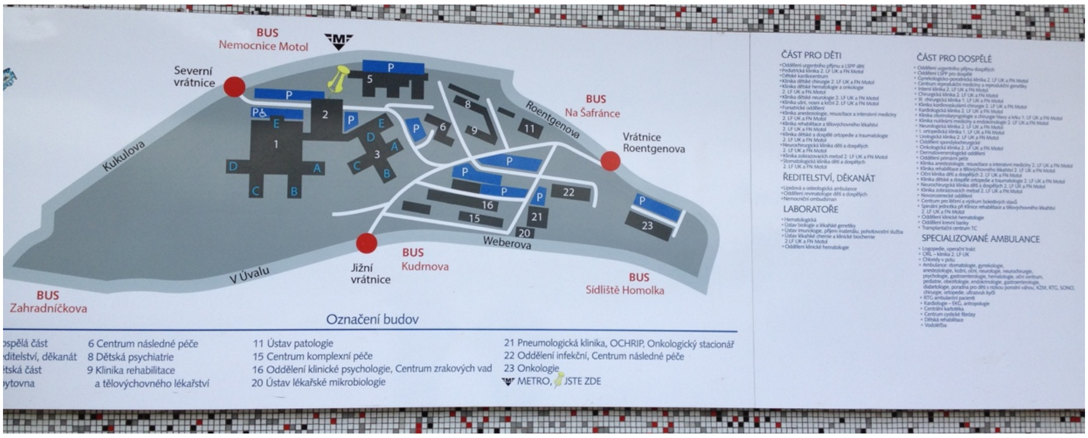

Figure 11: Main entrance map at FN Motol

Inside a particular building of the hospital, you are supposed to follow coloured lines on the floor to find your way. These guidelines can be helpful if you are not visually impaired, but they have some confusing problems such as finishing unexpectedly or changing its colour suddenly (Figure 12).

Figure 12: Guidelines at FN Motol

Most of the doors are true obstacles for visually impaired people[3]. Since they are not automatic and the coloured guidelines have no relief, it is not easy to distinguish such kind of doors from a wall when using a white cane (Figure 13).

Figure 13: Manual doors at FN Motol

They used to have some kind of information kiosk, but it is not working any more. In addition to that, the lack of homogeneity in the used fonts of some signs is confusing (Figure 14).

[3] From the first question of the interview to the first participant (appendix A.1).

Figure 14: Kiosk and signs at FN Motol

The alternation between "-P" and "SP" to define the floor immediately under the ground floor is confusing (Figure 15 and Figure 16).

Figure 15: Lift buttons and signs at FN Motol

Some lifts have no braille signs nor audio indications. Furthermore, in some cases in which they put braille signs, the labels disappeared (Figure 16).

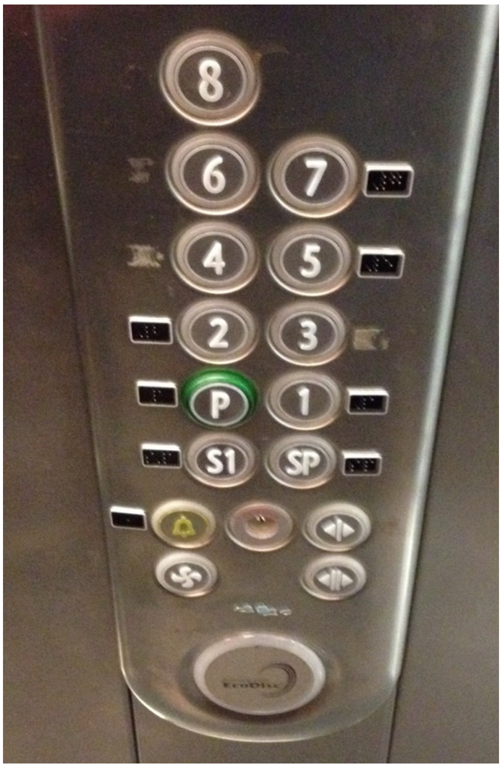

Figure 16: Lift buttons with braille labels at FN Motol

The waiting room screen is useful to know when your turn is or where to go, but it is completely useless for visually impaired people, since there are no voice indications (Figure 17).

Figure 17: Motol's waiting room screen

In conclusion, we can state that the hospital has many orientation problems, even for people with no visual impairment, and that it is not friendly at all with visually impaired people.

3.2 User interviews

Newman and Lamming [16] state that "*to design an effective interactive system, we must identify the people it is to support -the users- and gain some familiarity with their activities*." There are several methods to conduct user studies. The most common ones are interviews, questionnaires and observation. Newman and Lamming also define the interviews as a "*particularly rapid and congenial way of gathering data*" and, compared to other methods, "*the data are available immediately after the interview*". Nevertheless, interviews "*can backfire or give misleading results. (...) This makes it imperative to take care in their preparation and conduct*."

In our user study, we decide to carry out interviews. Specifically, three semi-structured interviews are held. The questions are planned beforehand and all the interviews follow the same structure. They can be found in appendix A. The three participants are two males and one female with an average age of 46.7 years old and a standard deviation of 18.6 years. A detailed description of their profiles can be found also in appendix A. In order to characterize users while respecting their privacy, the profile was defined using four important parameters such as age, gender, category of visual impairment (from 1 to 5 where 1 is the lowest impairment and 5 the highest, meaning total blindness) and time (distinguishing between L "later impairment" and C "congenially impairment").

Findings from the interviews are reflected by our persona (see 3.5).

3.2.1 Proposed questions to the participants

The following proposed questions were thought in order to respect some basic rules such as to avoid binary answers, to avoid forced opinions and to respect the participants' privacy as suggested by Newman and Lamming [16].

Q1 How do you orientate yourself in a hospital?
Q2 Once you are in the waiting room, how are you informed all the time? What would you like to know?
Q3 How do you to find a free seat in the waiting room?
Q4 How do you think that the hospital staff is prepared to help visually impaired people?
Q5 How would you like to receive the information?
Q6 After the visit to the doctor, how would you like to set the next appointment?
Q7 After the visit to the doctor, would you like to be guided to go to the entrance point, pharmacy or public transport? Would you like to be guided throughout a free-obstacles (maybe longer) route?
Q8 Any additional idea to improve your visits to the hospital?

3.3 Other user research

In a brainstorming session held by some of the students who take part in the navigation system design, all the user research done was gathered together in an experience map [17] (Figure 18). The conclusions were divided into three lists: “what we know”, “what we need to prove” and “what we don’t know”.

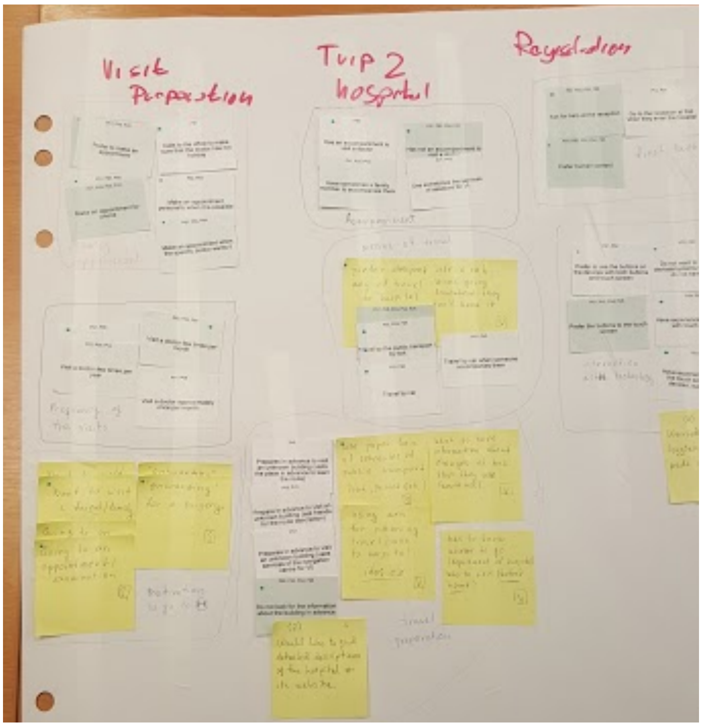

Figure 18: Experience map section

What we know

1. Participants make an appointment before going to the hospital or visiting the doctor.
2. Most of the participants use the phone to make an appointment.
3. The most common reasons to visit a hospital are surgery on-boarding, examination or visiting another patient.
4. Visually impaired participants (VIP) prepare their visit to the hospital beforehand.
5. Those VIP who are used to use a computer do search the route to the hospital on the internet beforehand.
6. Those VIP who are not used to use a computer do ask for a description of the route to a friend, a relative or an assistant.
7. SP and VIP prefer phones with buttons.
8. Most VIP have experience with touch screens but prefer phones with buttons.
9. VIP use white cane and transmitter for visually impaired people.
10. SP and VIP ask for help at the reception or to passers-by, if needed.

11. Most of the hospital staff members do not know how to orientate those VIP who ask for help.
12. VIP have problems with navigation when the hospital consists of several buildings.
13. There is no support for VIP in hospitals.
14. VIP have good experiences with other people when asking them for help and orientation.
15. VIP expect some usual problems in their way through the hospital. The most common ones are hanging objects and closed doors.
16. Most of the VIP feel really worried when they get lost.
17. Many VIP are not sure about how to inform the nurse when they arrive to the waiting room.
18. VIP are not able to read electronic waiting lists.
19. Most VIP do not have problems in asking for a free seat in the waiting room.
20. When VIP are sent to visit another doctor in the same building, there is always someone who accompanies them.
21. When VIP and SP are sent to another doctor, they ask for a description, the address and the name.
22. Many visitors want to use other hospital services besides the doctor, like the cafeteria or the pharmacy.
23. Many patients have to carry some documents when going to the hospital.
24. VIP use computers more likely than SP.

What we need to prove

25. Some VIP ask for directions at the main entrance reception.
26. Some VIP are worried about overtaking someone's turn or being overtaken by someone in the waiting room.
27. Where and for how long do patients wait before they are admitted (hospitalized).

What we don't know

28. VIP search for information about the hospital on its website.
29. The amount of VIP who use a computer or a smartphone regularly.
30. VIP (and maybe even SP) are worried about the hygiene of touching pads or braille texts.
31. VIP suffering from severe diabetes cannot read braille.
32. The amount of VIP who use a guide dog and how.
33. Statistics about VIP usage of smartphones vs. feature phones.
34. VIP need help with electronic waiting lists.

3.4 Statistical data

The definitions of blindness and partial sight vary from one European country to another. The European Blind Union (EBU) adopts the definitions used by the World Health Organisation (WHO) for visual impaired and partial sight [18]: "*the term 'visual impaired' is used to indicate blind plus partially sighted people together. Partially sighted and low vision are used as equal indication of limited sight*."

According to the EBU:

- "*There are estimated to be over 30 million blind and partially sighted persons in geographical Europe.*
- *An average of 1 in 30 Europeans experience sight loss.*
- *There are four times as many partially sighted persons as blind persons.*
- *Women are more at risk of becoming blind or partially sighted than men.*
- *Sight loss is closely related to old age: one in three senior citizens over 65 faces sight loss. 90 percent of visually impaired persons is over the age of 65.*
- *The WHO estimates, in figures dating from 2010, that in Europe there are 2,550,000 blind people and 23,800,000 low vision people, giving a total of 26,350,000 visually impaired individuals*."

Considering these figures, we can state that visual impairment is a global problem in our society. We cannot forget this when we design buildings or think solutions to satisfy needs: it is a major problem that has to be taken into account in every step we take as engineers and designers.

3.5 Persona

According to Adlin and Pruitt [19], "*Personas are fictitious, specific, concrete representations of target users. Personas put a face on the user*."

Personas are a methodology to describe and gather characteristics of a target group. They represent real people and they are used along the design process to make users more real. When designing, designers often base scenarios and situations on people similar to themselves. The creation of these personas allows the designers to keep the distance and be more objective.

Adlin and Pruitt describe some specific rules about how to create and use personas during a designing process:

- "*Building personas from assumptions is good; building personas from data is much, much better.*
- *Personas are not documents. They are effective only if they seem to be alive.*
- *Personas are a highly memorable, inherently usable communication tool if they are communicated well.*"

The findings from the user research described in sections 3.1, 3.2 and 3.3 are reflected by our persona (see below).

3.5.1 Profile and description

- Name: Tereza
- Age: 46
- Gender: Female
- Category of visual impairment (1-5): 5
- Time: L (Later blindness)
- Address: Prague

Tereza is a 46 years old lady who works as a university professor. She is living in Prague, where she moved when she started losing her sight since there is a much greater support for blind people in big cities than in small towns.

Tereza loves going to the library and, if the weather is nice, she likes to go for a walk. Normally, she does not travel with assistant, because she feels better when she is independent of other people (P1-Q1)[4]. She uses a white cane to help herself moving around and, if needed, she does not mind to ask passers-by for help (P1/2/3-Q1). When she tries a way for the first time, she plans it carefully: firstly, she searches the nearest bus stop to her destination and then she finds the appropriate bus connection on the internet (P2-Q1). Usually she arranges somebody to describe her the way using Google Street View (P2-Q1). Once she is on her way she uses orientation points and guidelines to orientate herself. The most common guidelines are walls or curbs. Open spaces are challenging for her due to the lack of these orientation guidelines (P1-Q7). When going anywhere, she always takes her special transmitter for blind people with her (P1-Q1). It helps her to find out the number of tram or bus that arrived, to open the doors of public transport vehicles, to activate acoustic beacons and get some information from public buildings, etc.

Last week Tereza went to the doctor, who told her that she must go to the hospital for an examination. When going to the hospital, Tereza always needs to ask somebody to accompany her (P1/2/3-Q1). She would prefer going alone, but it is too challenging for her to remember such a complicated way inside the building. Furthermore, this problem is more serious in very large hospital complex consisting of several buildings. Tereza had to visit the hospital alone once. She had to ask the hospital staff for help. Unfortunately, they didn’t know really well how to orientate or guide her properly. When she finally reached the waiting room, she asked some other patient to find a free seat for her and to let her know when her turn was. After visiting the doctor, Tereza set the next appointment with the nurse. Tereza also asked the nurse the to guide her out of the hospital building.

[4] “P1-Q1” means that this characteristic is based on the answer the first participant gave to the first question (appendix A).

3.6 User needs

According to the findings, our persona and the situations she may experience, we are ready to list those user needs that can be technologically solved.

3.6.1 VIP needs

1. To know the waiting time and when their turn is. (P1/2/3-Q2)[5]
2. To find a free seat in the waiting room. (P3-Q3)
3. To ask for directions. (P2-Q8)
4. To ask for assistance.
5. To choose among different languages.
6. To choose how the information is displayed. (P1/2/3-Q5)

3.6.2 Hospital staff needs

7. To know that a VIP arrived to the waiting room. (P1-Q8, What we know #17)[6]
8. To know that a VIP is lost and to find them. (What we know #16)
9. To know that a VIP needs help.
10. To know that a VIP has been attended.

3.7 Conclusions

The goal of this chapter was to gather all the user research in order to analyse the problem and be able to state the user needs. We started by analysing the main Prague's hospital and we understood that is has several navigation issues even for not VI users. The main finding there is that waiting rooms are generally not VI user-friendly at all due to its lack of an adapted presentation of information. After that, we interviewed three users and we found out how VI feel when they visit a hospital. We discovered that they normally need somebody to accompany them even though they don't like this dependency. They are specially concerned about what to do when they arrive to the waiting room because there is not a defined protocol. These and some more findings were shared with two other researchers who have held user research. And finally, all this knowledge added to some statistical data was put together into the creation of Tereza, our persona, and the subsequent user needs determination. In this way, the user research concludes and we are ready to start the designing process in the following chapters.

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[5] "P1/2/3-Q2" means that this user need is based on the answer all three participants gave to the second question (appendix A).

[6] "What we know #17" means that this user need is based on the knowledge arisen from the Experience map session (section 3.3).

Part II: Design

The second part of our project is the design. This is the creative part of the work, in which the engineer has to think about a solution able to fulfil the needs of the users. We have to start by imagining all the possible situations a user can face in order to state their needs. After that, we are going to propose a proper solution to them in order to be tested afterwards. This part is divided in two chapters. The first one defines and analyses the different scenarios that a user can experience. The second chapter is about the conceptual solution we propose to satisfy the requirements arose from the user needs.

Chapter 4: Scenarios and HTA

In the previous chapter, we studied the users from our target group and defined a persona (Tereza) who gathers the main characteristics of the participants. The aim of this chapter is to put Tereza in all the possible situations she might face when visiting the hospital and, from that, understand her needs.

4.1 Scenarios

According to Hsia et al. [20] "*scenario analysis is the process of understanding, analyzing, and describing system behavior in tens of particular ways the system is expected to be used*." We define scenarios in order to picture all the situations that could happen in the studied environment. Our persona, Tereza, will be placed in the described scenarios to find out the necessities our system can satisfy. All the scenarios have a common start point which is explained below and a scenarios diagram can be found at the end of this section (Figure 19).

Today, Tereza has an appointment with a specialist at the hospital. Normally, she goes to the hospital with her brother, but today he couldn't accompany her.

Before her visit, Tereza prepares it using the website application of the hospital. On it, she can make an appointment so the system will know when and where her scheduled visit is. After arriving, she checks-in using her insurance card at the main entrance kiosk. The system scans her face and links her face to her profile. Thanks to the website application, the system knows her needs and her scheduled visits, so the navigation process to the waiting room can start. Since the system knows that Tereza is blind, it will display the information through the speakers.

4.1.1 Scenario 1: Tereza feels lost

Tereza feels confused because she is not able to remember the directions she was following. At this moment, she is not sure whether she has to turn left or right. Luckily, she remembers that any kiosk in a waiting room of the hospital can help her to find her way. Using her white cane, Tereza is able to follow the floor guidelines to the nearest waiting room kiosk. The system recognizes her immediately and she can ask for **directions again (S1.1)** or **assistance (S1.2)**.

Sub-scenario 1.1: Tereza asks for directions

Tereza feels helped enough by hearing the directions once more, so she asks the system to recalculate her way and provide the new directions. After hearing the instructions again, Tereza feels comfortable enough to keep on going and, following the directions, she **arrives to the waiting room (S5)**.

Sub-scenario 1.2: Tereza requires assistance

Tereza needs assistance, so the system informs the hospital staff about Tereza's situation and her location. After receiving the alert, one of the available members of the hospital staff marks it as "alert attended" and goes to find and help Tereza. After helping her to **find the waiting room (S5)**, the member of the hospital staff marks the alert as “solved”.

4.1.2 Scenario 2: Tereza doesn’t arrive within the expected time

After a pre-set timeout, the system detects that Tereza didn’t arrive to the next kiosk or the waiting room when expected. Then, it alerts the hospital staff and, by using the system cameras, a member of the staff can look for Tereza around her last confirmed location. If needed, someone can be sent to this last position in which Tereza was detected by facial recognition.

Sub-scenario 2.1: Tereza is delayed

While Tereza was following the directions, she receives a phone call. She stops and picks up the phone. Since she knows that it is quite early for her scheduled visit, she has time to answer and talk calmly with the friend who is calling her. Using the system cameras, a member of the staff looks for Tereza around her last location and checks out that she is there, using her phone normally. Therefore, the nurse marks the alert as “solved”. Lately, when Tereza finishes the call, she continues her way normally to **the waiting room (S5)**.

Sub-scenario 2.2: Tereza “disappeared”

Tereza felt a bit sick on her way to the waiting room and she decided to go to the toilet. Although the member of the hospital staff looks for her using the cameras, they are not able to find Tereza. Therefore, a member of the staff is sent to her last confirmed position to start the search there, always guided by a staff member behind the cameras. After a few minutes, they assume that Tereza must be in the restroom because she hasn’t appeared anywhere else detected by the facial recognition cameras. After a few more minutes, they decide to go inside the restroom and ask whether Tereza needs assistance. They find Tereza a bit dizzy, standing next to the wall. They offer their help and accompany her to the emergency room in order to be treated.

Sub-scenario 2.3: Tereza left unexpectedly

While Tereza was following the directions, she receives a phone call. She stops and picks up the phone. Her brother is calling her because of an unexpected emergency. Tereza must leave the hospital and go to find him. She doesn't even have time to check out at the main entrance kiosk, so she leaves the hospital without informing about her departure. The hospital staff is not able to find her using the cameras, so they call her to her mobile phone to ask whether she left definitely or not. Tereza feels better being asked and she is happy to explain that she left because of an emergency. Furthermore, she can reschedule her appointment with the doctor.

4.1.3 Scenario 3: Tereza goes to the wrong waiting room

When Tereza is following the directions, she misunderstands one of the indications and goes to the wrong floor. Finally, she arrives to a waiting room which is not the one that she needed. Following the guidelines on the floor, she is able to place herself in front of the waiting room kiosk. The system detects that she is in the wrong place and alerts her with an audio warning. Then, Tereza has the option to **get new directions (S3.1)** to the correct destination or to call someone from the hospital staff and **ask for help (S3.2)**.

Sub-scenario 3.1: Tereza requires assistance

Same as sub-scenario 1.2.

Sub-scenario 3.2: Tereza asks for directions

Same as sub-scenario 1.1.

4.1.4 Scenario 4: Tereza wants to leave

Same as sub-scenario 5.2.

4.1.5 Scenario 5: Tereza goes to the correct waiting room

Tereza follows the directions provided by the system and arrives to the waiting room normally. Then she goes to the waiting room kiosk and the system detects that she arrived to the right place. The system tells her the estimated waiting time. It also informs the nurse that a visual impaired person arrived to the waiting room. After that, the system asks Tereza whether she needs assistance to find a free seat or not. Since there is nobody nearby and the waiting time is a lot, Tereza decides to ask for help. The system activates an audio beacon from the set of reserved seats in order to guide Tereza to the free seat. Tereza follows the beacon alarm and finds the seat ready to wait. When Tereza's turn arrives, the system informs about it out loud, not only on the screens.

After the visit, Tereza exits the doctor’s office and follows the guidelines until the kiosk in the waiting room. Then, the system offers to guide her to some **specific locations** such as the hospital pharmacy **(sub-scenario 5.1)** or to **the exit (sub-scenario 5.2)**.

Sub-scenario 5.1: Tereza wants to go somewhere else

Since the doctor prescribed her some medicines, Tereza decides to visit the hospital pharmacy before leaving. She chooses this specific option from the list and the system starts guiding her to the pharmacy. She follows the directions until her destination, buys the medicines she needs, and **leaves the pharmacy (sub-scenario 5.2)**.

Sub-scenario 5.2: Tereza leaves the hospital after the visit

Tereza wants to leave the hospital and go home, so she chooses this option from the list and follows directions until the exit. After passing by the main entrance kiosk, the system detects that she left and stops tracking her.

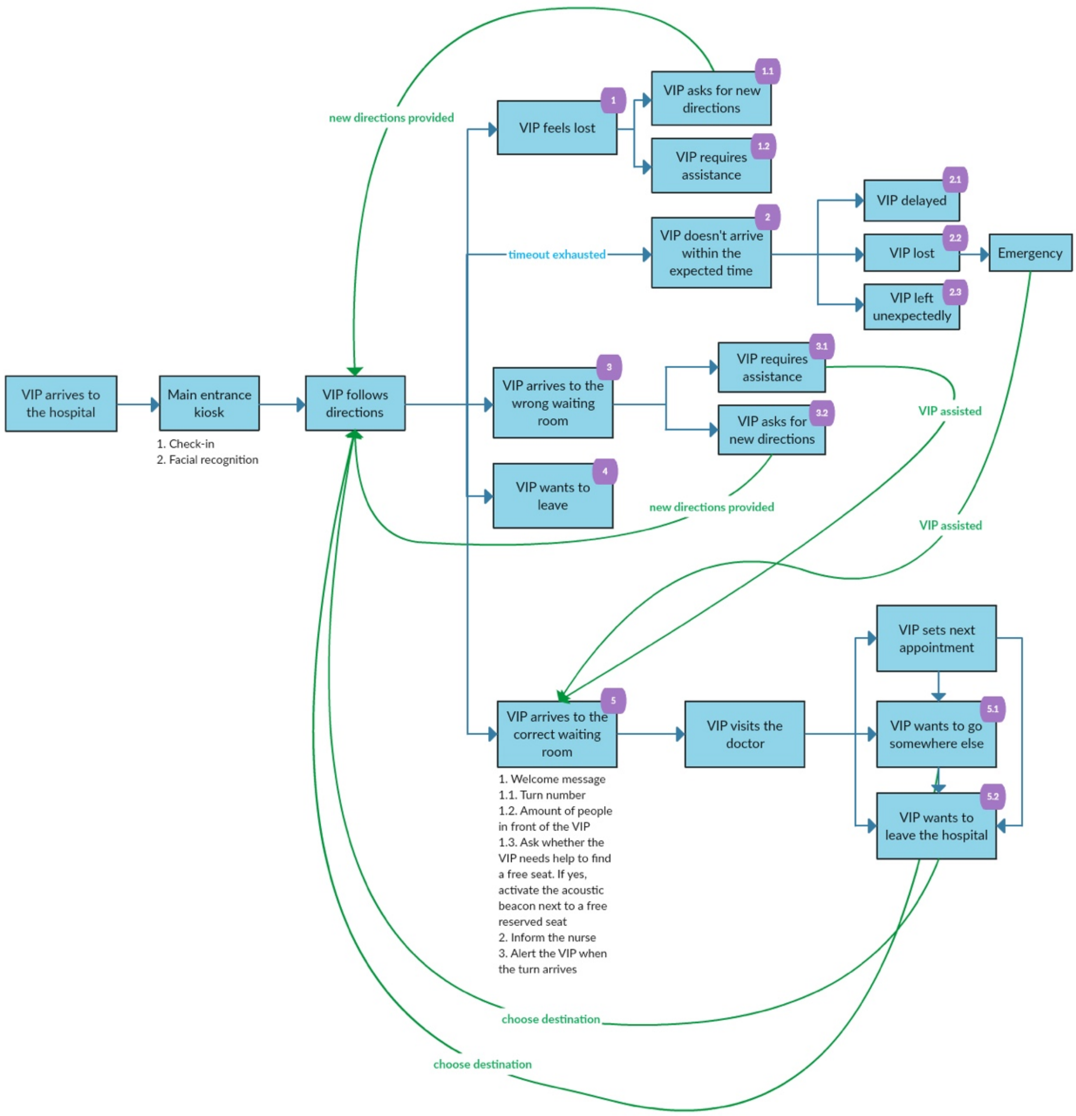

Figure 19: Scenarios diagram

4.2 Hierarchical task analysis

Hierarchical task analysis (HTA) is a task description method. According to Stanton et al. [21], "*HTA is used to produce an exhaustive description of tasks in a hierarchical structure of goals, sub-goals, operations and plans*".

In our case, the main goal of the HTA (Figure 20) is to provide a quality hospital experience. Particularly, we have to focus on the waiting room part of the visit. Nevertheless, it is quite useful to have a whole picture of the process.

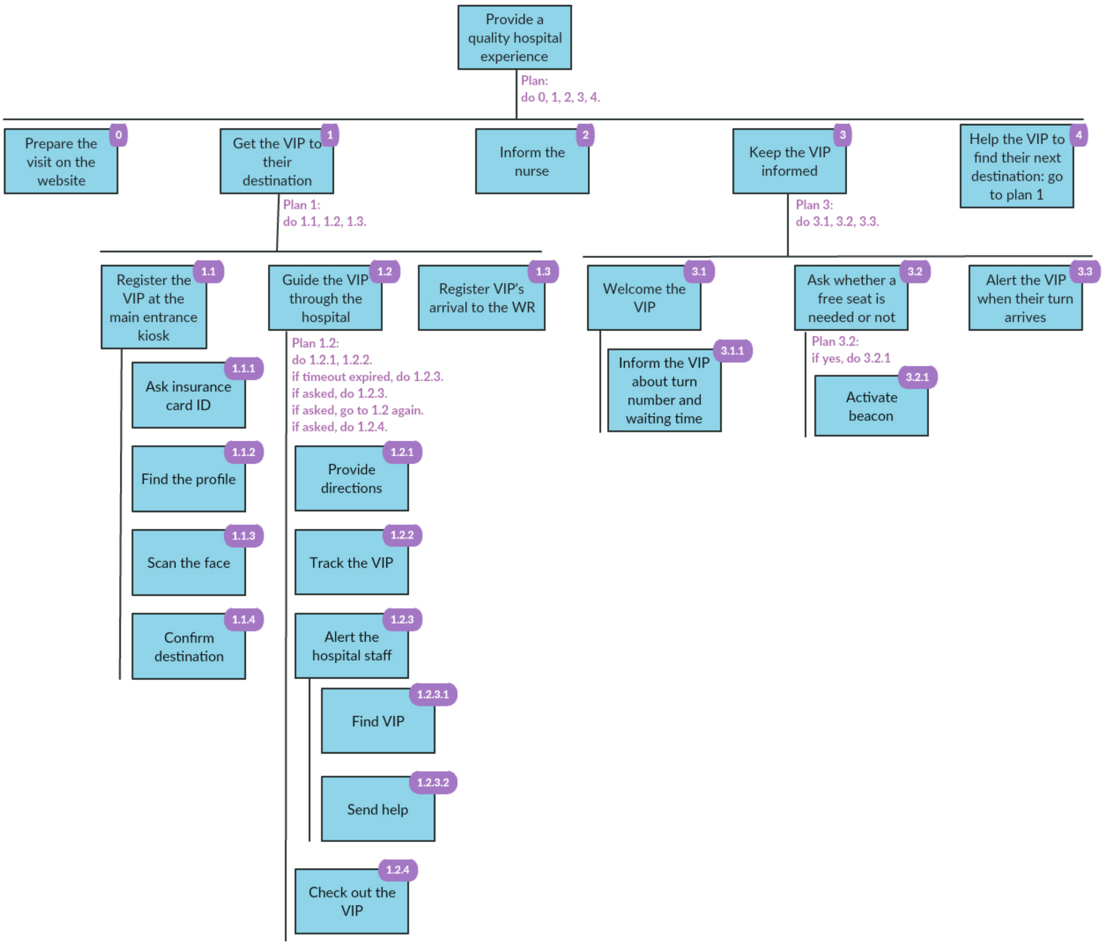

Figure 20: HTA diagram

By following the different vertical paths of the HTA diagram, we can determine the set of individual actions (called plans) that the system should perform in order to achieve specific goals.

4.3 Conclusions

The goal of this chapter was to figure out and understand the range of situations in which the system has to operate. Tereza, our persona, has been imagined in a wide variety of scenarios in order to determine the exact features the solution should have. This could be considered the first design step of the solution: it is a well-defined and justified collection of steps that the system has to be able to accomplish in order to fulfil our user's needs. Basically, as we can read in the HTA diagram, the system we are designing should perform three main actions: keep VIPs informed about their turn number and waiting time, inform the nurse about their arrival to the waiting room and help them to navigate to new destinations if required. These actions can be split into several smaller steps that, when taken into account, will define entirely the system: the next chapter will start by stating the requirements arisen from these scenarios and the subsequent HTA diagram.

Chapter 5: Solution design

The previous chapters 2 and 3 formed the analytical part of the engineering process. They allow us to diagnose the problem and understand the needs our system should satisfy. In this chapter, the aim is to propose a suitable technological solution for the diagnosed problem. The solution has to fulfil some requirements which were obtained from the user study. After these requirements are defined, the designing process can start.

5.1 Requirements

The requirements of a system are those characteristics the system must fulfil in order to perform properly. These requirements can be divided into functional and non-functional ones.

5.1.1 Functional requirements

According to the software management multinational company ReQtest [22], "*A functional requirement describes what a system should do, that is to describe the behaviour of the system as it relates to its functionality*."

1. Waiting room kiosk

a) To identify people.
b) To guide a VIP until the kiosk.
c) To provide information about the calculated average waiting time.
d) To detect whether a patient is in the correct waiting room or not.
e) To provide descriptions of the way to specific locations.
f) To help a VIP to find a free seat if required.
g) To inform the hospital staff device when a VIP arrives to the waiting room.
h) To inform the hospital staff device when a VIP doesn't arrive to the waiting room when expected.
i) To inform the hospital staff device when a VIP requires assistance.

2. Waiting room seats

a) To reserve some seats for patients with special needs.
b) To detect whether a seat is free or not.
c) To guide a VIP to a free seat if required.

3. Directional kiosk

a) To guide a VIP until the waiting room/specific doctor's office.
b) To identify people.
c) To guide a VIP until the kiosk.
d) To detect when a VIP is lost or in the wrong way.

e) To inform the hospital staff device when a VIP is lost or in the wrong way.
f) To inform the hospital staff device when a VIP requires assistance.

4. Hospital staff device

a) To receive the alerts from the kiosks.
b) To inform the hospital staff about the alerts.
c) To send information to the system.

5.1.2 Non-functional requirements

On the other hand, ReQtest [22] states that "*a non-functional requirement describes how the system will do what it is supposed to do*."

1. Waiting room kiosk

a) To use facial recognition to identify a person.
b) To provide the information in different languages.
c) To provide audio information.
d) To provide hygienic interaction.
e) To activate a beacon in order to guide a VIP until the kiosk.

2. Waiting room seats

a) To activate a beacon in order to guide a VIP until a free seat, if required.

3. Directional kiosk

a) To use facial recognition to identify a person.

4. Hospital staff device

There are no non-functional requirements for the hospital staff device since it is not the aim of this thesis to explain how should it be designed and implemented.

5.2 Initial design (low-fidelity prototype)

The initial design is, as its name indicates, the first step in the designing process. The low-fidelity (lo-fi) prototypes are a good way to begin with this process. According to Egger [23], they are characterised by "*a quick and easy translation of high-level design concepts into tangible and testable artefacts*." Egger also states that "*A clear advantage of lo-fi prototyping is its extremely low cost and the fact that non-programmers can actively be part of the idea-crystallisation process*." Therefore, a low-fi prototype permits basic ideas to be studied in a simple, quick and cheap way. Thus, the designer is able to easily test the prototype throughout the process and change those features that must be improved.

Balsamiq Mockups is a program that substitutes paper and pencil when it comes to draw schematically the lo-fi prototypes. And it is also the tool we chose to present the different screenshots of the kiosk.

5.2.1 Waiting room kiosk

The main functions of the waiting room kiosk are to detect the VIP's arrival and keep them informed about the waiting time and the turn number. It has a camera that scans the VIP's face and links it to the temporary profile created after their check-in at the main entrance kiosk. In this way, the system knows that the VIP arrived to the waiting room and informs the hospital staff about it.

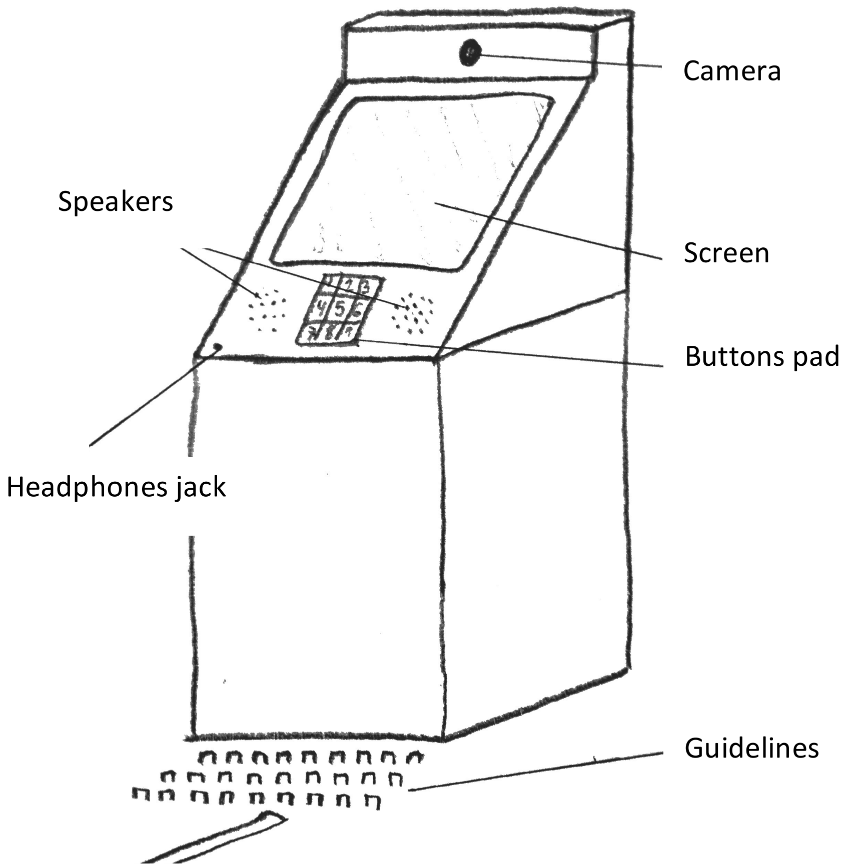

Figure 21: Sketch of waiting room kiosk

Parts:

Camera

Function: facial recognition and observing areas if needed.

Description: the camera has to scan the patient's face in order to identify them. It is located on the top of the kiosk. In addition to this main use, the cameras of the kiosks can be used by specialised members from the hospital staff in order to, for example, search for lost patients.

Button pad

Function: information input.

Description: the buttons are the only information input source of the kiosk (Figure 22). It is similar to a phone button pad, formed by ten keys with the numbers from 1 to 9 and three special keys named *Time* (which reads out loud the current time), *Repeat* (which repeats the options displayed on the screen) and *Emergency* (which alerts somebody from the hospital staff). All the buttons are labelled with a braille sign. Hygiene of this pad is a matter of concern, but alternatives like voice input are not realistic in a hospital environment. The hospital cleaning staff has to be trained to become especially conscious about the hygienic conditions of the kiosk.

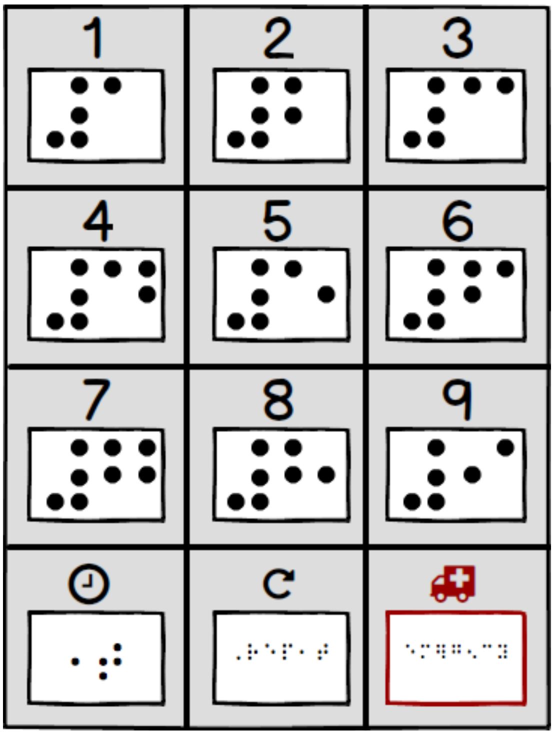

Figure 22: WR kiosk, Button pad

Screen

Function: information output.

Description: the screen is the main interaction device of the kiosk. It has to provide visual information about the whole range of options the patient has. All the options must be linked to one of the buttons of the pad (Figure 22) in order to be selected.

The system knows that the patient is a VIP since their registration at the main entrance kiosk. Therefore, if the patient is a VIP, the options on the screen are read out lout through the speakers and repeated after a defined timeout.

In order to prevent the system to be abandoned in a specific screen option, the system goes back to the *Main menu* screen (Figure 25) after another defined timeout.

A detailed description of all the options and paths a user can find on the screen can be found below. The design of these menus takes into account all the user research done and the considered scenarios. It is worth saying that the following screenshots are not the very first version of the design: since this is an iterative process, the “initial” design includes some of the main findings from the evaluation session of the lo-fi prototype (section 7.2).

The stand by state of the kiosk is a screen that informs about the department and asks the users to place their face properly in front of the kiosk in order to proceed with the facial recognition (Figure 23).

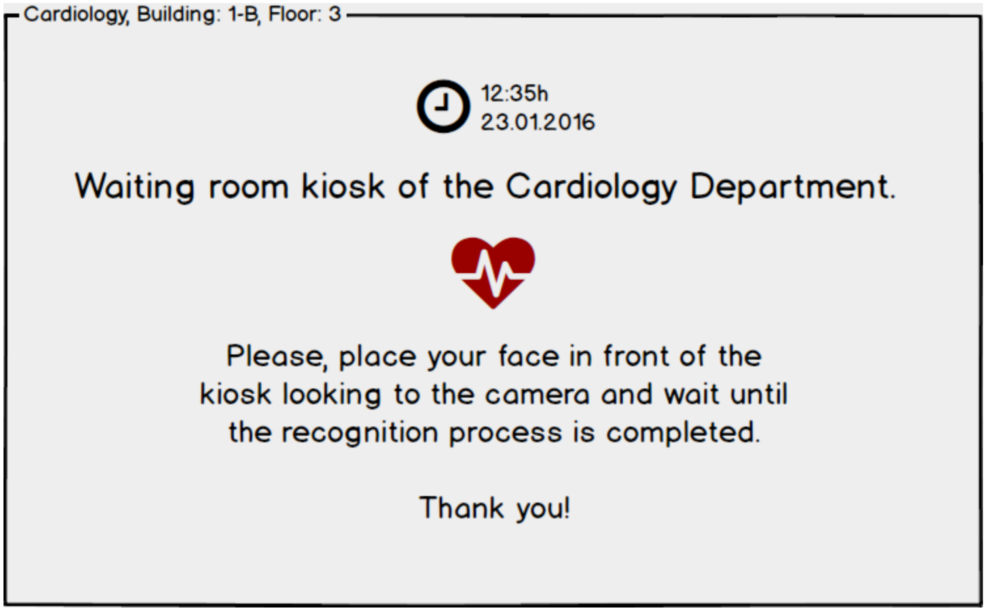

Figure 23: WR kiosk, *Stand by* screen

When the user faces the kiosk camera, the face recognition starts. While the process is being done, the system shows a loading screen (Figure 24).

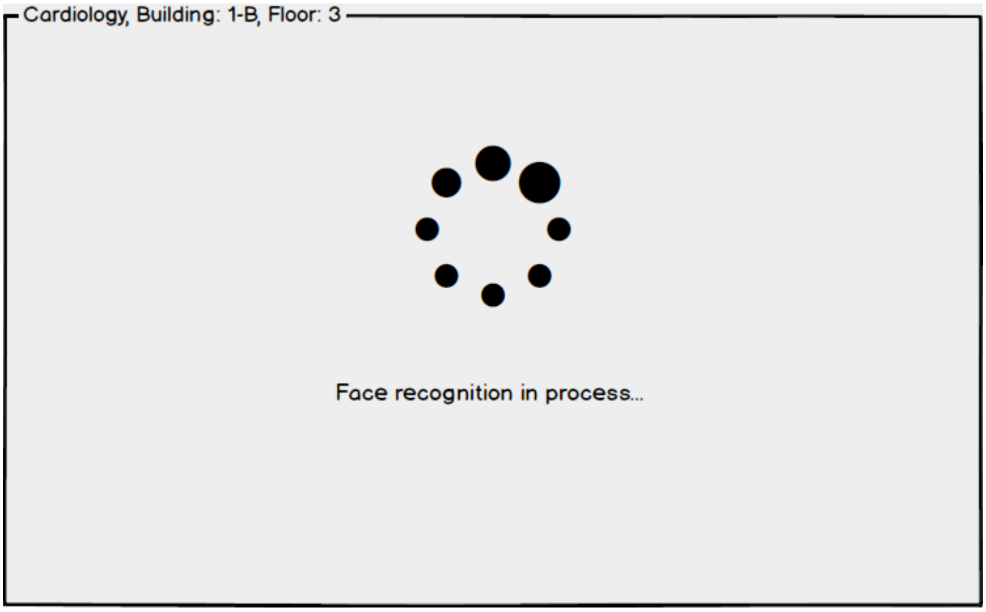

Figure 24: WR kiosk, loading screen

Once the face recognition is completed, the system shows the *Main menu* screen (Figure 25). On the left upper side of this screen, information about the location of the kiosk can be read. Here, the users are welcomed and informed about their turn number, an estimated waiting time and the office and doctor that they have to visit. After this information is transmitted, the system notifies the users that they are going to be informed when their turn arrives. In the case of the VIP, this informing process is done by saying the turn number out loud and activating an acoustic beacon on the top of the assigned office's door.
Finally, the user can simply leave to the waiting room seats or choose among six options: *1. Repeat information, 2. Find a free seat, 3. Where am I?*, *4. Navigate to a new destination, 5. Change the language* and *6. Require assistance*.
The *Repeat options* button is a common option throughout all the screens. It makes the system to read again all the options from the menu through the speakers.
The *1. Repeat information* option makes the system to read again the information displayed on the screen through the speakers.

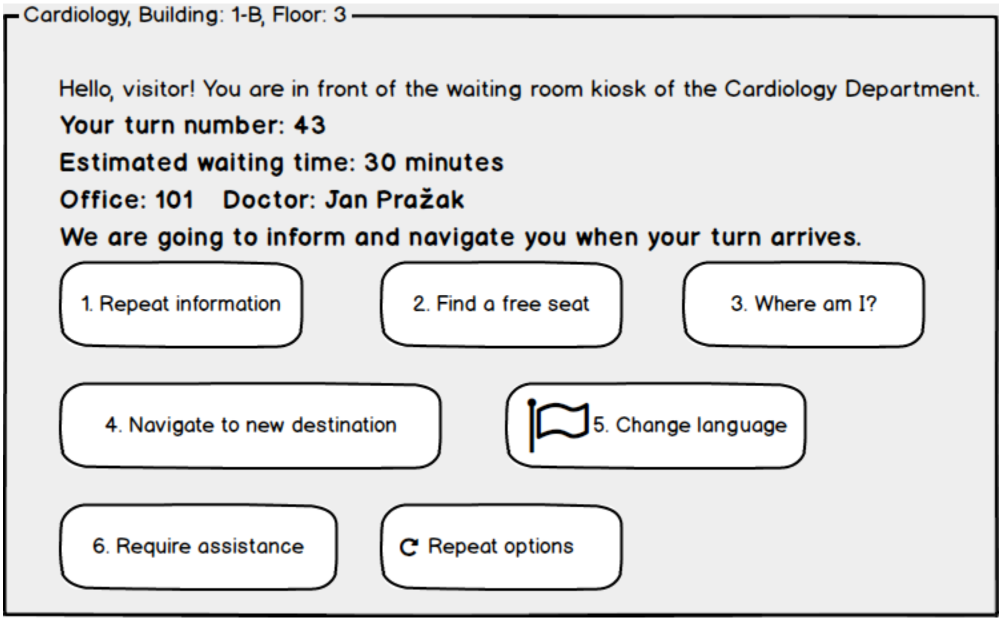

Figure 25: WR kiosk, *Main menu* screen

The *2. Find a free seat* option helps the user to find a free seat, and it is only available if the user is a VIP. As explained in the next section (5.2.2 Waiting room seats), the solution includes keeping some reserved seats of the waiting room for those patients who may need them. The system asks the VIPs whether they want help in order to find a free seat or not (Figure 26).

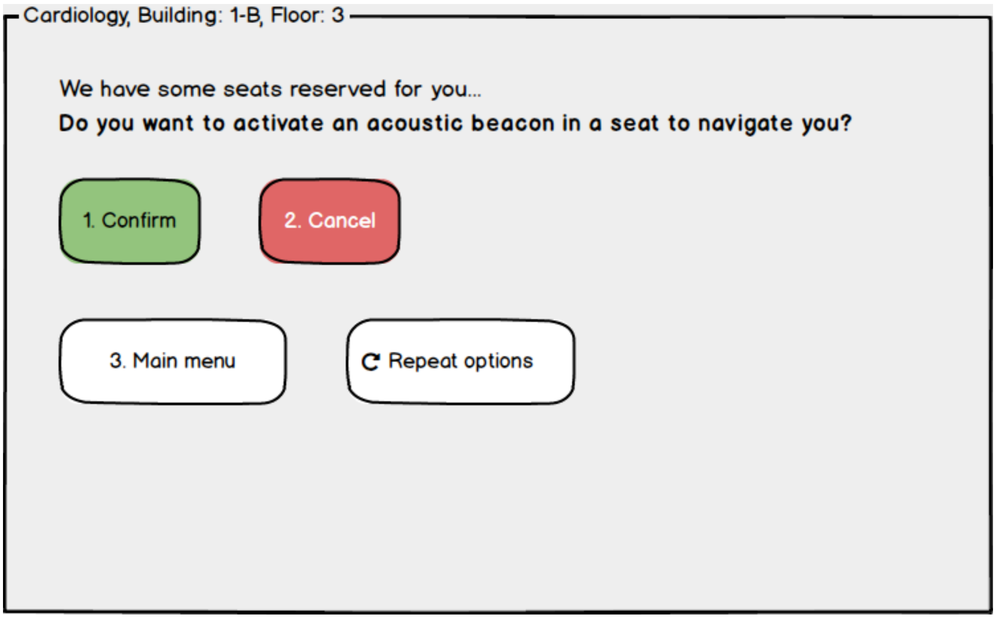

Figure 26: WR kiosk, *Find a free seat* screen

If the user confirms the help request, a pop-up alert informs them about the activation of the acoustic beacon on the reserved seats (Figure 27). If the user cancels, presses the *3. Main menu* option or the predefined timeout expires, the system goes back to the *Main menu* screen (Figure 25).

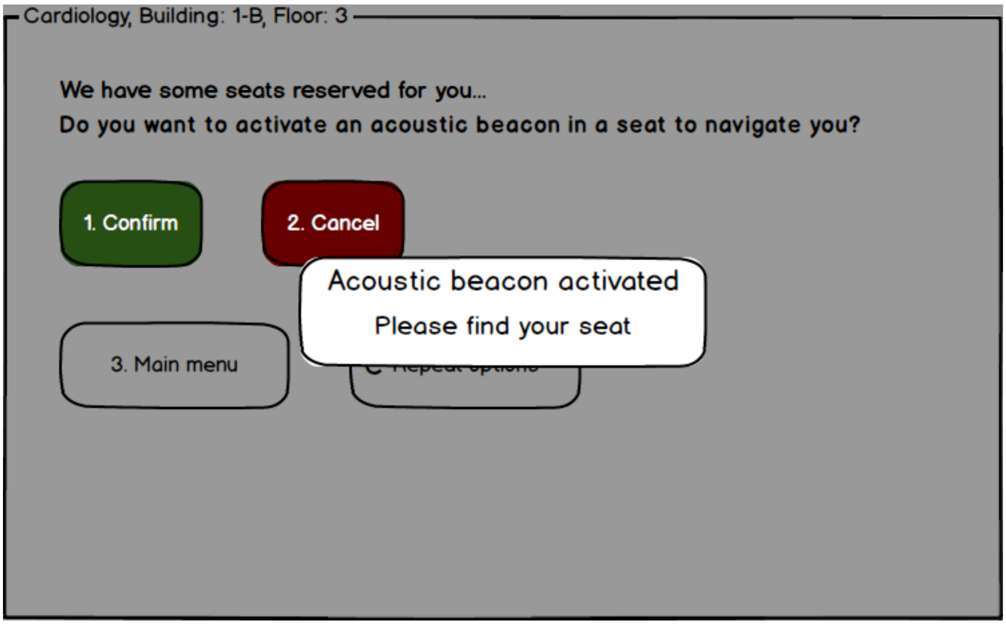

Figure 27: WR kiosk, *Acoustic beacon activated* pop-up

The *3. Where am I?* option of the main menu explains the location of the kiosk to the user (Figure 28). It shows a hospital map and a detailed description of the location. The options menu provides three alternatives: *1. Repeat information*, to make the system to read again the location through the speakers; *2. Main menu*, to go back to the *Main menu* screen (Figure 25); *2.* and *Repeat options* to make the system to read again all the options. As explained before, this last button is common in all the screens when the user is a VIP.

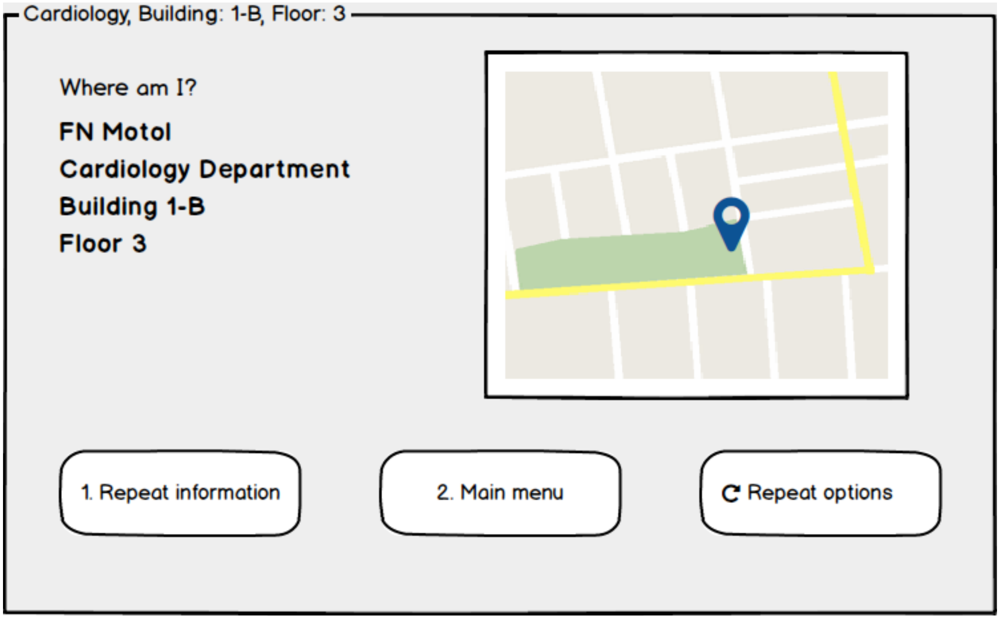

Figure 28: WR kiosk, *Where am I?* screen

The *4. Navigate to a new destination* option of the main menu allows the user to ask for directions to another place of the hospital such as the exit, the pharmacy, the cafeteria and others (Figure 29). It also allows the user to select another doctor's office if the visit is scheduled beforehand. In addition to that, this screen allows the user to go back to the *Main menu* screen (Figure 25) or to listen again to the options, as usual.

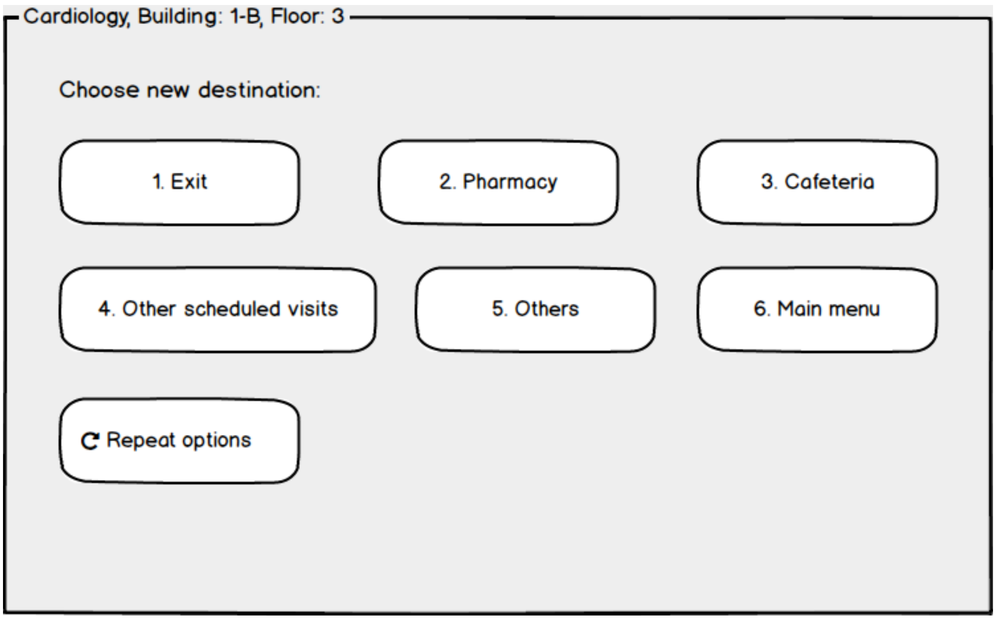

Figure 29: WR kiosk, *Navigate to a new destination* screen

When the user selects a predetermined option (exit, pharmacy, cafeteria, etc.), the system shows detailed information about the chosen destination and asks for confirmation to start the guiding process (Figure 30). It also provides the *4. General route audio description* option to listen to a general description of the selected route and the *5. Detailed audio description to next kiosk* option to listen to a detailed description of the way to the next kiosk of the route. In addition to that, the user has the usual options to go back to the *Main menu* screen (Figure 25) and to listen again to all the alternatives.

If the chosen destination is cancelled, the system goes back to the *Get new directions* screen (Figure 29).

On the other hand, if the user accepts the chosen destination, the system shows a screen with information about this destination and the location of the next directional kiosk on their way. It still offers the possibility to cancel the route and listen to the audio description of it again. After a predefined timeout, the system goes back to the *Stand by* screen (Figure 23).

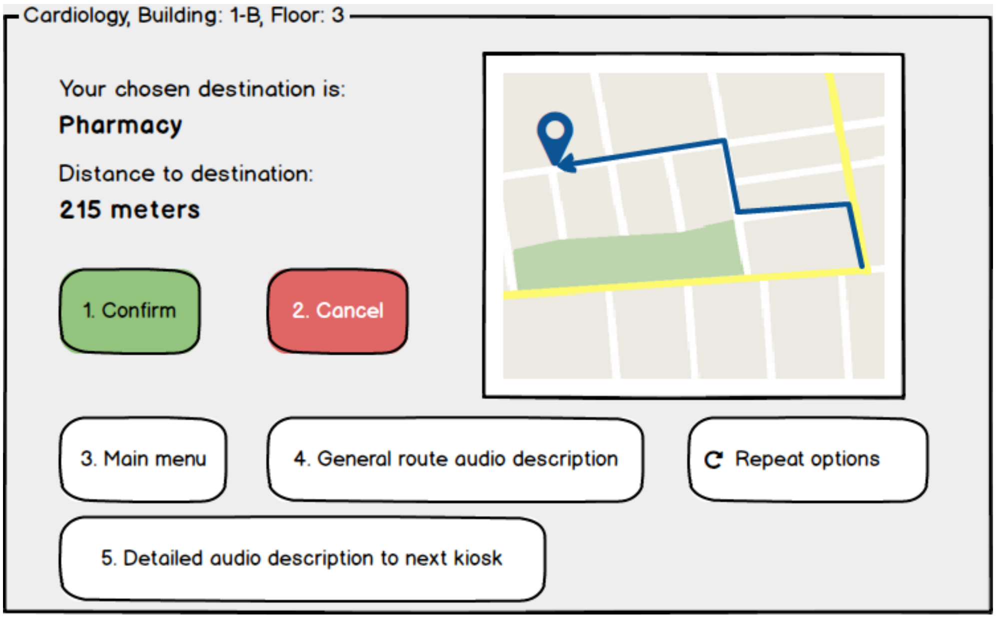

Figure 30: WR kiosk, *Predetermined new destination* screen

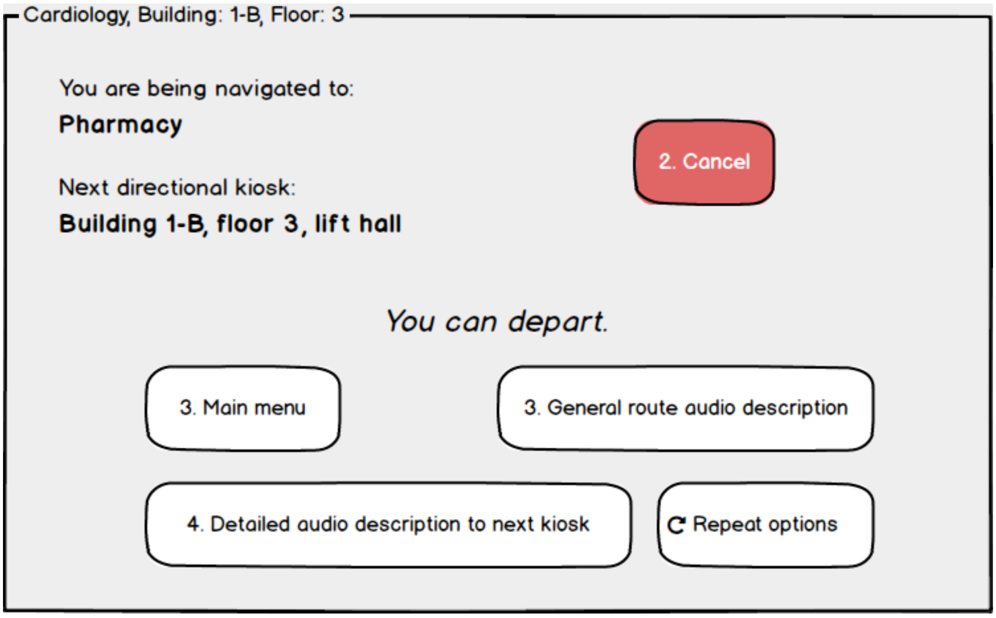

Figure 31: WR kiosk, *On your way* screen

When the user choses the option *4. Other scheduled visits* from the *Navigate to a new destination* screen (Figure 29), the system shows a list of all the appointments the user has for the present day (Figure 32). We assume that the user will not have more than 8 appointments, so the 9th button is reserved for going back to the *Main menu* screen (Figure 25) and the repeat button is reserved to listen to the options again, as usual. When the users select one of the visits, the system shows them the *On your way* screen as if they had selected a common destination like the pharmacy or the cafeteria (Figure 31).

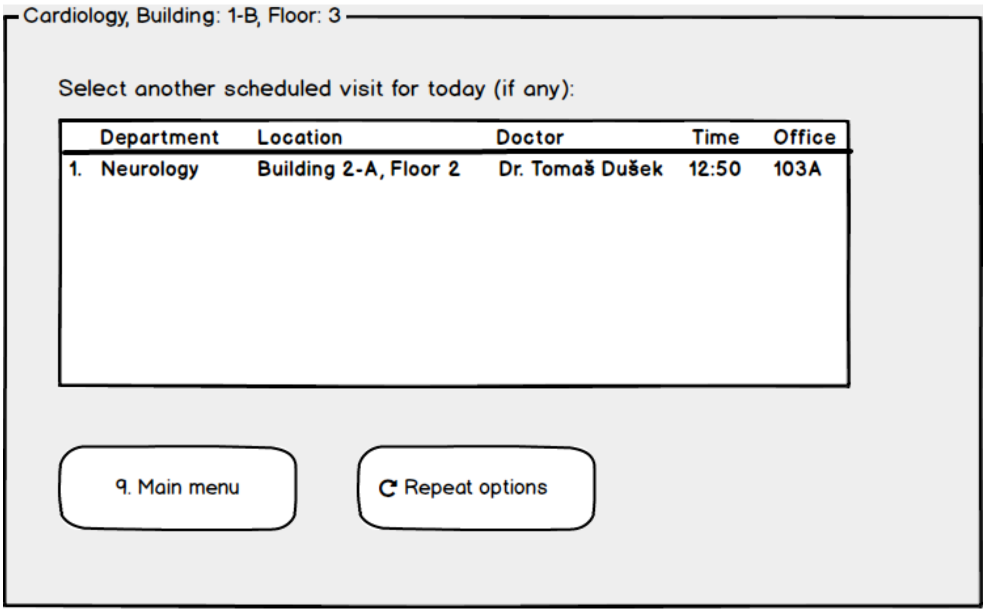

Figure 32: WR kiosk, *Scheduled visits* screen

The *5. Change language* option of the main menu allows the user to change the language of the system (Figure 33). As usual, it provides the alternatives to go back to the *Main menu* screen (Figure 25) or to listen to the options again.

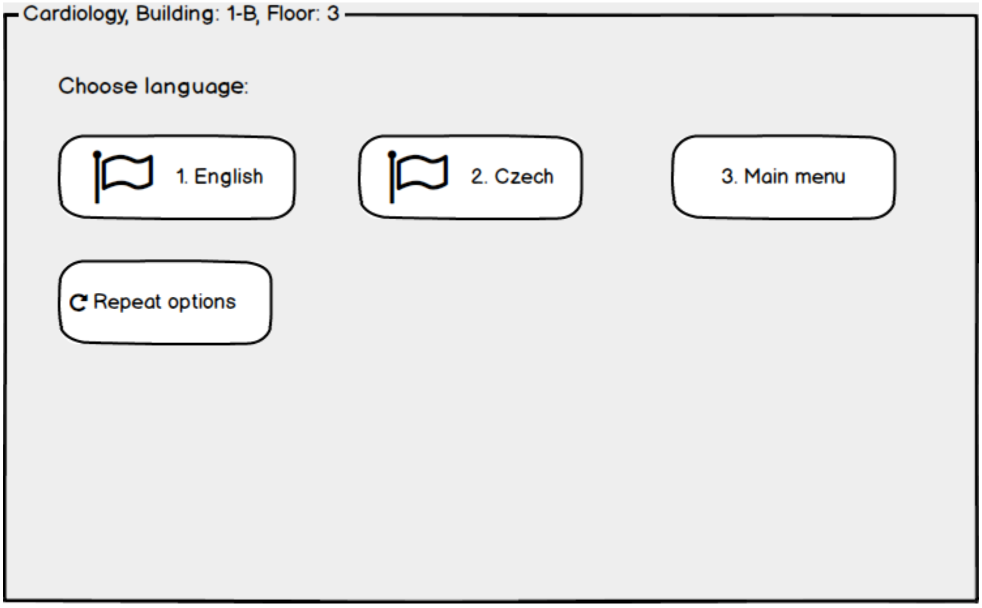

Figure 33: WR kiosk, *Choose language* screen

As soon as the user selects a language, the system shows a pop-up alerting that "the language has been changed". This message is already written in the new selected language and the user has the option to confirm or dismiss the change (Figure 34).

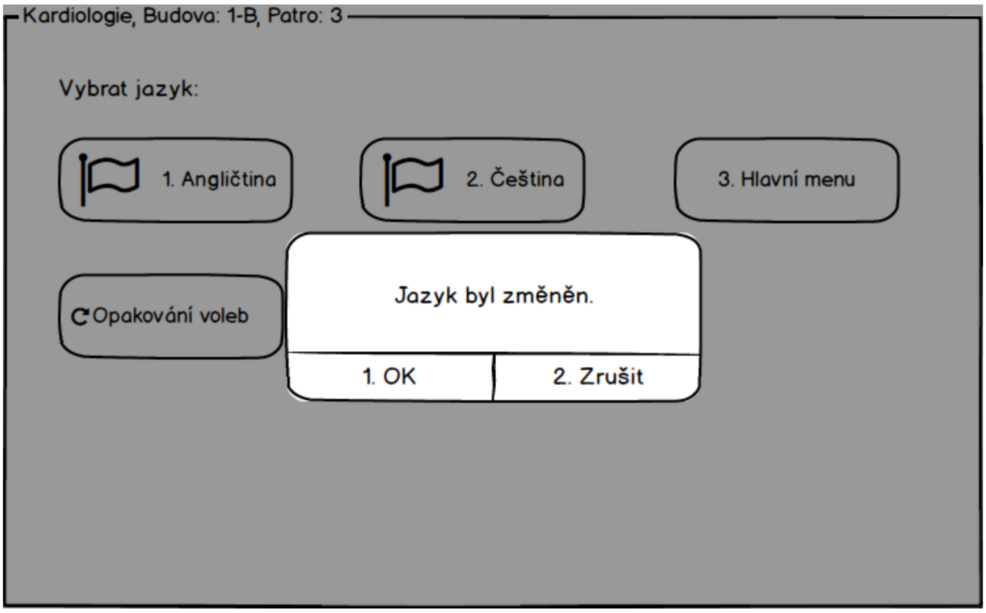

Figure 34: WR kiosk, *Language changed* pop-up (in Czech)

If the change is confirmed, the language of the whole system is changed (Figure 35).

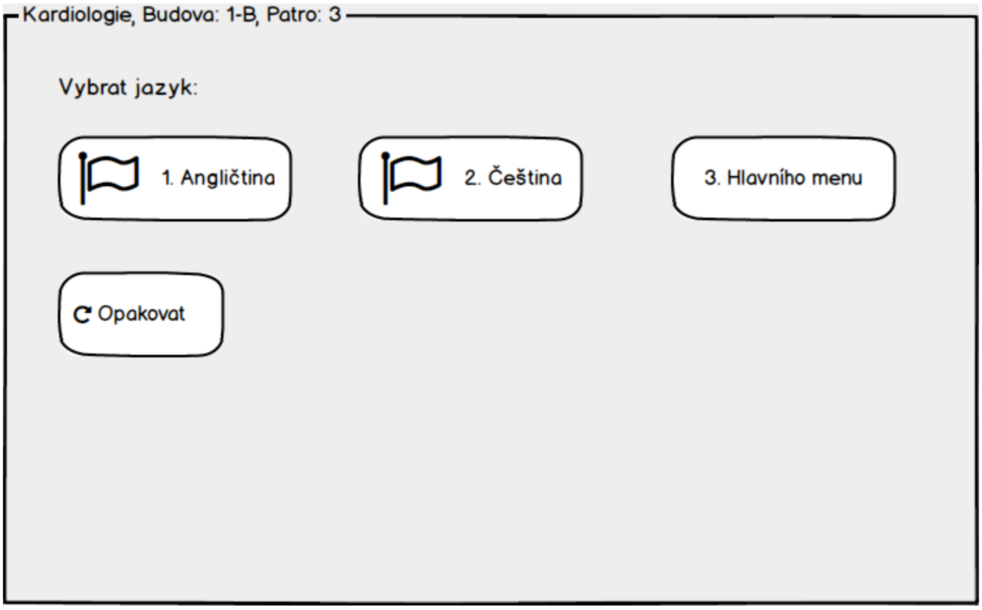

Figure 35: WR kiosk, *Choose language* screen in Czech

The *6. Require assistance* option of the main menu alerts someone from the hospital staff. Before launching the alert, the system asks for confirmation (Figure 36). As usual, it provides the alternatives to go back to the *Main menu* screen (Figure 25) or to listen to the options again.

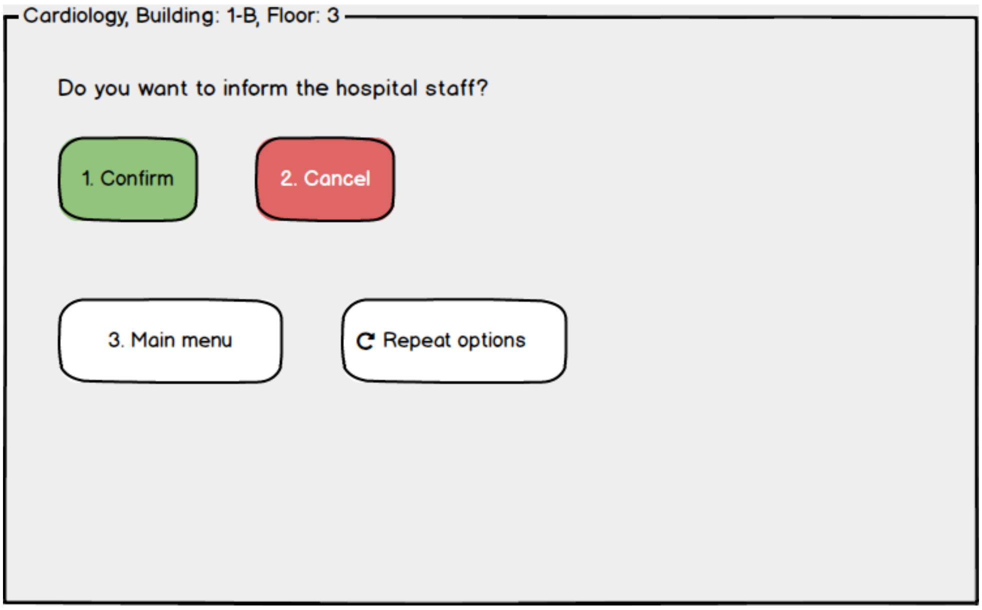

Figure 36: WR kiosk, *Require assistance* screen

If the user cancels the alert, the system goes back to the *Main menu* screen (Figure 25). On the other hand, if the user confirms the assistance request, the system alerts someone from the hospital staff and asks the user to wait for it with a pop-up (Figure 37).

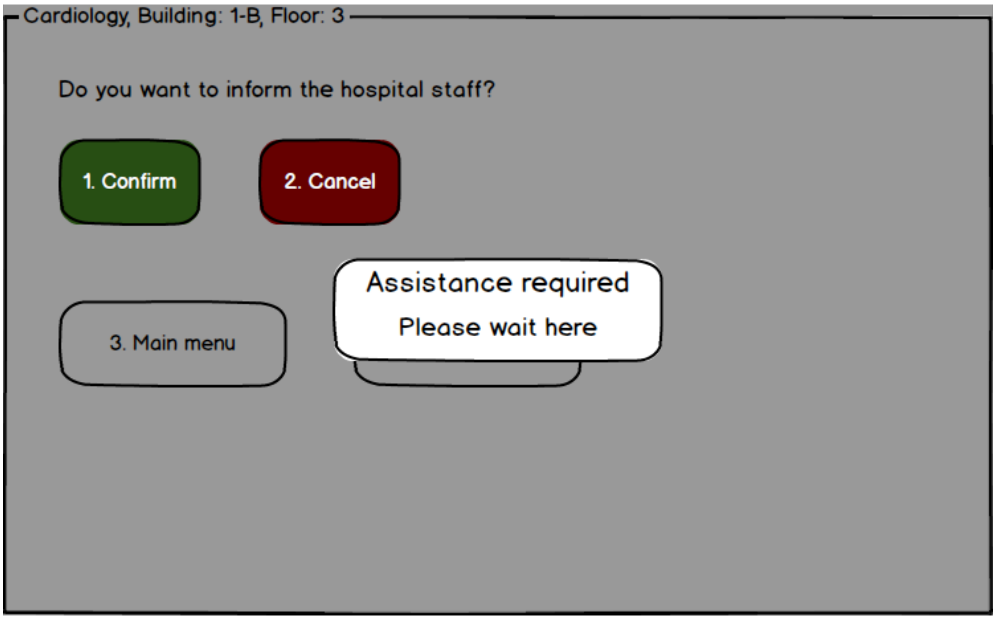

Figure 37: WR kiosk, *Assistance required* pop-up

We must consider that the patient might arrive to the wrong waiting room. If this happens, the *Main menu* screen (Figure 25) is slightly different (Figure 38). All the options are the same, but they are moved because of the inclusion of the *2. I am OK* option. This option exists to ensure that the human judgement is more reliable than the system's one: the system may say that the users are at the wrong waiting room when they are not because of an error or an unexpected change in the hospital's organization.

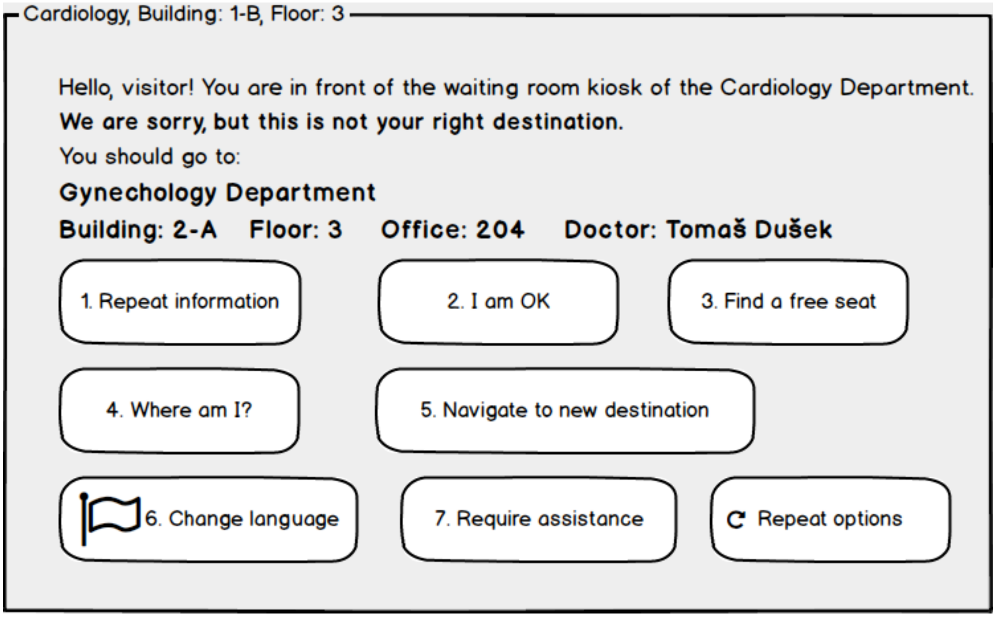

Figure 38: WR kiosk, *Wrong WR* screen

Speakers

Function: information output.

Description: the speakers are the way whereby the kiosk communicates information to the VIP. All the options from the screen are read out loud through the speakers. In order to prevent a wrong use of them, specially in a hospital, the volume is not adjustable by a user without headphones. Beside reading the options and the information from the screen, the speakers can be used as an acoustic beacon that may help a VIP to find the kiosk. This beacon is activated by the device that many VIP use to activate such acoustic beacons when approaching traffic lights or using public transport. The third use of the speakers is to inform out loud about the turn number displayed on the LEDs screen that informs visually about it. This last function is only activated when the turn number belongs to a VIP.

Computer

Function: system control.

Description: to describe the computer specifications is not the aim of a start design section, but it must be a computer able to perform satisfactorily all the requested functions.

Framework

Function: protection and structure.

Description: the external structure of the kiosk must be tall enough to place the camera in an average human height and hard enough to protect all the elements inside it. If the hospital buildings' organization is following a colour pattern, the kiosk framework should be painted according to it.

5.2.2 Waiting room seats

The proposed solution includes the reservation of some seats of the waiting room. The exact amount of reserved seats and their location may be different depending on the hospital characteristics. An acoustic beacon is placed in the area where these seats are. This acoustic beacon is activated by the options of the WR kiosk (Figure 27). In addition to this, the reserved seats must be easily identifiable by a special colour and written signs informing about it.

5.2.3 Directional kiosks

It is not an aim of this project to design the directional kiosks. Anyway, in order to preserve the coherence of the whole system, they should be similar to the waiting room kiosks but simpler.

5.2.4 Hospital staff device

The hospital staff members have a device which is able to receive and send alerts. In order to save money, this device can be an app in the member's personal smartphone connected to the Wi-Fi network of the hospital. The system sends a notification to the closest devices and the members from the hospital staff who receive it can attend or refuse the alert (Figure 39). In the "Details" box, some information about the alert such as the location or the problem the patient has is exposed.

Figure 39: Hospital staff device, *Alert notification* screen

When the alert is accepted, the system tracks the status of the alert. During this process, the hospital staff member has three options: indicate that the alert has been solved, ask for help from the cameras or declare an emergency (Figure 40). If the hospital staff member asks for help from the cameras, the app calls an operator with access to the cameras of the hospital for assistance.

Figure 40: Hospital staff device, *Alert status* screen

It is not the aim of this thesis to go further into the hospital staff device design because we do not have the option of testing it with real hospital staff members. Furthermore, the needs of these users may change from one hospital to another, according to their training and technological possibilities.

5.3 Conclusions

The aim of this chapter was to propose a suitable technological solution for the diagnosed problem. After the requirements were defined, the proper designing process started. The proposed solution takes into account those requirements and, therefore, we expect it to satisfy the user needs. The evaluation of this low-fidelity prototype can be found in section 7.2. Findings arisen from this evaluation are added to the initial requirements in order to implement the high-fidelity prototype that follows (chapter 6).

Part III: Implementation

The first part of the current work was about to study the users and the environment of the problem. The second part was about to propose a solution that solves properly the needs of the users found on the first part. Therefore, this third part is about to implement a prototype of the designed solution in order to test it with real users afterwards.

Chapter 6: Solution implementation

This chapter brings the initial design into a real prototype. The lo-fi prototype was just the design of the menus of the kiosk. The next logical step is to develop a usable implementation of those screenshots and options.

6.1 First implementation (high-fidelity prototype)

Egger [23] defines high-fidelity (hi-fi) prototypes as a "*high-tech representation of the design concepts, resulting in partial to complete functionality*." Its main advantage is that "*users can truly interact with the system, as opposed to the sometimes awkward facilitator-driven simulations found in lo-fi prototyping*." Hi-fi, however, "*implies higher costs* (…) *and necessitates good programming skills to implement the prototype*."

This section briefly explains the development of the hi-fi prototype, the technologies used and the implementation process.

6.1.1 Goal of the prototype

It is important to keep in mind the goal of the prototype during the process. Only this way we can prevent ourselves from spending too much time and resources on it. The main goal of the prototype is to simulate the system operation in order to be tested by VIPs. Therefore, the implementation of a visual user interface is unnecessary; it is better to focus on the text-to-speech issue. Moreover, since the solution is a part of a whole that will merge different fragments into a homogenous complex system, the programming language and even the code are not a matter of deep concern: they may be changed to adapt them to the whole system and the hospital needs and capabilities. If the prototype is able to perform properly when users go through menus and options with audio description, it will accomplish its mission and we will be ready to evaluate it.

6.1.2 Used technologies

Although we just explained why the used technologies should not concern us very much, it is important to explain which ones we chose and why we took them as a first choice. Two main decisions are going to be made in this section: the first one is about the programming language and environment; the second one is about the text-to-speech technology.

Programming language

Only two programming languages were considered as options since they are the ones that we are more used to: C++ and Java. Between them, Java seemed the best one considering the interactive goal of the prototype.

Text-to-speech technology

There are many text-to-speech technologies, but most of them are either web applications with no easy integration to a programmed code or not-free ones. The first option considered was FreeTTS [24] a speech synthesizer in Java by the Speech Integration Group of Sun Microsystems Laboratories. The main problem it has is that it does not provide a Czech language option (needed to test the prototype with real Czech VI users). Using MBROLA [25] a project initiated by the TCTS Lab of the Faculté Polytechnique de Mons (Belgium) to obtain a set of speech synthesizers for as many languages as possible, this language issue would be solved. The problem now is that MBROLA is a 10-years old project with no compatibility with the current operative system of our computers. The second option considered was the definitive one: MacOS X's text-to-speech feature. The code only needs to call the terminal and its "say" command. Even though this technology certainly has a compatibility problem with other operative systems, it is very easy to implement and it has a big range of different languages with an accurate pronunciation.

6.1.3 Implementation

This is a technical section that explains the most relevant methods of the programmed Java code. The main idea behind the code is simple: the code reads text from a set of files that contain the different menus and options texts, it shows the content on the screen and it reads it out loud by calling the "say" command.

ShowContent (file_path, language)

This method shows on screen some content from a text file specified by its path. The *language* variable affects directly the path name: the path can be /Users/user/KioskScreens/**eng**/file.txt for the English version or /Users/user/KioskScreens/**cz**/file.txt for the Czech version. This way, when a new language wants to be added to the system, it is enough to create a folder with that version of text files and change the variable *language*.

WhatToSay (file_path, language)

This method tells the terminal how and what to say out loud from a text file specified by its path. The *language* variable affects the path name like in the *ShowContent* function. The "say" command has two optional features that we use:

-v name_of_the_vocie: voice used to read. In our case, Victoria for the English version and Zuzana for the Czech one.

-f file_path: file containing the text to read.

Say (file_path, process, language)

This method launches a process that starts the command "say" and uses *WhatToSay* in order to choose what is going to be read out loud. It is worth to explain that the method destroys previous processes in order to prevent the program from overlapping audio messages when the user selects an option before the message is completely read.

6.2 Conclusions

The goal of this implementation was to perform like a real system when users go through menus and options. Even though the code is clearly improvable and its efficiency is not the best we could achieve, simplicity and accurate pronunciation are the remarkable features of the prototype. When tested by the programmer simulating scenarios, it performs properly and with no incidents: this is a good start point before the prototype is tested by real VI users.

Part IV: Evaluation

The evaluation is a crucial part of the engineering process. We started by studying the users and the environment, after that we designed a solution and finally we implemented it. This part focuses on evaluation of the implemented solution. Concretely, we focus on usability and accessibility evaluation with real users described in chapter 7. As far as the intended result was a high fidelity prototype, the source code of the implementation was not formally evaluated yet.

Chapter 7: Usability testing

The usability testing is the main part of the evaluation process. Its main goal is to find design problems. According to Nielsen [26], "*It is important to realise that usability is not a single, one-dimensional property of a user interface. Usability has multiple compliments and it is traditionally associated with these five usability attributes:*

- Learnability: The system should be easy to learn so that the user can rapidly start getting some work done with the system.
- Efficiency: The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.
- Memorability: The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.
- Errors: The system should have a low error rate, so that users make few errors during the use of the system, and so that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.
- Satisfaction: The system should be pleasant to use, so that users are subjectively satisfied when using it; they like it.

Only by defining the abstract concept of usability in terms of these more precise and measurable components can we arrive at an engineering discipline where usability is not just argued about but is systematically approached, improved, and evaluated."

There are many methodologies to test the usability and evaluate the validity of the prototype. The third lecture of the CTU's Department of Computer Graphics and Interaction subject "Testování webového rozhraní (Web Interface Testing)" [27] lists three different user-based methods:

- User surveys: Questionnaires with open-ended questions oriented towards expected usability problems. The pros of this method are that it is inexpensive and it can be done remotely. The cons are that it relies only on the data provided by the users and recruiting the right people is a problem due to self-selection bias.
- Ethnographic observations: Observing users in their environment, without any intervention. The observer stays with the users and watches them how they use the system. The pros of this method is that it is truly based on the reality. On the other hand, the cons are that it needs a thorough preparation, it is a not interactive method, it could have some ethical problems and it is expensive.
- Usability engineering: Observing the users using the system in a simulated environment where aspects of the real world are feigned. Users work on predefined, but realistic tasks while they are observed. The pros and the cons of this method are two faces of the same coin: if well prepared, the results of such a test are comparable to the results obtained from the "real-world observation". If not, since users are not in their natural environment, the results can be totally away from reality. Therefore, it is important to create lifelike tasks in a realistic environment and, if possible, to use real target users of the system.

After considering all three user-based methods and following the recommendations of the mentioned subject lecture, we decide to carry out a usability engineering test. The goals of the testing are:

- To find errors and minor mistakes in the designed prototype.
- To observe whether the users complete the assigned tasks or not.
- To listen to the users' feedback.

7.1 Tasks

All the users are asked to complete five tasks that cover the main situations that the system is going to face. Therefore, the system is tested in almost real conditions and it can be improved with the feedback from the users.

There is a common start (below) for all the tasks and then a specific description for each situation. The users hear the description from the interviewer and then they use the prototype in order to complete the task.

The common start goes like follows: imagine that you arrive to the waiting room after following the directions provided by the system. You follow the guidelines on the floor (or activate the kiosk beacon with your device) and place yourself in front of the waiting room kiosk. After a few seconds, your face is recognized and the kiosk starts talking.

7.1.1 Task 1: to find a free seat

In this task, the users are asked to imagine that they are going to visit Doctor Jan Pražak, from the Cardiology Department of the FN Motol hospital. They want to know when their turn is and, after that, to find a free seat in order to wait for it.

The expected resolution of this task is to listen to the message automatically displayed at the beginning (after the face recognition) and then select the "find a free seat" option from the menu.

When the task is completed, the users are told that, in a real scenario, they would follow the sound of the beacon and find the seat. After a few minutes, when their turn arrives, the system would inform them about it out loud and a beacon at the doctor's office door would be activated.

7.1.2 Task 2: to go to the exit

In the second task, the users are asked to imagine that the doctor had some problems with previous visits and everything is late. The waiting time the system tells to the users is five hours, so they would like to go home (this means finding the exit) and come back in a while.

The expected resolution of this task is to listen to the message, then select the "navigate to a new destination" option from the menu and finally select the "exit" option.

7.1.3 Task 3: to go to another waiting room

In the third task, the users are asked to imagine that they had two different scheduled visits for today and they went firstly to the one that is later. The waiting time the system will tell them is five hours, so they would like to solve it by going first to the other scheduled visit.

The expected resolution of this task is to listen to the message, then select the "navigate to a new destination" option from the menu and finally select the "other scheduled visits" option. Then, it will be the same resolution as the previous task.

7.1.4 Task 4: to request assistance

In the forth task, the users are asked to imagine that they made a mistake while following the directions and they arrived to a wrong waiting room: they would hear a different welcome message at the beginning. Then, the users are told to imagine that they are in a hurry because they will be late for their scheduled visit. Therefore, they would like to be assisted.

This task can be solved by pressing the alarm button directly from the keypad or by selecting the correct option from the menu.

7.1.5 Task 5: to change the language

In the last task, the users are asked to imagine that they want to change the language of the system into English.

The task is solved when they change the language and there is no need to go through the task again in the new language.

7.2 Low fidelity prototype evaluation

The low fidelity prototype is composed of simply the menu of the kiosk. In this first evaluation, participants will be asked to complete the tasks in order to check whether the options fulfil their expectations or not. This evaluation is not about the correct operation of the system because it is the tester who performs through the menus like the system would.

7.2.1 Participants

Three visually impaired participants take part in this evaluation session: two females and one male, all of them from Prague and presenting different types of visual impairment. The average age of the participants is 53 years old with a standard deviation of 14.1 years. A detailed description of their profiles can be found in appendix B.

7.2.2 Procedure

The testing with real users is held in a testing room of the Electrical Engineering Faculty at the CTU. The users are asked to complete a test shorter than half an hour. The test simulates a real environment in where the users have to go through the menus of the kiosk. The tester reads the options out loud and simulates the response of the system when the user interacts with the keypad.

7.2.3 Findings

Since the design process is iterative, most of the findings arisen from this evaluation session are already included in the initial design (section 5.2). Findings can be distinguished between positive and negative ones. Positive findings are those that praise the system and allow us to see that the designed prototype is working properly. On the other hand, negative findings are those that should be taken into account in a re-design process.

Positive findings

- Overall, menus and options are understandable.
- Overall, participants express satisfaction with the information displayed when they arrive to the kiosk.

Negative findings

Priority 1:

- The alternation of the words "accept" and "confirm" for the same action is confusing and should be homogenised. (P1-T3)[7]

Priority 2:

- One participant feels confused about when to leave the kiosk after hearing the route description. (P3-T2)

Priority 3:

- One participant feels uncomfortable with the numeric pad. (P1-T1)
- One participant expects the option "navigate to the exit" to be independent from other navigation options and accessible from the main menu. (P2-T2)

Other concerns

- How will users find the correct doctor's office after hearing their turn number? (P2-T1)
- The speakers can be bothering for other patients in the waiting room. (P3-T1)

[7] "P1-T3" means that this finding comes from how the first participant performed the third task of the evaluation session (appendix B).

7.3 High fidelity prototype evaluation

The high fidelity prototype is composed of the Java implementation, the Mackintosh Text to Speech feature and a numeric keypad. The aim of this evaluation is not to test how the code performs but to verify that menus and options are understandable, intuitive and visually impaired user-friendly.

7.3.1 Participants

Seven visually impaired participants take part in this evaluation session. All of them are from Prague and present different types of visual impairment. A complete description of their profiles can be found in appendix C.

Seven visually impaired participants take part in this evaluation session: five females and two males, all of them from Prague and presenting different types of visual impairment. The average age of the participants is 38.3 years old with a standard deviation of 13.7 years. A detailed description of their profiles can be found in appendix C.

7.3.2 Procedure

The testing with real users is held in a testing room of the Electrical Engineering Faculty at the CTU. The users are asked to complete three tests in a row, each shorter than half an hour. This three tests simulate the three parts of the navigation system in order: the web application, the main entrance kiosk and the waiting room kiosk.

The web application is the first part to be tested. The testing environment is formed by a Windows laptop and a normal keyboard. The second part to be tested is the main entrance kiosk, simulated by a tablet into a 3D printed framework. The third and last part to be tested is the waiting room kiosk, that is the purpose of the current thesis, which is formed by a MacBook Air laptop running the Java source code, its Text to Speech feature and a normal numeric keypad (Figure 41).

Figure 41: The three parts of the user testing environment

The complete set of testing sessions can be found in appendix C.

7.3.3 Findings

Apart from minor spelling or Czech translation mistakes that were instantly fixed, the main findings of the testing sessions can be distinguished between positive and negative findings, as we already discussed (section 7.2.3). The positive findings are those that praise the system and allow us to see that the designed prototype is working properly. On the other hand, the negative findings are those that should be taken into account in a re-design process. Negative findings are classified in different levels of priority depending on the urgency with which they must be fixed. Obviously, the negative findings are much more interesting in and engineering process. Therefore, we are going to focus on them.

Positive findings

- Overall, the prototype is understandable and works properly.
- Two participants think that the idea of using an acoustic beacon on the waiting room seats is a great idea. (P4/5-T1)[8]
- Six participants used the emergency button. (P1/2/3/4/5/6-T4)
- Overall, participants express satisfaction with the information displayed when they arrive to the kiosk.

Negative findings

Priority 1:

- The kiosk doesn't have a volume control for headphones. (P7-T1)

[8] "P4/5-T1" means that this finding comes from how the forth and the fifth participant performed the first task of the evaluation session (appendix C).

- VI users are more used to find the "0" button of the keypad rather than a "repeat" button. (P7-T1)
- The "change the language" section is not well designed when considering monolingual users. (P7-T5)

Priority 2:

- Three participants would not use the acoustic beacon feature and would ask for help instead. (P3/6/7-T1)
- Three participants are confused about when to leave the kiosk after selecting the "navigate to a new destination" option. (P3-T3, P4/5-T2)

Priority 3:

- The word "next" might be confusing referred only to the immediately next kiosk of the route and not the rest of it. (P3-T3)
- One participant thinks that the "navigate to the exit" option shouldn't be hidden inside another option. (P4-T2)
- One participant expects more direct orders in the route descriptions. (P5-T3)

Other concerns

- How will the waiting room seats be reserved? (P1-T1)
- The suggested routes must be free-obstacles routes. (P1-T2)
- How would the system inform VI users when a delay on the waiting time is produced while they are already waiting? (P7-T2)

7.4 Redesign suggestions

After drawing the findings from the usability testing, we can suggest some solutions to the solvable negative ones in order to improve the system.

Priority 1:

- To add a volume control for headphones to the kiosk, with buttons "+" and "-". The buttons must be readable by VI users, so the symbols must have relief.
- To change the "repeat" button for the "0" button on the keypad.
- To reconsider the "change the language" section taking into account monolingual users. Each language option has to be written (and read) in the same language the option is.

Priority 2:

- To display the sentence "now, you can depart" before the options in order to make clear that the user can leave.

Priority 3:

- To reconsider whether the word "next" referred only to the immediately next kiosk of the route should be replaced by "first" or not: "Detailed audio description to the *next* kiosk" vs. "Detailed audio description to the *first* kiosk".
- To reconsider whether the "navigate to the exit" option should be independent from the "navigate to a new destination" or not.
- To take into account that the audio description of the route must be clear and easy to follow and remember.

7.5 Conclusions

The aim of this chapter was to evaluate the hi-fi prototype in a process that should be iterative with the design one. The more iterations you can afford, the better the solution will fulfil requirements and user needs. This hi-fi prototype could and should be improved after this iteration, as we exposed in the re-design suggestions (section 7.4). Going through Nielsen's [26] five usability attributes after the evaluation, we can state that our system's strengths are learnability, satisfaction and a low error rate while the main weakness is efficiency. Memorability is a difficult attribute to evaluate with such a few testing sessions. Overall, we can state that the proposed solution is a very good start point that sets the basis for the definitive solution.

Chapter 8: Conclusions

The aim of this chapter is to conclude this thesis and propose the possible future work. Firstly, the extend of achievement regarding particular thesis objectives is described.

1. *To study and understand the state of the art in hospital navigation systems.*

Chapter 2 provided us a detailed study of seven existing solutions for in-hospital navigation issues. None of them approached the problem as our target group (VI) needs it to be approached.: most of them consider the use of special devices such as touchscreens or smartphones. Nevertheless, the study was useful in order to take some ideas and it reminded us some important topics to take into account like users' privacy or noise pollution. In addition to that, we explained the complex system which our waiting room management system is going to be a part of.

2. *To analyse the user needs.*

User needs were analysed after an exhausting user research in chapter 3. Research started with a visit to the main hospital in Prague that showed many navigation issues, even for people with no visual impairment. It continued with three interviews to VIP which were useful to understand better our target group and, from there, create a persona with realistic characteristics: Tereza. After the interviews, in chapter 3 we stated the findings from the experience map arisen from a brainstorming session held with other researchers. Some of those findings were useful to define user needs at the end of the chapter, namely: to know the waiting time and when their turn is, to find a free seat in the waiting room, to ask for directions, to ask for assistance, to choose among different languages and to choose how the information is displayed.

3. *To state the system requirements according to these needs.*

Requirements are stated in section 5.1.

4. *To propose a design fulfilling the stated requirements.*

After defining the requirements, the proper designing process started. The initial design is a low fidelity prototype description (see section 5.2) of the different parts of the system: waiting room kiosk, waiting room seats, directional kiosk and hospital staff device. We focused on the WR kiosk and defined every screenshot of the menus and options following the scenario analysis of chapter 4. The lo-fi prototype was evaluated in section 7.2 and, after some redesign steps, it proved to be performing as users need.

5. *To implement and evaluate a high-fidelity prototype of the solution.*

In chapter 6, we provided an implementation that was able to perform like a real system when users go through menus and options. Even though the efficiency of the proposed programed code is clearly improvable, the hi-fi prototype works properly throughout the different evaluation tasks.

6. *To state future developer documentation.*

After this objectives and achievements analysis, a future work section can be found.

7. *To help visually impaired people to understand information displayed in a hospital waiting room.*

   The proposed solution keeps VIPs informed by telling them out loud an estimated waiting time and turn number when they arrive. Moreover, it warns them when that turn number comes.

8. *To improve visually impaired people's experience in a hospital waiting room by, for example, helping them to find a free seat or navigating them to specific locations such as toilet or cafeteria.*

   The proposed solution allows VIPs to ask for help in order to find a free seat in the waiting room by using an acoustic beacon. It also helps them to be navigated to other destinations within the hospital: exit, toilet, cafeteria, pharmacy, other waiting rooms…

9. *To make visually impaired people independent from other people while they are in their way to the waiting room and in there.*

   The whole system is designed to avoid as much dependence as possible. It always minds that VIP is alone and all the information input/output is accessible, but it keeps some external help available for emergencies such as the help button and the "request assistance" option.

10. *To design a waiting room management solution integrated in the complex in-hospital navigation system.*

    The designed solution takes into account and even assumes the rest of the complex system. VIPs prepare their visit on the web application, then go to the hospital and get signed in by the main entrance kiosk, follow directions provided by simple navigation terminals and finally arrive to the waiting room. But it is worth to point out that we do not believe that arriving to a waiting room is the end of navigation process: after their visit, VIPs can be navigated to the exit and leave the hospital or they can ask for directions to any other place within the hospital and start the process again. Therefore, waiting room kiosk must perform very similar to main entrance kiosk.

It seems fair to state that these four main goals were accomplished by following a formal engineering process. Nevertheless, some steps could have been improved if the means had allowed us to do so: a wider range of interviews would have provided a more reliable user research or having a hospital available to test the prototypes and having all parts of the complex system working together would have contributed to a more realistic evaluation. It would have also been interesting to ask hospital staff and propose a solution for their device. Unfortunately, resources of a single thesis are limited. This is why describing the expected future work is so important.

Future work

This thesis is just a first step that opens the door to anyone interested in hospital navigation systems. It is the subject of future work to address issues discovered during evaluation of our final prototype (see section 7.4). Next prototype should assimilate those redesign suggestions and eventually be perfectly integrated with the rest of the complex system in order to be tested in a real environment. Designing a device for the hospital's staff is also a matter of future approaches to this issue.

Going further in the future, the ideal complex system should be a small part of an even more complex hospital system that will manage all kind of visitors and needs. This system should provide assistance to different kind of people with orientation difficulties, but also free nurses and administrative staff from paperwork.

Further approaches to this issue have to take into account the financial face of the problem: hospitals need to know the costs of implementing such a system in their facilities. Another concern to be considered in the future is users' privacy. If the system is managing confidential data and electronic health records, it has to be protected against attacks and errors.

Appendices

Appendix A: User research interviews

This appendix contains the three interviews carried out in order to collect information for the user research.

A.1 Interview to participant I

Profile
Age: 38
Gender: M
Category of visual impairment (1-5): 5
Time: L
Address: Prague

Q1 How do you orientate yourself in a hospital?
He uses a white cane to orientate himself and, although he prefers to be independent from other people, he normally goes to the hospital with a relative or a friend who can help him. The participant points out that the worst orientation problem he faces when visiting a hospital are closed doors without guidelines: they are undistinguishable from walls when you use a white cane. While traveling to the hospital, he uses his transmitter for blind people, which interacts with beacons all around the city, specially while crossing the street or when using the public transport.
Q2 Once you are in the waiting room, how are you informed all the time? What would you like to know?
The user thinks that, like all the other patients, he is not informed enough. Knowing the amount of people in front of him or knowing an estimated remaining time would be useful.
Q3 How do you to find a free seat in the waiting room?
The user has no particular difficulties in finding a free seat and he thinks that to reserve an amount of seats for disabled people makes no sense in a hospital waiting room because in there everyone has some special needs.
Q4 How do you think that the hospital staff is prepared to help visually impaired people?
The user thinks that, in general, hospital staff are not kind and they don't know how to deal with visually impaired people. Maybe some specific course about how to deal with this user group is needed.
Q5 How would you like to receive the information?
The user explains that not many visually impaired people are able to read braille and he points out that people with diabetes may have difficulties with tactile interaction. According to his opinion, the best alternative is an audio system (with your own headphones in order not to bother the other patients) with numbers like "if you

want this, press that" similar to a call centre. He recommends short messages and voice confirmation always. The user also thinks that the hygiene of the buttons can be a problem in a hospital.

Q6 After the visit to the doctor, how would you like to set the next appointment?

The nurse usually does that and it is the best option for him.

Q7 After the visit to the doctor, would you like to be guided to go to the entrance point, pharmacy or public transport? Would you like to be guided throughout a free-obstacles (maybe longer) route?

Yes, even though the user normally visits the hospital with a guide. The user points out that closed doors are like walls when using a white cane, and hanging objects can be invisible. Open areas are a problem too.

Q8 Any additional idea to improve your visits to the hospital?

The user thinks that there should be a way to know when his turn is and a well-defined protocol to inform the nurse that the user arrived and to know what to do with the health insurance card.

A.2 Interview to participant II

Profile
Age: 68
Gender: F
Category of visual impairment (1-5): 5
Time: L
Address: Prague

Q1 How do you orientate yourself in a hospital?

The user uses a white cane and a guide dog to move around, but she normally goes to the hospital accompanied by some relative or friend. If she is going to some new place, she prepares her way carefully and asks somebody to describe it to her by using Google Maps or similar apps.

Q2 Once you are in the waiting room, how are you informed all the time? What would you like to know?

The user thinks that she is not informed enough. She would find useful to know the number of patients in front of her or the remaining waiting time. She usually asks this kind of information to the nurse or to other patients.

Q3 How do you to find a free seat in the waiting room?

Normally, other patients help her to find a place without need to ask.

Q4 How do you think that the hospital staff is prepared to help visually impaired people?

The user thinks that sometimes the hospital staff don't know how to help her.

Q5 How would you like to receive the information?

The user has no relevant experience with any touchpad; she would like to receive the information in audio or braille.

Q6 After the visit to the doctor, how would you like to set the next appointment?

The user explains that she always asks the nurse to set the next appointment.

Q7 After the visit to the doctor, would you like to be guided to go to the entrance point, pharmacy or public transport? Would you like to be guided throughout a free-obstacles (maybe longer) route?

The user would find really useful to hear detailed descriptions that may guide her to specific locations.

Q8 Any additional idea to improve your visits to the hospital?

The user would like to find detailed descriptions of the hospital on the website.

A.3 Interview to participant III

Profile
Age: 34
Gender: M
Category of visual impairment (1-5): 5
Time: C
Address: Prague

Q1 How do you orientate yourself in a hospital?
The user uses a white cane, but he normally goes to the hospital with somebody and asks for help when needed. He feels comfortable when asking to strangers and he has not had relevant bad experiences with that.
Q2 Once you are in the waiting room, how are you informed all the time? What would you like to know?
The user says that the information received depends on the waiting room he is in. Normally, he keeps asking to other patients or to the nurses. The user would found useful to know the amount of people in front of him or the waiting time. He explains that when the patient order is regulated by a number displayed on a screen, it is a big problem that forces him to keep asking all the time.
Q3 How do you to find a free seat in the waiting room?
Somebody helps him to find the free seat, normally the person who accompanies him can do that.
Q4 How do you think that the hospital staff is prepared to help visually impaired people?
The user thinks that nurses and doctors are normally prepared enough to help him. On the other hand, the other hospital staff such as administration personnel is not able to help visually impaired people.
Q5 How would you like to receive the information?
The user is familiarized with smartphones and he uses a keypad for the information inputs and audio descriptions for the outputs. He feels also comfortable reading braille.
Q6 After the visit to the doctor, how would you like to set the next appointment?
The user explains that he always asks the nurse to set the next appointment.
Q7 After the visit to the doctor, would you like to be guided to go to the entrance point, pharmacy or public transport? Would you like to be guided throughout a free-obstacles (maybe longer) route?
The user normally asks the hospital staff for directions, and he would find really useful to hear detailed descriptions that may guide him to specific locations.
Q8 Any additional idea to improve your visits to the hospital?
The user would like to know when his turn is. And he would find useful to hear detailed descriptions of the hospital on the website.

Appendix B: Evaluation tasks of the low fidelity prototype

This appendix contains the three tests carried out in order to evaluate the low fidelity prototype.

B.1 Participant I

Profile
Age: 40
Gender: F
Category of visual impairment (1-5): 4
Time: L
Braille: No
Address: Prague

Task 1: to find a free seat

The task is completed normally, but the participant prefers to use the numbers on the keyboard rather than the numeric keypad.

Task 2: to go to the exit

The task is completed normally.

Task 3: to go to another waiting room

The task is completed normally, but the participant points out that the alternation of the words “accept” and “confirm” is confusing.

Task 4: to request assistance

The task is completed normally by using the emergency button.

Task 5: to change the language

The task is completed normally.

B.2 Participant II

Profile
Age: 68
Gender: F
Category of visual impairment (1-5): 5
Time: L
Braille: Yes
Address: Prague

Task 1: to find a free seat
The task is completed normally, but the participant wonders how she would find the door after hearing her name.

Task 2: to go to the exit
The participant is unable to complete the task without help. She expected to find the option “go to the exit” in the main menu.

Task 3: to go to another waiting room
The task is completed normally.

Task 4: to request assistance
The task is completed normally by using the emergency button.

Task 5: to change the language
The task is completed normally.

B.3 Participant III

Profile
Age: 51
Gender: M
Category of visual impairment (1-5): 5
Time: C
Braille: Yes
Address: Prague

Task 1: to find a free seat
The task is completed normally, but the participant thinks that this feature is unnecessary and may be bothering for other patients.

Task 2: to go to the exit
The task is completed normally, but the participant is unsure about the end of it.

Task 3: to go to another waiting room
The task is completed normally.

Task 4: to request assistance
The task is completed normally by using the emergency button.

Task 5: to change the language
The task is completed normally.

Appendix C: Evaluation tasks of the high fidelity prototype

This appendix contains the seven tests carried out in order to evaluate the high fidelity prototype.

C.1 Participant I

Profile
Age: 41
Gender: M
Category of visual impairment (1-5): 4
Time: C
Braille: Yes
Address: Prague

Task 1: to find a free seat
The task is completed normally, but the participant wonders how will the free seats be reserved and preserved from other people to sit in them.

Task 2: to go to the exit
The task is completed normally, but the participant points out that the route to the exit must be without stairs and properly detailed.

Task 3: to go to another waiting room
The task is completed normally.

Task 4: to request assistance
The task is completed normally by using the emergency button.

Task 5: to change the language
The task is completed normally.

C.2 Participant II

Profile
Age: 40
Gender: F
Category of visual impairment (1-5): 5
Time: C
Braille: Yes
Address: Prague

Task 1: to find a free seat
The task is completed normally.

Task 2: to go to the exit
The task is completed normally.

Task 3: to go to another waiting room
The task is completed normally.

Task 4: to request assistance
The task is completed normally by using the emergency button.

Task 5: to change the language
The task is completed normally.

C.3 Participant III

Profile
Age: 66
Gender: F
Category of visual impairment (1-5): 4
Time: L
Braille: No
Address: Prague

Task 1: to find a free seat

The participant presses the help button instead of selecting the *2. Find a free seat* option from the menu. She explains that she would ask for help to find a free seat to someone around her because she does not want to bother anyone with the beacon. She also feels confused about the *3. Find out where you are* option of the menu because she already knows where she is.

Task 2: to go to the exit

The task is completed normally but the participant has some trouble in order to make the system repeat the main menu info.

Task 3: to go to another waiting room

The participant is confused about the end of the task, but she completes it normally. In addition to that, she points out that the word "next" is confusing referred to the kiosks because one would expect the option of hearing one after the other when pressing the *5. Detailed route audio description to next kiosk* option more than once.

Task 4: to request assistance

The task is completed normally.

Task 5: to change the language

The task is completed normally.

C.4 Participant IV

Profile
Age: 28
Gender: F
Category of visual impairment (1-5): 5
Time: C
Braille: Yes
Address: Prague

Task 1: to find a free seat
The task is completed normally and she thinks that the beacon on the seat is a great idea.

Task 2: to go to the exit
The participant is confused about the end of the task. She also points out that, in her opinion, the "exit" option should not be hidden inside the *4. Navigate to a new destination* option but independent and accessible from the main menu.

Task 3: to go to another waiting room
The task is completed normally.

Task 4: to request assistance
The task is completed normally by using the emergency button.

Task 5: to change the language
The task is completed normally.

C.5 Participant V

Profile
Age: 30
Gender: F
Category of visual impairment (1-5): 4
Time: C
Braille: Yes
Address: Prague

Task 1: to find a free seat
The task is completed normally. The user thinks that the beacon on the seat is a great idea but she is concerned about bothering the other people in the waiting room. And she would definitely use headphones.

Task 2: to go to the exit
The task is completed normally, but she feels confused about the end of the task. She would expect the "you can depart" just after the information is displayed.

Task 3: to go to another waiting room
The task is completed normally but she would expect more direct orders like "turn left".

Task 4: to request assistance
The task is completed normally by using the emergency button.

Task 5: to change the language
The task is completed normally.

C.6 Participant VI

Profile
Age: 25
Gender: F
Category of visual impairment (1-5): 5
Time: C
Braille: Yes
Address: Prague

Task 1: to find a free seat
The task is completed normally, but the participant opines that the acoustic beacon is a sci-fi and too expensive solution: it is easier to ask someone for help. She also explains that knowing the turn number is very useful.

Task 2: to go to the exit
The task is completed normally and she thinks that this is a very useful feature.

Task 3: to go to another waiting room
The task is completed normally.

Task 4: to request assistance
The task is completed normally by using the emergency button.

Task 5: to change the language
The task is completed normally.

C.7 Participant VII

Profile
Age: 38
Gender: M
Category of visual impairment (1-5): 5
Time: L
Braille: Yes
Address: Prague

Task 1: to find a free seat

The task is completed normally, but the participant thinks that he would ask for help to someone in the waiting room without using the beacon. He suggests a couple of changes: the *2. Find a free seat* option should be “ask for help to find a free seat” and the “repeat” button should be the “0” on the buttons pad because visually impaired people is completely used to find it on the pad. In addition to that, the participant expresses his concern about the lack of a volume control.

Task 2: to go to the exit

The task is completed normally, but the participant is concerned about how he would be informed if the delay occurs while he is already waiting in the waiting room.

Task 3: to go to another waiting room

The task is completed normally.

Task 4: to request assistance

The task is completed normally, but the participant explains the he wouldn’t use this feature of the system: in case of an emergency, he would shout or call somebody.

Task 5: to change the language

The task is completed normally, but the participant suggests that each language on the list should be written and read in the same language the option offers.

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