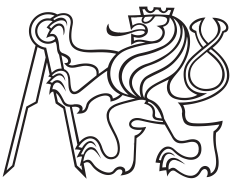
Master's Thesis



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Supporting hospital visit preparation for specific user groups

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Program: Open Informatics
Field: Software Engineering

May 2016
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Acknowledgement / Declaration

I would like to thank my supervisor, Ing. Miroslav Macík, for giving me the opportunity to work on this project, for his patient guidance and valuable advice. I would especially like to thank my family and friends for their incredible support and encouragement throughout my studies.

I hereby declare that I have written the submitted thesis myself and I quoted all used sources of information in accord with Methodical instructions about ethical principles for writing academic theses.

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Tomáš Flek

In Prague, 25th May 2016

Prohlašuji, že jsem předloženou práci vypracoval samostatně, a že jsem uvedl veškeré použité informační zdroje v souladu s Metodickým pokynem o dodržování etických principů při přípravě vysokoškolských závěrečných prací.

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Tomáš Flek

V Praze, 25. května 2016

Abstrakt / Abstract

Návštěva nemocnice může být daleko více stresující pro jedince se specifickými potřebami v oblastni navigace a orientace, jako jsou lidé se zrakovým postižením nebo senioři. Tato práce představuje nástroj, který poskytuje podporu vyvinutou na míru tak, aby splnila jejich specifické potřeby. Práce je zaměřena na design, implementaci a evaluaci webové aplikace podporující lidi před návštěvou nemocnice. Představené řešení je součástí komplexního nemocničního navigačního systému vyvíjeného na ČVUT v Praze.

Klíčová slova: asistivní technologie, zrakové postižení, navigace, nemocnice, přístupný web, uživatelské testování

Překlad titulu: Podpora přípravy návštěvy nemocnice pro specifické uživatelské skupiny

Visiting a hospital could be significantly more stressful for individuals with specific navigation and orientation needs such as the visually impaired or seniors. This thesis presents a tool that provides support tailored to address their specific needs. We focus on design, implementation and evaluation of a web application supporting people before visiting a hospital. The described solution is a part of a complex In-hospital navigation system which is currently being developed at CTU in Prague.

Keywords: assistive technology, visual impairment, navigation, hospital, accessible web, usability testing

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Chapter 1
Introduction

The quality of health care has significantly increased in the past. However, the quality of providing orientation support for individuals with visual or motor impairments has not changed much — especially in hospitals. Large hospitals (e.g. Motol University Hospital in Prague) are usually very hard to navigate inside even for healthy individuals. Despite this fact visiting a hospital is often connected with negative feelings, nervousness and anxiety.

To improve such experience the In-hospital navigation system is being developed at Czech Technical University in Prague [1–2] (CTU). The system provides additional support for people with disabilities by providing personalized navigation instructions inside the building. The proposed system architecture consists of several stages of navigation. The first stage is preparation at home, which is important mainly for visually impaired individuals. This thesis is focused on the first stage of the navigation system — visit preparation at home.

1.1 Motivation

To improve the quality of life of all individuals it is necessary to find out the most problematic scenarios when a hospital is visited. It is important to provide a solution which makes the hospital visit easier. The typical hospital environment might be stressful even for healthy individuals and hospital buildings having a number of similar hallways does not bring it to a better condition. Hospitals are trying to help visitors navigate inside e.g. by providing signs or colored lines on the floor, nevertheless, these are still not present in all hospitals in the Czech Republic.

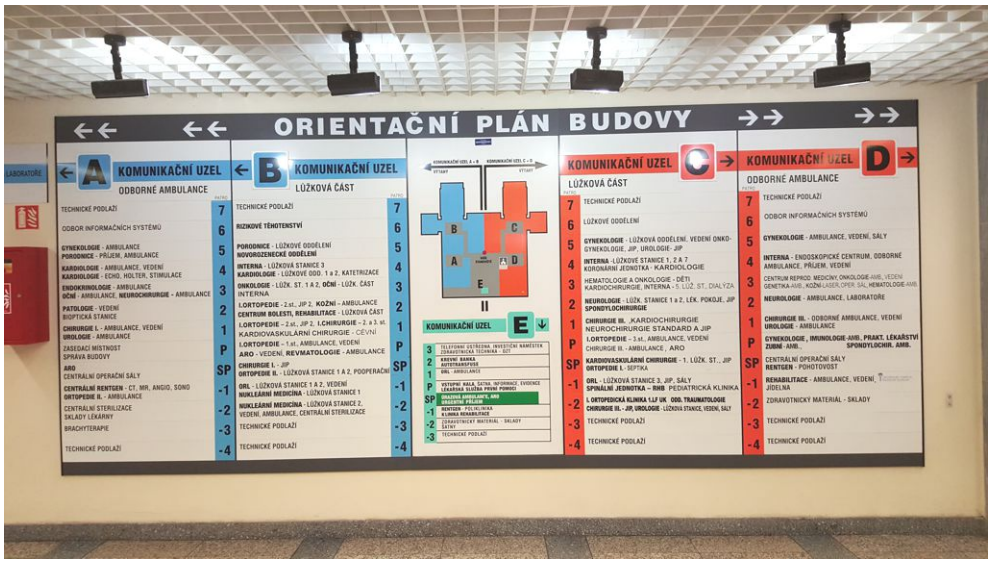

Figure 1.1. Orientation plan of one of the Motol University Hospital main buildings.

With increasing size of the hospital building the complexity of colored horizontal navigation lines increases significantly. The orientation plan depicted in Figure 1.1 illustrates the complexity of one of the many Motol University Hospital buildings. The horizontal colored lines on the floor are helpful only for individuals without vision impairments. Many hospital buildings are also full of many doors and unexpected obstacles. Both colored lines on the floor and structuring of the hallways are depicted in Figure 1.2. Therefore, we should focus on individuals with vision impairments as the current navigation and orientation cues are not suitable for them. The visually impaired are not the only ones being disadvantaged if navigation support is taken into consideration, but it is also the seniors since they represent a group which goes to hospitals very often. This is supported by statistical data discussed further in Section 3.2. Seniors have often reduced capability to orientate in complex buildings as all cognitive capabilities are worsen with increasing age.

Figure 1.2. Preview of the hallway in one of the Motol University Hospital buildings.

Even though hospitals are doing their best to improve the navigation inside their buildings, one of the reasons why visitors get lost is a lack of preparation. Our user research (Chapter 3) has shown that visitors do not usually prepare for the visit in advance. There can be many reasons — they are not used to doing it or they do not know where to find useful information about the hospital. To make people prepare themselves before the visit it is necessary to offer a service that provides useful information. For example the website of the Motol University Hospital[1] offers a great deal of information but the ordinary visitor can make use of just a fraction of it. There is a possibility to take a virtual tour of the hospital complex and read brief descriptions of how it is possible to reach individual buildings. Neither of those is suitable for visually impaired individuals.

1.2 Goals of the thesis

The main goal of this thesis is to provide a solution which will support people before visiting a hospital and to provide the In-hospital navigation system with user information. The design process should employ user centered design approach (UCD) [3] as it

[1] `http://www.fnmotol.cz/en/`

is one of the best practices regarding development for target user groups with special needs such as visually impaired individuals and the seniors.

The structure of this thesis is based on main goals of the thesis. Below is a brief description of main goals:

- *To analyze existing solutions*
  The first step is to analyze the existing solutions to navigation systems in hospitals and advance preparation. The analysis consists of a description of the proposed navigation system and another analysis of the development tools. All these topics are covered in Chapter 2.
- *To conduct user research with focus on the visually impaired and seniors*
  The second step is to perform qualitative user research with the target group. The parts of the research are preparation, screening process and interviews. Interviews are analyzed and summarized into simple facts. The functional and non-functional requirements for the tool which is going to be developed are based on these facts. All these topics are covered in Chapter 3.
- *To design a solution based on the user research*
  The third step is to design a solution based on the user research. As the design is an iterative process, multiple prototypes are going to be developed. Each iteration has to be properly evaluated by a suitable testing method. Based on the previous iteration results and their interpretation the next prototype is to be developed. All these topics are covered in Chapter 4.
- *To implement the designed solution and integrate it into other components of the navigation system*
  The fourth step is to implement the designed solution. As the implementation is also an iterative process resulting fluently from the design, some of the implementation topics are already covered in Chapter 4. The details about implementation are covered in Chapter 5.
- *To evaluate developed solution*
  The assessment of each prototype with suitable evaluation methods is the last fifth step. The most important evaluation method is the usability test with target audience. The final solution should be also evaluated as a white box using suitable testing methods (e.g. unit tests). All these topics are covered in Chapter 6.

The steps mentioned above describe how the tool which provides people with special navigation and orientation needs will be designed, implemented and lastly evaluated. This tool will be developed as a part of the proposed In-hospital navigation system currently being worked on at CTU in Prague.

Chapter 2
Analysis

In this Chapter are analyzed existing solutions for indoor navigation — especially in hospitals. There are also briefly analyzed possibilities of preparation for hospital visit. With knowledge gained from the state of the art (SoA)[1] analysis the proposed navigation system is described. This Chapter also contains analysis of the development tools and technologies that can be used for realization of the intended tool for supporting hospital visit preparation.

2.1 Related work

In last decades indoor navigation systems were widely investigated area. Quite a lot of research teams came up with ideas with own navigation systems. For our purpose let's focus on the indoor navigation systems that can be used in hospitals. Another criteria is that system has to be suitable for visually impaired users and seniors.

The navigation system presented by Flores and Farcy [4] is designed for visually impaired users. It uses inexpensive sensors which are nowadays present in almost each smartphone such as compass, gyroscope, accelerometer and barometer. By processing signals from all these sensors the position of the user can be determined. The system uses audio commands to navigate a visually impaired user to the desired location. The main drawback of this system is that user has to be trained before he or she can use it. Also it is necessary to have a smartphone which is not suitable for many seniors as they still usually use old feature phones.

Also Panasonic presented its Comprehensive Solutions for Entire Hospitals [5] which covers also indoor navigation and waiting room management. The system is capable of navigating patients and it also does basic paperwork. The main drawback of this system is that the user has to carry a single-purpose pager. From the pictures and brief description of the device — as no detail information about the system has been published — we can assume that it is not accessible for the visually impaired users. It is also hard to say if it is suitable for seniors.

Another navigation system presented by Nakajima and Haruyama [6] uses a LED light emitter and receiver in combination with a smartphone. The position of a user is provided by the LED light which is aware about its position in the building. Light is processed by receiver which provides visible light ID to a smartphone via Bluetooth. The position is then corrected by geomagnetic field sensor in a smartphone which determines the direction of walking. The main drawback of this system is that user has to carry the receiver in visible place (f.e. suspended from a strap around around a neck). Also, user has to have a smartphone which exclude seniors.

The PERCEPT [7] is a navigation system for visually impaired users presented by Ganz et al. The system's main advantage is low cost and easy maintenance due to use of passive RFID[2] tags. Those tags are placed inside the building on all important

[1] https://en.wikipedia.org/wiki/State_of_the_art
[2] https://en.wikipedia.org/wiki/Radio-frequency_identification

navigation places such as exits, elevators and halls. Those tags are scanned by using special glove. Information about the tag is given in audio format from the user's smartphone which has to have the Percept application installed. As in aforementioned paragraphs, the main drawback is still the need of having a smartphone. On top of that, to operate with navigation system user has to have a special glove.

Another navigation system proposed by Fukasawa and Magatani [8] is for visually impaired users only. It is based on the fact that majority of the visually impaired uses a white cane during navigation. The navigation uses horizontal colored lines on the floor which are usually present in hospitals. The system uses a set of RFID tags placed beneath the navigation lines and an intelligent white cane. The cane is augmented with a RGB color sensor on its tip, transceiver for RFID tags and vibrator. The main drawback of this system is that user has to have an augmented white cane with special sensors. This navigation system is also not provided to seniors — they have to rely on their ability of following the colored navigation lines which can be a problem.

The next navigation system proposed by Atzori et al. [9] uses already present sensors such as an accelerometer and gyroscope in smartphones. To determine where a user is located 2D-bar codes are used. 2D-bar code is scanned via smartphone which provides information about the current location. Map of the area is displayed on the phone with highlighted position. By using sensors in a smartphone the position is tracked. Due to cumulative error of the position estimation system needs to recalibrate. To do that user has to scan the 2D-bar code again after a while. The main drawback of this system that the user still needs a smartphone to use the system. Also, the visually impaired users will not be able to scan the 2D-bar code so the system is also not suitable for them.

It is very hard to provide good and precise indoor navigation system that will be easy to maintain and affordable for everyone. Several interesting solutions has been presented but they all have one main disadvantage in common. All of these systems are based on the fact that users have something to have or carry. Analyzed systems are compared in Table 2.1. This is not suitable for seniors as they prefer and still use feature phones. This is supported by user research results discussed in Section 3.6. Some systems require to carry some special device such as glove with RFID receiver or augmented white cane. To make system scalable and usable for wide target audience it is necessary to avoid solutions which requires carrying some special objects or devices.

Considering hospital visit preparation tools, Step Forward organization offers pre-visit planning module [10]. This module provides recommended workflow of managing patients. The primary purpose is to make doctor visit (and examinations connected with it) as fast as possible. As the module offers just paper documents that should be used while employing this approach, it is not suitable for visually impaired patients. Another service that can be considered as an existing solution how the visitor can prepare for the visit is to use the website of the target hospital and search for information there. As hospitals are huge institutions, websites contains a huge amount of information that are usually not important to a regular visitor. If we take a look on the website of the Motol University Hospital[1] you can see that there are general contacts listed. There is an option to take a virtual tour of the building but it is not suitable for visually impaired users. Also, there is a section called "How you can get to the hospital" containing just names of the bus stops with list of lines stopping there. There is no description how to get from the public transport stop to the entrance of the building which is important for visually impaired users.

[1] `http://www.fnmotol.cz/en/`

system	positioning technology	what the visitor has to have or carry	suitable for VI	suitable for seniors
Flores and Farcy [4]	approximation of position by using sensors in smartphone	smartphone with compass, gyroscope and accelerometer; headphones; training	yes	no
Panasonic [5]	none, only description of the navigation's target	single purpose pager	no	unknown
Nakajima and Haruyama [6]	LED emitters and receivers; Bluetooth and other sensors in smartphone	LED receiver on visible place and smartphone	yes	no
PERCEPT [7]	passive RFID tags placed in the building provides position information to the user	special glove with RFID reader; smartphone with the Percept application installed	yes	no
Fukasawa and Magatani [8]	passive RFID tags and horizontal colored guiding lines are read by augmented white cane	augmented white cane with RGB color sensor, RFID transceiver and vibrator	yes	no
Atzori et al. [9]	approximation of position by using sensors in smartphone; calibration by reading 2D-bar codes placed in the building	smartphone with compass, gyroscope and accelerometer	no	no
In-hospital navigation system developed at CTU [1–2]	navigation instructions provided automatically by terminals placed in the building	optionally transmitter for visually impaired	yes	yes

Table 2.1. Comparison of indoor navigation systems which are suitable for hospital.

2.2 Proposed navigation system

To support wide target audience and especially visually impaired users and seniors it is important to make the navigation system as simple as possible. Thus, user should not carry any special device or have a smartphone. The architecture of hospital indoor navigation system described by Macík et al. [2] consists of visit preparation (at home), trip to the hospital, interaction with smart kiosk, step-by-step navigation and destination room management. The whole procedure is depicted in Figure 2.1.

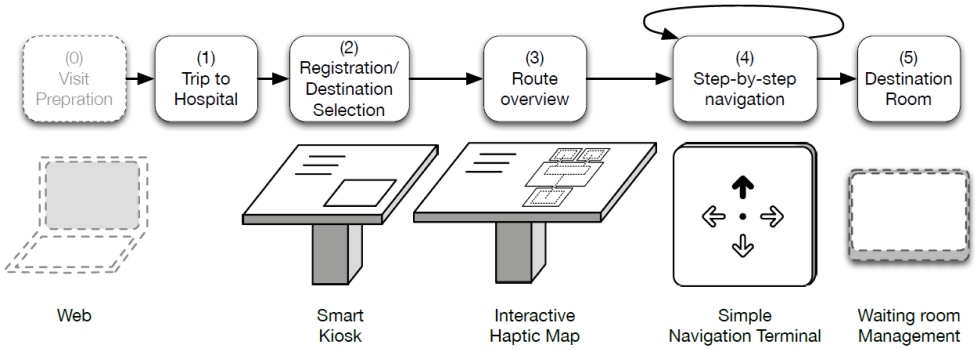

Figure 2.1. Navigation procedure with In-hospital navigation system [2].

The architecture of the system allows user to use the system without any special device or object he or she has to carry. The key feature of authentication is covered by camera and face recognition system. Therefore, user is recognized automatically by the system and provided with personalized navigation instructions. The key feature of the system is that it is not necessary to know the exact position of the user at the time. Visually impaired users are used to navigate by step-by-step instructions often provided even by external navigation services like SONS[1]. Step-by-step navigation is also key feature for seniors because they do not have to remember the whole path to the destination. By using this approach Naviterier [11–12] navigation system was designed and developed at CTU in Prague. Naviterier was developed as both outdoor and indoor navigation system based on providing guiding instructions segment by segment of the path to the destination.

As it was mentioned earlier, proposed navigation system consists of 4 main stages:

- The first part, which is discussed in this thesis, is called *hospital visit preparation*. Based on the user research result and requirements by the In-hospital navigation system discussed in Sections 3.6.1 and 3.6.2, the tool providing hospital visit preparation support will be fully accessible senior friendly web application. On this website will be information about the hospital and the navigation system along with important contacts and descriptions. The website will also allow user to make an appointment with specific doctor for a specific time from the comfort of the home. This will reduce the risk of waiting for several hours in a waiting room. It will also provide user to add tasks to the specific appointments not to forget important documents. It will also allow user to view other visitors experience with the navigation system and the hospital and also share their experience with others. It will also allow to prepare navigation to the specific place in hospital to save time in hospital itself.
- The second part is called *smart kiosk*. The smart kiosk will be equipped with camera, speaker, display and hardware buttons. The smart kiosk will allow user identification

[1] `http://www.sons.cz/`

in case he or she has visit prepared using the web application. The visitor will identify by using insurance company card that every visitor has (or at least should have as the hospital requires it). The smart kiosk will take a picture of the visitor's face to be able to recognize him or her later in step-by-step navigation. The picture will be saved in the system only for the time of the navigation. The smart kiosk will allow visitor to find the destination where visitor want to navigate. The part of this kiosk should be also an interactive haptic map displaying route overview to a visually impaired individuals. Smart kiosk will start the indoor navigation process by initial navigation instructions to the closest simple navigation terminal on the route.

- The third part is called *simple navigation terminal*. Those terminals will be placed on the wall on each important place from the navigation point of view such as corridor split, hallways and stairs. These terminals will have ability to be located by using acoustic beacon remote controller which visually impaired users have. The navigation terminal will be equipped with camera, speaker and small display. Once visitor will be detected by the navigation terminal and successfully recognized, visitor will be guided to the next navigation terminal by visual and audio feedback. This process will repeat until the visitor arrives to the desired destination.
- The fourth part is called *waiting room management*. In the waiting room will be kiosk similar to the main smart kiosk which will provide the same identification and navigation functionality. Also, the waiting room kiosk will be able to tell the visitor his or her waiting number and estimated time of waiting. It will also allow visually impaired visitor to find the empty seat by using the acoustic beacon placed in some reserved seats. This will help also to the hospital staff that they would know that the visitor already arrived in the waiting room.

This section has described the general design of the distributed In-hospital navigation system. All of its stages has been described as well as the workflow of the navigation. This thesis is focused on the first part of the navigation system — web application providing support for visitors. The main purpose of the web application is to provide support to visitors before reaching hospital's front door. It will also provide information about the visitor to the navigation system which is important to be able to provide personalized navigation instructions. Other parts of the system are being developed in parallel as separate master theses.

2.3 Analysis of development tools

In this Section is described analysis of development tools for the tool supporting people visiting hospital. As the tool is in a form of a web application, there are plenty of technologies available for development. Despite this wide range of technologies all of them are based on combination of HTML[1], JavaScript[2] and CSS[3]. In today's world there are huge amount of frameworks for creating a web applications but the majority of them are focused on development of the non-visible (back-end) part of the system. For our case it is very important to focus on the design of the front-end and keep the application simple, easy to use and suitable for visually impaired users. As the design of the tool is an iterative process from the very first mock-up to the final design it is important to make quick changes in the prototype. Those requirements rules out all

[1] https://en.wikipedia.org/wiki/HTML
[2] https://en.wikipedia.org/wiki/JavaScript
[3] https://en.wikipedia.org/wiki/Cascading_Style_Sheets

heavy-weight solutions designed mainly for the application's back-end with only partial support of creating front-end.

To satisfy aforementioned requirements pure HTML5 with JavaScript was chosen for the Lo-Fi and Hi-Fi prototype that ensured the application's structure and logic. In the case of the Hi-Fi prototype JavaScript also ensured the data persistence by using Session Storage in client's browser. A set of the HTML pages is easy to maintain and easy to edit for the purpose of the prototype. Another big advantage is that the prototype can be tested on any computer with any browser.

The most important part of the development process is to focus on the styling of the presentation layer. The front-end has to be fully accessible and responsive to be able to use it even on mobile devices across all major browsers. To achieve that the most suitable form of doing that is to apply Bootstrap framework[1]. Bootstrap is a framework developed mainly for the styling of the HTML pages using CSS3 with support also for JavaScript. The main advantage of this framework is that it provides build-in graphical user interface (GUI) scaling for all type of devices, browsers and screen dimensions. It is really easy to use — it employs the grid system sustaining of the 12 columns and unlimited number of rows. Each element is then positioned in the grid and styled according to the HTML attributes — mainly by use of prepared Bootstrap's classes that specify position and visual appearance of the component. The next advantage is that there exists a Bootstrap accessibility plugin[2] providing even better support for screen readers such as accessible modal dialogues and appending necessary ARIA[3] roles and states.

Regarding the final design of the prototype it is necessary to improve Hi-Fi prototype and ensure basic security such as validation of the forms not just via JavaScript and replacing Session Storage as the persistence layer by a database. There are plenty of types of databases but the most common and again lightweight solution for our purpose is the SQLite[4] database. To be able to communicate with the database not just from the proposed web application but also from the smart kiosk and other parts of the In-hospital navigation system it is necessary to provide service which will provide REST[5] API for communication with the database. To ensure basic security the validation of data must be handled also on the back-end side — REST service must not accept data that were not validated. For the implementation of the web application was selected Java EE platform with JAX-RS[6] framework that provides API for RESTful services. The main advantage of this setup is that whole web application (front-end and back-end) can be deployed as single artifact to an application server.

2.3.1 Accessibility on the web

The accessibility on the web is widely discussed topic in last years. It is necessary or even enforced by law in some countries that the important websites such as government institutions has to fulfill standards of the accessible web [13]. It is essential in order to provide equal access and equal opportunity to people with disabilities. There is not standardized tool for creating fully accessible websites as the requirements often vary depending on the website purpose and content. The best way how to create a good accessible web is to read through all standards and evaluate if you have to use them or

[1] http://getbootstrap.com/
[2] https://paypal.github.io/bootstrap-accessibility-plugin/
[3] https://developer.mozilla.org/en-US/docs/Web/Accessibility/ARIA
[4] https://www.sqlite.org/about.html
[5] https://en.wikipedia.org/wiki/Representational_state_transfer
[6] https://jax-rs-spec.java.net/

not depending on the website's purpose. It is also really important to perform usability test during the development of the website or at least consult with visually impaired users. If there is no possibility to do that, developer should use a screen reader to "listen to the website" and use only a keyboard to navigate on the website and try it from visually impaired user perspective. It is important to say using a screen reader for the first time can be confusing. It requires training to understand how it works, how it is used and controlled.

The main resources of the articles and guidelines how to develop accessible rich internet application are WAI-ARIA [14] and WebAIM [15] sites. Those articles define best practice in the development of the accessible web. Following guidelines were identified as the most important for our web application.

- **Semantic structure**

  As there is a pressure on graphic designers to get pages to look the way they want they often avoid using standard heading elements in HTML. For example heading elements `<h1>`,`<h2>` are in most browsers absurdly large and `<h4>`,`<h5>`,`<h6>` are on the other hand too small. Those elements are crucial for screen readers as they can identify important parts of the page just by processing the HTML. Screen readers also support several shortcuts for the user to jump among the headings to speed up the movement on the page. Pages should be structured in the hierarchical manner as the first degree heading `<h1>` contains the main information of the page. Headings also should never be used to emphasize or highlight an element which is not heading. In those cases `<strong>` and `<em>` elements should be used instead.

  Another important element giving hierarchical structure to a page are HTML lists. There are three types of lists and each of them has rules regarding their use. Unordered lists `<ul>` should be used for list of elements where there is no order of sequence or importance. If there is an order ordered lists `<ol>` should be used instead. Definition lists `<dl>` should be used only for presenting list of definition and its explanations. Empty lists are not valid HTML. In case of definition lists there has to be definition title `<dt>` and definition description `<dd>`.

  To improve orientation in the structure of the page it is necessary to use semantic elements and to provide appropriate ARIA roles to elements that have different role. For example if the link `<a>` is visually presented as a button, there should be `role=''button''` attribute included so the screen reader will recognize element as a button. For the section that contains navigation elements should be placed in `<nav>` element. Also the main content of the page should be placed in `<main>` element. For sections of the page you should use `<section>` element and for header use `<header>` element. This will provide necessary information to a screen reader user about what is the meaning of the par of the page he or she just entered.

- **Links and hypertext**

  Hypertext links are the one of the most used elements of HTML in most cases providing navigation on the website. It is important to realize that some types of hypertext links are more accessible than others, and some type of links are completely inaccessible. First of all, link has to be accessible by keyboard as the visually impaired users uses only keyboard to navigate in website's content. The most common mistake are links that leads nowhere. Links with empty `href` attribute are inaccessible to the keyboard users. Links are also often used to invoke JavaScript functions to display for example drop-down menu. For example link `<a href=''#'' onmouseover=''showDropDownMenu();''>Books</a>` is a bad example of link that is unusable for keyboard users. They are not able to access the drop-down menu

items. One solution is to avoid this implementation or specify real link to another page which will provide the same list of items as the drop-down menu. When an image is used as a link then the alternative text `alt` performs the function of link text.

To achieve good screen reader compatibility and eliminate redundancy it is important to realize that screen reader often read type of the element before its content. For example "Books" link would be read as "link books". It is not needed to include word "link" in the name of the link. Screen reader often uses TAB key to jump to the next link of input field. In those situation is text in between skipped. Therefore, links should make sense even out of the context. Developer should avoid links such as "More" or "Click here". Next recommendation regarding links is to put extra information on the end of the link. For example information that the link will open in a new window should be at the end of the link title not force user to listen the prefix every time. Screen reader also provides shortcuts to display all links present in page. They can be even sorted alphabetically which sometimes helps screen reader users to find specific link. For example if they look for contact information they will look for a link such as "Contact us" or "Contacts". Developers should keep naming conventions of those links and avoid titles like "You can contact us at ...".

As the regular websites often contains navigation links, sub-list of links, corporate icons, site searches and other elements before reaching the main content it is good practice to provide a link to skip navigation. This link should be at the top of the page as it should be read by screen reader as the first one. However, those navigation skipping links are usually breaking design of the page or may even confuse sighted users. Best option is to make this link visible only for screen reader users and make it accessible by TAB key. To achieve that, there are several tricks. The first one is to change a color of the link to the color of the background. The second one is to change a sizing of the link to 0 pixels.

- **Site searches and indexes**

  A page that contains a lot of content that user will probably search in it is important to provide search feature to skip the part of the page user is not interested in. One way is to provide simple search form that should be marked with appropriate ARIA role `<form role=''search''>`. This will allow screen reader users to easily access the search feature. Another approach is to index the content by some key. Alphabetical site indexes should be used for content on a site that can be alphabetically ordered. To navigate to the specified letter there should be for example navigation section with letters which will redirect user to the content starting with given letter. Topical site indexes should be used for content that can be organized by a topic or category.

- **Forms structure**

  Creating accessible forms is critical — especially on the sites where user has to fill in some form in order to accomplish the desired task. Forms should be organized in a logical manner. Important think is to provide instructions, cues and field formatting requirements. It is also important to indicate required input fields. It is important to make all form input fields accessible with keyboard. In some cases JavaScript can make form unusable so developer has to be careful while manipulating data in form, setting focus and changing elements. The next very important think is labeling of the form controls such as check box or radio button. It is important to associate text label to a form control with a `<label>` element. Use `<fieldset>` element to group form controls with description of the group by using `<legend>` element.

To make form controls accessible it is important to match label with control by using `for` and `id` attributes. Because `id` attribute must be unique on each page only one label can be associated to each unique form element. Screen readers does not support multiple labels that are associated to the same form element. For select menus is not recommended to use `<optgroup>` element as it is not fully supported by some user agents and screen readers. Developer should also avoid select menus that supports selection of multiple items. Set of check box options should be used instead as they provide similar functionality and they are more accessible.

If it is necessary to provide a label or a description to a form control but it is not needed to be visible for sighted users, there are three ARIA attributes that can help with that. Attribute `aria-labelledby` overcomes the 1 to 1 limitation of the `<label>` element. Multiple form controls then can be labeled by one one element. Important note is that if control has both `<label>` and `aria-labelledby` associated then `aria-labelledby` text will override and be read instead of the associated `<label>`.

If it is necessary to include an information to a form control but it is not exactly a label `aria-describedby` attribute can be used. This can be useful in situations where is need for additional information such as "Password must be 6-20 characters long and include at least one number". This attribute also overrides 1 to 1 limitation so it can be used for multiple form controls. The main difference from `aria-labelledby` attribute is that `aria-describedby` does not override `<label>` element and is always read as an addition to the label usually after a short pause. To make labels invisible to the sighted users use `class=''hidden''`. The label will be still read by the screen reader but will not appear visually.

- **Form validation and error recovery**

  To make forms user friendly and easy to use the first rule is to accept multiple versions of the field format if there are some. For example if the user enters the day of the birth as "7", "7.", "07" or "07." the good system should accept all version of input not to worry user about specific format. Considering the validation of the form there should be always a true URL action value in case the scripting is disabled on the client-side. Always use `<form action=''submit.php'' onsubmit=''return validateForm();''>` instead of `<form action=''#'' onsubmit=''validateForm();''>`.

  If the validation fails it is important to ensure usable and accessible error recovery. At first, alert the user to the presence of an error in an apparent and accessible manner. Then allow the user to easily access the form controls that need to be modified. After all modifications allow the user to submit the form again for revalidation. There are 3 ways how to meet those requirements.

  1. *Error alert, then focus*

     The first one starts with informing user about the presence of an error. This error message should be visible, informative and directly accessed for example by displaying alert box or accessible modal dialog. The dialog should contain `role=''dialog''` attribute. Once user is informed about the error a focus is given to the invalid control. The advantage is that the user is informed immediately and can easily resolve the issue. The disadvantage is that only one error is handled at time. This approach can be adjusted to display all errors in dialog and set focus on the first invalid field.

2. *Errors on top*

   The second one starts with informing user about the presence of an error by writing error details before the form on top of the page. The focus is set on the error message so the screen reader user will hear error details before he or she enters the form again. The advantage is that information remains on the page so user does not have to remember which field has to correct. It is also recommended to provide quick access from the error message to the appropriate input field by link which sets focus on this field.
3. *Inline errors*

   The third one starts with setting focus to the first field where error occurred. Description of an error is present next to the control associated for example by `aria-describedby`. The advantage is that the information of what is wrong appears in context of the control. The disadvantage is that user has to go through the form to find out which controls are invalid.

Regardless of the used approach the form controls which were identified as invalid has to be marked by adding attribute `aria-invalid=‘‘true’’`. This attribute is recognized by screen readers and interpreted as an invalid input field which needs an attention.

- **JavaScript event handlers**

  Event handlers which are used for dynamic changing of the HTML document can be sometimes inaccessible. Some event handlers are dependent upon use o the mouse or keyboard — these are called device dependent. Event handlers which are triggered by both mouse and keyboard are called device independent. The recommended approach is to replace all device dependent event handlers with their device independent variants. For example `onMouseOver` and `onMouseOut` events can be replaced by `onFocus` and `onBlur` events. If the element is not keyboard-navigable it can be overridden by adding and specifying `tabindex` attribute. `onClick` event is device independent only if it is used on the link or form control by pressing ENTER.

2.4 Summary of the analysis

Analysis has shown that there are several indoor navigation systems that can be used in hospital. However, all of them requires to have or carry some device (often a smartphone) which is not suitable for seniors. The proposed In-hospital navigation system has shown to be the best option in comparison to others. The proposed navigation system and its parts has been described as well as the workflow of the navigation process. Analysis of development tools has shown that the most suitable technology for prototype creation is pure HTML5 in combination with the Bootstrap framework and JavaScript. Those technologies were selected as the accessibility of front-end is crucial. Analysis also discussed the most important guidelines that should be followed while creating accessible web application.

Chapter 3
User research

In this Chapter is described preparation, course and results of the user research. To collect data qualitative user research approach was used. One-to-one in-depth semi-structured interviews [16] were selected as they are the most suitable method for gaining user insight for UCD. Interviews were conducted with individuals from target audience selected by the screening process.

3.1 Goals of the research

The main goal of research is to find out how people prepare before going to hospital and what is the main purpose of visit. To determine functional and non-functional requirements for the In-hospital navigation system it is important to answer these questions:

- *What is the main purpose of hospital visit?*
  This is important question to determine reasons why do people visit hospital. It will give us an answer what is the motivation to visit hospital and what situations usually leads to hospital visit.
- *What type of transport do they use to get to the hospital?*
  This is important to find out what means of transport visitors usually use. It is also important to determine how the current situation affects their selection of means of transport.
- *How do they exchange information with doctors/hospital?*
  This is important to determine which information are handed over the patients and the hospital. Also what communication channels do visitors use.
- *How they prepare for hospital visit?*
  This is important to find out what are visitors used to do before visiting hospital. It is also important to find out where the gather information about the hospital and how they prepare for a visit.
- *What is the most frustrating factor while preparing for hospital visit? How people alleviate their fears from visit?*
  This is important to identify the most common fears and stressful factors that affect visitors. It will give us an idea where is the room for improvement to reduce visitor's stress.

3.2 Target group

Target group of this research are individuals that have difficulties with navigation and orientation in indoor and outdoor environment. Navigation and orientation in a hospital environment can be challenging for people with limited ability to orient themselves — especially for visually impaired and elderly people. Target group consists of 2 main subgroups:

- **Seniors**

  The most frequent group of hospital visitors are seniors. This is supported by statistical data from 2012 provided by Czech Statistical Office[1] and Institute of Health Information and Statistics of the CR[2] where 60.66% of all hospitalized individuals (except newborns) were 65+ years old [17–18]. The number of hospitalized individuals per thousand people sorted by age groups in CR (2012) is depicted in Figure 3.1. Generally, with advanced age number of health problems increases, so they visit hospital more often than other age group. Seniors have also very often problems with vision or mobility. Mobility problems have a huge impact on preparation of travel to hospital. In hospital itself, there is problem with vision quality and orientation abilities as the hospital buildings are large and often distributed into several buildings.

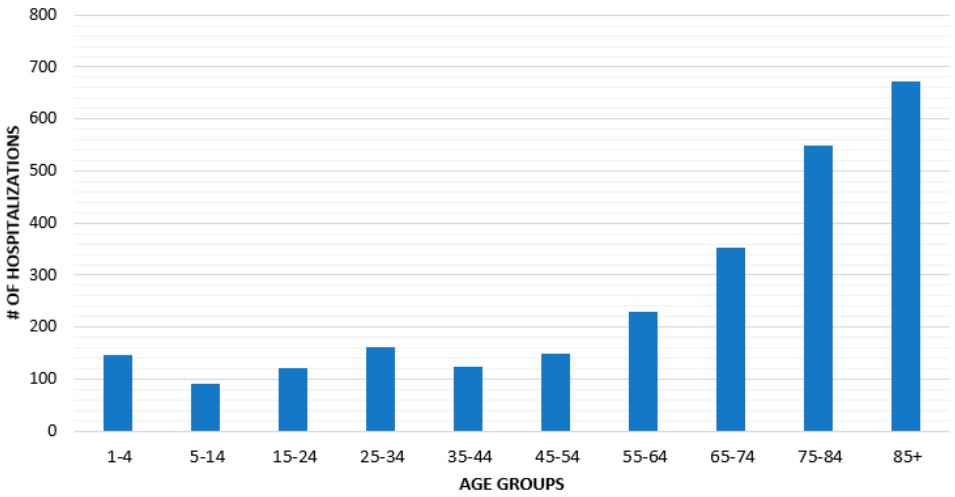

Figure 3.1. Number of hospitalized individuals per thousand people sorted by age groups in CR (2012) [17–18].

- **Visually impaired**

  A special group of hospital visitors which system should support are visually impaired individuals. There are no exact statistical data about the number of visually impaired individuals. According to World Health Organization [19] 285 million people are estimated to be visually impaired worldwide — 39 million are completely blind. Their condition requires thorough preparation before going to a hospital. They usually search for information on several places before going to hospital itself. They also usually requires assistance or accompaniment by another person. They also need support in the hospital building, especially when they visit it for the first time. Also the problem is that hospital buildings are complex with unexpected obstacles.

3.3 Screener

The goal of screening process is to provide relevant target group sample based on the target group description. With representative sample is then conducted a semi-structured interview that will provide some answers for the main research questions. There are also criteria for each question stating desired number of participants needed

[1] https://www.czso.cz/csu/czso/home
[2] http://www.uzis.cz/en

for each answer. The goal was to conduct an interview with six participants. Three of them were expected to be visually impaired and three of them expected to be seniors.

Question number	Question	Answers	Criteria
1	What is your age?	○ 20 or less ○ 21-40 ○ 41-60 ○ 61-80 ○ 81 or more	3x [61+] 3x visually impaired of any age
2	What is your gender?	○ Male ○ Female	3x [Male] 3x [Female]
3	What is your marital status?	○ Single ○ Married ○ Widowed	At least one from each group
4	Where do you live?	○ In a village (less than 20 000 residents) ○ In a city (20 000 – 80 000 residents) ○ In a big city (more than 80 000 residents)	At least one from each group
5	Which mean of transport in a city do you prefer?	○ Own car/motorcycle (I am a driver) ○ Public transport ○ Walking ○ Other	1x [Own car/motorcycle] 5x [Public transport]
6	Are you in touch with your relatives?	○ Yes, we meet regularly (at least once a month) ○ Yes, we meet once in a while ○ No	At least one from each group
7	Do you have vision problems?	○ No, I can see well ○ Yes, I have glasses but I can see pretty well without them ○ Yes, I have glasses but I can hardly see without them ○ Yes, I am blind	3x [blind] 3x [with glasses]
8	Do you have motion problems?	○ No, I can move without problems ○ Yes, but I can move unaided ○ Yes, I need assistance to move	At least one from each group
9	When was the last time you visited hospital?	○ 0-6 months ago ○ 6-12 months ago ○ Few years ago ○ I have never been to hospital	No more than year ago
10	Hospital visit is for me....	○ Nice time ○ Problem-free ○ Stressful time	Stressful or problem-free
11	How far is your nearest hospital?	○ Hospital is in a city I live in ○ Hospital is in city nearby (0-30km) ○ Hospital is in a city far from my home (more than 30km)	At least one from each group
12	Do you currently suffer from any health problems?	○ No, I am in good health ○ Yes, but I do not visit any doctor ○ Yes, I visit doctor regularly	Everyone with medical problems

Figure 3.2. Screener used for selection of participants for an interview.

Interviews were successfully conducted with three seniors and three visually impaired participants. There was limited number of potential senior participants so selected sample did not match all criteria defined in screener. However, most of the criteria were successfully satisfied so the sample can be considered as representative for qualitative research. Visually impaired participants matched almost all criteria defined in screener which was really good especially when the number of participants was limited. Visually

impaired participants were hired by the Department of Computer Graphics and Interaction (DCGI) which also provided financial resources as the reward for participants.

3.4 Interview preparation

The interview was designed as a semi-structured interview. There was a set of topics and questions prepared for an interview but it was not so important to stick to these topics. Important part of a semi-structured interview are follow-up questions which usually provide deeper insight into a problem — mainly on the hidden feelings. Another important part of an interview is briefing and debriefing. When participant arrived to an interview there was always time for introduction and ice breaking. Participant was familiarized with the In-hospital navigation system project. Participant was always asked if it is fine to make a recording of an interview and assured of anonymity. At the end of an interview, participant was assured that he or she really helped to contribute to the research. There was also space for any further questions. All interviews with senior participants took place at their homes. All interviews with visually impaired participants took place at CTU - Faculty of Electrical Engineering at Karlovo náměstí. For every interview was maximum time frame one hour but interviews were usually slightly shorter.

An interview script:

- Briefing (10 min)
  - Introduction and ice breaking
  - Getting to know participants with the course of the interview
  - Anonymity assurance and agreement about interview recording
  - Space for questions
- Interview topics (40 min)
  - Basic information about participant
    - How old are you?
    - Where do you live?
    - Do you work or are you retired?
    - What is your marital status?
    - Do you have any friends which with you meet regularly?
    - How good is your orientation in space? Have you ever got lost?
  - Health problems
    - What health problem do you have if any?
    - How your health problems affect/restrict you?
    - How often do you visit a doctor?
  - Relation to a modern technology
    - What is your relation to computers?
    - What is your relation to mobile phones?
    - If you use computer or mobile phone what do you use it for?
    - Do you use computer or mobile phone for trip planning?
    - Have you ever looked for an information about any hospital on internet?

- Last hospital visit
  - When have you been in a hospital for the last time?
  - What have led you to visit a hospital?
  - Which hospital it has been?
  - How long have you been in hospital?
  - How often do you visit hospital?
  - Have you ever visited other hospitals? Which one?
  - Do you have any story connected with hospital visit?
- Visit preparation
  - Have you prepared somehow before going to the hospital?
  - What have you had to manage before going to the hospital?
  - Have you got any instructions before hospital visit?
  - If so, what instructions and from whom? Have you followed them?
  - Have somebody helped you with visit preparation?
- Trip to hospital
  - How have you transported to the hospital?
  - Have somebody helped you during trip to hospital?
  - Have been there any problems during the trip?
  - Who was the first person you have talked to when you got to the hospital?
  - Would you do something different the next time you go to the hospital?
- Orientation in hospital
  - How have you orientated in a hospital?
  - Who have you talked to during the hospital visit?
  - Have you found everything in a hospital?
  - Have somebody helped you with orientation in a hospital?

- Debriefing (10 min)
  - Thank participant for an interview
  - Make participant sure that he or she was huge contribution to the research
  - Space for questions
  - Saying goodbye

3.5 Interview analysis

In this Section is described analysis of all conducted interviews. Each participant has its brief description based on the screener 3.2. Then, there is a shorten interview transcription based on the interview script topics 3.5.

3.5.1 1^{st} participant (S1)

Short profile of participant: The first participant is a woman, 72 years old senior. She is single and she lives in Loket (small city with about 3,000 residents). She mainly walks around the city and uses train when she has to get to the bigger city. She meets with relatives and friends regularly, about every two weeks. She uses glasses but mainly for reading. She has no difficulties with movement even for long distances. The last

time she was in a hospital was about half year ago. Hospital visit is very stressful for her. She has the closest hospital in a city approximately 30 km away from home. She regularly visits a doctor.

Interview transcription: Participant has not a big problem with vision. She can see pretty good without glasses but she has glasses for reading. The doctor advised her to buy pills so the vision get better but she refused that as the pills are too expensive for her (500 CZK). She said she rather save money for traveling. Despite her age she is very active. She goes for 10 km walks almost every day. She has never got lost in a manner that she could not find her way back. She said she sometimes goes opposite direction but she recognizes soon that she has to go another way. She does not own a computer but her daughter does, so she sometimes work with it. She uses the computer to find things on the internet, to write letters and memories from her travels. She also uses the computer to sort pictures from her digital camera. She has also a feature phone with buttons which she uses for making phone calls and SMS messaging. He has never searched for any information about hospital on the internet.

She has been in a hospital several times — mainly because of surgery. The last time she has been in a hospital was because of a hand surgery. She has been at senior consultant of surgical ward with her hand and he recommended to go to surgery. She had to visit all examinations required for the surgery which was really stressful for her. She had low level of potassium in blood so she had to visit doctor several times until bloods results got better. Her doctor had a vacation, so she had to go for blood examination to an another doctor where she did not know it. Her first surgery ever was several years ago when they had to remove her uterus. She was so afraid of the surgery that she even wrote a goodbye letter for her that time 18 years old daughter what she should do. She eventually did not gave her the letter but she hid it somewhere in the flat and after successful surgery he threw it away not to scare her daughter. Now her daughter works in Karlovy Vary hospital so she helps her a lot when she has to go somewhere.

So far she used only train to travel to Karlovy Vary from the city where he lives. Then, she walks to the hospital from the train station or some of relatives gives her a lift by car. She prefers train as she has train for free. When she first got to the hospital she usually talked with someone at the reception, with a nurse or with her daughter who accompanied her. She has bad experience with waiting in a hallway until she has been admitted to hospital for surgery. She had to be there early in the morning (around 7 o'clock) but was not accepted until 11 o'clock. She had to carry all the documents from doctors with herself. She found orientation even in a small hospital very hard and without daughter she would not find anything. If she would not have daughter in the hospital to help her she would ask someone for direction. She has never been in a big hospital such as Motol in Prague but she had problems even in a small hospital.

3.5.2 2^{nd} participant (S2)

Short profile of participant: The second participant is a man, 69 years old senior. He is married and he lives in Karlovy Vary (middle-sized city with about 50,000 residents). He uses mainly the public transport to move around a city. He meets with relatives and friends regularly, almost every week. He uses glasses — one pair for a reading and other that he wears all day. He can see without glasses but the vision is very limited. He can move without any help but only for short distances. His right leg is weaken from the time he had to have spine surgery. The last time he was in a hospital was

about five years ago. Hospital visit is a stressful experience for him. He has a hospital available in a city where he lives. He regularly visits a doctor due to several diseases.

Interview transcription: Participant has big problems with vision — the right eye can process only shadows and the left eye has 5 diopters. He can hardly see without glasses. He has also hearing ability reduced by 50%. For short distances he walks until the leg let him. He visits his doctor every 4 months because of pills prescription. He has been lost several times. He travels a lot even to foreign countries and despite he cannot speak any foreign language he has always found himself again. He actively uses a computer for internet browsing and for trip planning. He has also a feature phone with buttons which he uses for making phone calls and SMS messaging. He has never searched for any information about hospital on the internet.

He has been in several hospitals, mainly because of surgery. His worst surgery was the spine surgery which consisted of several weeks traveling from one small hospital to another small hospital where they could not help him. He ended up in a hospital in Ústí nad Labem where he finally had a surgery. He has used train to arrive in the very first hospital but then he was transported by an ambulance. Before every surgery (not the urgent one) he had to visit a health center where the diagnose has been stated and he has been recommended to visit a specialized doctor. This doctor gave him a recommendation for a surgery and then he had to visit several doctors to make the necessary examinations before surgery. He did not mind to visit these doctors as he is already used to it. Much more annoying was waiting on the hallway even for a half a day for an admission. He has always carried documents (e.g. blood results) from all the examinations which he had to bring to the hospital. But again, he did not mind it as he is already used to it.

So far, he has used mainly public transport to travel to hospital. Sometimes someone from the family gave him a lift by car if it was possible. When he entered the hospital he usually talked with someone at gatehouse, reception or with a nurse. When he did not know where to go he has always asked someone for help. This is what he would do always — he prefer the human contact instead of deciphering signs. Experience says that he has to usually ask several times before he finds what he was searching for. In small hospitals (as the one in Karlovy Vary according to his words) he had no problems with orientation. He has visited once the Motol hospital in Prague. He was there to visit a relative who was on surgical ward. His son gave him a lift to the side entrance of the hospital and he asked for direction immediately. He could not find it anyway because the person he was looking for was in the woman's section despite he was a men due to lack of space on the man's section. He had to call to the relative he was looking for who described him the path step-by-step. He compared Motol hospital to a huge meat processing plant. He pointed out that he finds colored floor navigation lines very useful but there were no lines at the side entrance.

3.5.3 3^{rd} participant (S3)

Short profile of participant: The third participant is a woman, 68 years old senior. She is married and she lives in Karlovy Vary (middle-sized city with about 50,000 residents). She uses mainly the public transport to move around the city. She meets with relatives and friends regularly, almost every week. She can see pretty well without glasses but she has one for long distance. She can move without any help but only for a short distances because of joint ache. The last time she has been in a hospital was about a month ago with an injured ankle. Hospital visit is a stressful experience for her. She has a hospital available in a city where she lives. She regularly visits a doctor due to several diseases.

Interview transcription: Participant has glaucoma but she can still see without glasses pretty well. She has glasses only for a long distance. She usually walks to nearby grocery store and to nearby bus stop. She avoids long distance walks because she suffers from a joint ache. She visits eye specialist 4 times a month because of glaucoma. She can hardly orientate in space — she has got lost even during mushroom picking in the forest where she has been many times. She has found herself when she found familiar river. She does not use any modern technology. She cannot use computer and she does not have ambition to use it — she just simply does not need it. She has husband that can work with computer so she asks him if she want to find something on the internet. She has also feature phone with buttons which she uses for making phone calls and SMS messaging. She carries it with her everywhere. She does not travel anywhere outside the city where she lives so does not plan long trips. To plan trip in a city she uses paper form (printed by her husband) of public transport schedule.

The last time she was in a hospital was about a month ago with an injured ankle. She fall when she was on her way home from dentist. At home she tried to reduce pain but nothing helped so she called her son to drive her to the hospital for X-ray. If she would not have injured ankle she would use public transport to go to hospital. She has been in a hospital also for a hernia surgery. She has started with visit of her general doctor who gave her recommendation for a surgery. With this recommendation she went to hospital to obtain surgery date. The doctor in hospital told her which examinations she has to go through before surgery. Se was able to do all these examinations in a health center. Once, she was in a hospital with gall bladder surgery. She has very bad memories about this one because at first they did not know that the reason why she had yellow skin. So hospital placed her for two weeks to isolation ward with hepatitis patients. She was mainly afraid of getting hepatitis from other patients. The surgery was delayed several times and in that time she has suffered another gall bladder attack. These attacks caused pancreas upset so they wanted to send her home again to calm pancreas. Because she had childcare arranged for a specific time she insisted to go to surgery as soon as possible.

So far she used mainly public transport to go to the hospital or someone from relatives has driven her by car. The first person she has always talked to was a nurse at the emergency or a doctor. Then, she has been handed over to the orderly which took her to the room. She also said that hospital in Karlovy Vary is not so big so she knows where the main entrance and emergency is. She has been once in Motol hospital in Prague. She was there to visit relative with her son, but even though he is from Prague he could not find right way either. They got to the desired ward with help from other nurses in hospital and signs. She said she would never find it by using only signs she would ask and ask until she reaches the desired destination.

3.5.4 4^{th} participant (V1)

Short profile of participant: The fourth participant is 40 years old vision impaired woman. She is single and she lives in Prague. She uses mainly public transport to move around a city. She meets relatives and friends regularly. She does not have any trouble with movement but she is blind. The last time she has been in a hospital was a month ago. Hospital visit is problem-free for her. She regularly visits a doctor due to several diseases.

Interview transcription: Participant has a diabetes and is blind. She has lost her sight due to diabetes time ago. Because of her health condition she uses modern technologies a lot. She has worked for a half a year after internet marketing course from

home thanks to the computer and mobile phone. She uses JAWS[1] as a screen reader mainly for the web browsers. She has feature phone which she uses for making phone calls and SMS messaging. She uses computer mainly for trip planning. Her most favorite website for planning is IDOS[2]. She said that it is perfectly designed for visually impaired people. When she goes somewhere she does not know it she search for an address or bus stop in "Contacts" section. Then, she uses IDOS for searching public transport connections from home to the destination. She used to use Navigation center for blind[3] but she does not use their assistance anymore. She said she can find connections by herself on the internet now and she even believes that their services are now paid. She used to use it when she traveled somewhere on the other side of Czech republic where she did not know it at all. Now she travels with someone or prepares by herself. She also asks a lot people in the field. Sometimes someone does not have time to help her but people are mostly willing to help.

She goes to the Motol hospital regularly every two months and to the hospital at Karlovo náměstí. She has been visiting Motol since she was young so she can navigate without any problems. She told that hospital at Karlovo náměstí is really large so she knows only one learned path. She has also been in hospital Na Bulovce to visit her mother. Despite the fact she has been there for the first time her mother had not told her on which ward she is (on purpose). She had to visit two different buildings to find out where her mother is. She noticed that hospital staff does not know how to navigate visually impaired people as they used expressions like "the building over there". The most helpful were other visitors in hospital. She uses mainly public transport to go to the hospital. The time when she went for an eye surgery her vision was pretty good so she did not have to prepare. Now the problem is with all the documents from the doctor. Nurse or relatives have to read it for her.

3.5.5 5^{th} participant (V2)

Short profile of participant: The fifth participant is 40 years old vision impaired man. He is married and he lives in Prague. He uses mainly public transport to move around a city. He meets relatives and friends regularly. He does not have any trouble with movement but he is blind. The last time he has been in a hospital was around 4 years ago. Hospital visit is problem-free for him. He does not visit any doctors regularly.

Interview transcription: Participant is blind from birth. He does not have any other health problems. He uses modern technologies on a daily basis. He uses his computer mainly for work. He uses JAWS as a screen reader. He also has feature phone with buttons and iPhone for work. He has tried once smartphone with Android and he found out that it can be also used pretty well so he might buy one in the future. He uses his phone to make phone calls, send SMS messages and emails. He also uses his phone for an internet access. However, he does not use smartphone for trip planning. Before he goes somewhere he does not know it he let someone to describe the path for him. He usually records instructions on his phone which he has by his side all the time. He also tried Google navigation but it does not warn blind people of any problems on the way.

He has been in hospital several times but always to visit someone. He has been in Motol hospital once alone to visit his wife. He used bus to get there and he asked someone to lead him to the entrance from the bus stop where his wife waited for him. He also visited Vinohradská hospital several times but he had an accompaniment. I

[1] http://www.freedomscientific.com/Products/Blindness/JAWS
[2] www.idos.cz
[3] http://navigace.sons.cz/

asked him to imagine that he has to go to the hospital on his own. He would try to find out as much information as he could. He would ask for names, hospital ward and address (bus stop). He would call a lot to find out these information. He mainly uses public transport to move around city but sometimes someone gives him a lift by car. Once, when he had to go to hospital on his own and he had not time to plan trip, he called a taxi. The taxi driver dropped him off in front of the entrance and then he asked someone from hospital staff for a help. At the end he added comment about how large hospitals are. Similar hallways with lost of turns where is really hard to orientate in.

3.5.6 6^{th} participant (V3)

Short profile of participant: The sixth participant is a 44 years old vision impaired man. He is married and he lives in Prague. He uses mainly public transport to move around a city. He meets relatives and friends regularly. He does not have any trouble with movement but he is blind. The last time he was in a hospital was several years ago. Hospital visit is problem-free for him. He does not visit any doctor regularly.

Interview transcription: Participant is blind from birth. He does not have any health problems. He uses modern technologies on every day bases. He was at the beginning of all readers for blind people. He is also interested in modern technology from the young age. He works as a teacher on school of art. He uses his computer for work and for trip planning. He uses JAWS as a screen reader. He also has feature phone with buttons (Nokia C5) and iPhone. He uses his phone to make phone calls, send SMS messages, as a calendar and notepad. He also uses his phone for an internet access to browse websites. He also uses his phone sometimes to navigate for example from bus stop to the building. He has searched several times for information about hospital on the internet but it was always just basic information such as address. He is also subscribed to RSS feed from Prague Integrated Transport[1] which he checks every time before he goes somewhere. When he has to prepare for a trip he combines Google search website to find out necessary information, IDOS website to search connections and navigation in phone in the field to make navigation more accurate.

He has been hospitalized several years ago in Thomayer hospital. His experience with hospital staff such as doctors and nurses was pretty good. He has been several times to visit someone in a hospital but usually with accompaniment. When he had to go to the hospital by himself he would search for the information on the website of the hospital and then found a way how to get there. He would also try to find out information about the ward and names of doctors. He said that going to the hospital without accompaniment overly complicated, even risky, but not impossible.

3.6 Research results

In this section are summarized all statements (facts) gained during interviews. They are divides into two groups. One group represents senior participant's statements which are shown in Table 3.1. The second group represents visually impaired participant's statements shown in Table 3.2. Each statements has reference to all participants that mentioned it or it flowed out of context during an interview.

[1] `http://www.ropid.cz/rss-kanal__s207x1131.html`

ID	statements	reference to participants
1	cannot walk long distances	S2, S3
2	prefer public transport	S1, S2, S3
3	prefer walking and train transport (for free) to save money	S1
4	wear glasses	S1, S2, S3
5	hospital visit is stressful	S1, S2, S3
6	pre-surgery examinations are frustrating	S1
7	go to hospital by public transport if health condition let them	S1, S2, S3
8	waiting several hours to be admitted to surgery is frustrating	S1, S2, S3
9	has to carry all documents from pre-surgery examinations	S1, S2, S3
10	use mobile phone with buttons	S1, S2, S3
11	use computer with internet for trip planning	S1, S2
12	use paper form of public transport schedule for trip planning	S3
13	have relative working in hospital to accompaniment his or her	S1
14	prefer ask someone for help (reception, nurse)	S1, S2, S3
15	cannot orientate at all in big hospital such as Motol	S1, S2, S3
16	found hospital hard to orientate in	S1, S2, S3
17	prefer human contact instead of signs	S1, S2, S3
18	find colored guiding lines on floor helpful	S2

Table 3.1. Overview of statements related to the seniors gained during the interviews.

ID	statements	reference to participants
1	prefer public transport	V1, V2, V3
2	use computer on daily basis	V1, V2, V3
3	use computer for trip planning	V1, V2, V3
4	use JAWS as a screen reader	V1, V2, V3
5	use mobile phone with buttons	V1, V2, V3
6	use smartphone	V2, V3
7	use phone for trip planning	V2, V3
8	use IDOS for trip planning	V1, V2, V3
9	use white cane	V1, V2, V3
10	search for addresses in contacts section on website	V1, V2, V3
11	use phone for internet browsing	V3
12	hospital staff do not know how to navigate blind	V1
13	documents before surgery reads nurse or relative for them	V1
14	when do no have time to plan use taxi for transport	V2
15	check for extraordinary events in public transport before trip planing	V3
16	hospital are large buildings usually separated to several buildings	V1, V2, V3
17	hospital visit is problem-free routine (in sense that it is not stressful)	V1, V2
18	people are usually willing to help	V1, V2, V3
19	going to hospital without accompaniment is really hard, but not impossible	V3
20	use phone for instructions/path description recording	V2, V3
21	prefer ask someone for help (reception, nurse)	V1, V2, V3
22	found hospital hard to orientate in	V1, V2, V3

Table 3.2. Overview of statements related to the visually impaired gained during the interviews.

Interviews has shown that visually impaired individuals and seniors really do have problems with navigation in hospital. Based on research results and facts extracted from them were created functional and non-functional requirements discussed in Chapter 4.

3.6.1 Motivation to go to hospital

Based on interviews there has been recognized basic scenarios which leads people to visit hospital. The most common reason why to go to hospital is for a surgery. Patient has to visit hospital several times before a surgery as he or she has to arrange date of surgery. There are some pre-surgery examinations which may took place in a hospital. Usually there examinations has to be done somewhere else such as patient's general doctor or doctor at health center. The next common reason why to visit hospital is acute injury. Based on the severity of the injury patient is driven by ambulance to a hospital or he or she gets to the hospital by him/herself. Another common reason why to go to hospital is for an examination such as blood samples taking, visiting specialized doctor or need for specialized examination such as X-ray or CT. The reason which has been mentioned many times in interviews is to visit someone — relative or friend — who is hospitalized there. The last thing that can lead people to visit hospital is local pharmacy as there are usually bigger and sometimes cheaper due to reduced additional charges for medicament.

Based on the statistics provided by the Institute of Health Information and Statistics of the CR there are only 3 main reasons why people are hospitalized. Statistics from 2012 [17] shows that 85.4% of patients is admitted due to medical reason, 10.8% due to "other" reason and only 3.6% due to diagnosis reason. Sadly, this is the only chart connected with reason of admission. As official numbers are not telling much about the reasons why do people visit a hospital we have to rely on knowledge gained from interviews.

Here is a summary of main reasons why do people visit hospital based on interviews:

- admission to a surgery
- date arrangement for a surgery
- pre-surgery examinations
- acute injury
- specialized examinations (e.g. specialized doctors, X-ray, CT, ...)
- visit a relative or friend
- use other hospital services (e.g. pharmacy, canteen, ...)

These reasons were processed and restated to functional requirements of the web application. Those requirements are based mainly on the user interviews and knowledge gained from them.

3.6.2 Information exchanged between hospitals and their visitors

Based on interviews there are just few information type exchange between people visiting hospital and hospital itself. As there is no current solution which supports people visiting hospital the information exchange is limited to very basics. As the hospital visitor goes to hospital he has to know where he is heading to — f.e. name of the doctor or hospital's ward — and the date they should go to the hospital. A hospital visitor can find these information on the hospital's website of he or she finds out the information by using phone. More common scenario is that these information are provided to hospital visitor by another doctor. Hospital visitors has to carry all personal information such as identity and insurance card. Usually they have to carry also all documents such as recommendations, examinations results and medical history.

As the new system for In-hospital navigation is being developed, there are other information that should be handed over between hospital visitors and In-hospital navigation system. System should have all the information required before hospital visitor

reaches its front door. Based on these information provided by visitor itself the system can adjust user interface according to visitor's needs and start step-by-step navigation right away from the very first moment.

Here is a summary of all information handed over between visitor and hospital:

- Basic information exchange:
  - personal information (name, surname, date of birth, personal identification number, address, phone number)
  - insurance company
  - where to go (hospital address, ward, doctor's name)
  - when to go
  - what to carry with (medical history, examination results, recommendation for surgery)
- Additional information exchange required by In-hospital navigation system:
  - motor impairment
  - hearing impairment
  - vision impairment
  - haptic impairment (e.g. cannot read braille)

These information affected the design of the application as they have to be entered by the user. More details about the design process are discussed in Chapter 4.

3.7 Summary of the user research

The user research has shown that main reasons why do people visit hospital are surgery, specialized examinations and visits of friends and relatives who are hospitalized. Both senior and visually impaired respondents have found hospital buildings complex and hard to orientate in. Almost all respondents had a bad experience with hospital visit. They also usually need someone's help to navigate inside hospital. The research has also shown that both seniors and visually impaired prefer older feature phones. Thus, navigation system requiring possession of a smartphone is not usable. The research has also shown that both target groups uses public transport to get to the hospital. Another finding is that seniors does not prepare in advance for a hospital visit. On the other hand, visually impaired visitors search for information about hospital in advance — for example on the internet or by phone. Both target groups prefer to have someone who accompanies them on the way and inside the hospital building. User research has also shown some stressful factors like not be able to find specific destination or wait for a long time in waiting room. Outcomes from user research will be used for the design process covered in Chapter 4.

Chapter 4
Design

In this Chapter is described how the tool for supporting people visiting hospital was designed. All design ideas are based on the qualitative user research discussed in the Section 3.6. The tool has been designed mainly for visually impaired users and seniors by using UCD approach. As the one of the main goals of the tool is to provide information to the In-hospital navigation system about visitor, the tool has been designed as a website service. This decision makes tool unavailable for all people who does not have access to the computer. However, the In-hospital navigation itself will be still available in a hospital but visitor will have to insert all information manually at the main terminal. Qualitative research has shown that visually impaired people usually have computer and uses it for browsing internet, so the visit preparation tool should be available and accessible for them. Also, 2 of 3 senior participants that have been interview also use computer for internet browsing. The fact that every year more seniors use internet is also supported by Czech Statistical Office. In past four years the percentage of seniors (defined as people 65+ years old) who use internet has grown from 16.2% to 28.4% [20]. Another reason why to design hospital visit preparation tool as a website is to be able to use external navigation engine provider for navigation from home to the hospital. It is important to use the existing solution as majority of participants and mainly the visually impaired ones are used to use service such as IDOS[1] which is pretty well designed and fully accessible. Another option that can be used as external navigation is Naviterier [21] which is being developed at FEL - DCGI. Sadly, Naviterier still does not have sufficient coverage of the area to be used as navigation engine. The area between Palackého náměstí and Muzeum in Prague is currently the only one covered.

4.1 Functional requirements

This section specifies functional requirements for the hospital visit preparation tool. All requirements are based on the user research and on the fact that this tool will provide information about visitor and his or her destination to the In-hospital navigation system.

Summary of functional requirements:

- make an appointment at specific doctor
- make an appointment at an examination
- display information about hospital
  - display hospital's address
  - display hospital's contacts
  - display hospital's wards
  - display hospital's doctors

[1] `http://jizdnirady.idnes.cz/praha/spojeni/`

  - display hospital's specializations
  - display hospital's services

- find route to hospital (from given location)
- prepare route to hospital's ward
- prepare route to hospital's doctor office
- prepare route to hospital's other services (pharmacy etc.)
- display information about navigation system
- create a user account
- log in to a user account
- browse previous visitors experience in the forum
- add new experience to the forum
- create "TODO" checklist as part of preparation

4.2 Non-functional requirements

Non-functional requirements are based on the specific needs of target groups. Visually impaired visitors must have website fully accessible. Senior visitors needs to have GUI adopted to their vision limitations. Important is simplicity of GUI even for visually impaired. Website has to be fully functional in every popular internet browser. Also, website should have layout for mobile devices as more and more people use internet in smartphones to browse web.

Summary of non-functional requirements:

- tool is a website based service
- simple and minimalist design
- fully accessible for visually impaired
- friendly for inexperienced senior users
- fully functional on every popular browser
  - Google Chrome
  - Internet Explorer v. 11
  - Microsoft Edge
  - Safari
  - Mozilla Firefox
  - Opera
- fully functional on mobile devices (smartphones)
  - Chrome for Android
  - Android Browser
  - Firefox for Android
  - iOS Safari
  - Opera Mobile
- HTML 5
- CSS 3
- JavaScript

4.3 Concept description

This Section describes the conceptual design of tool for hospital visit preparation. The concept is based on functional and system requirements stated in Section 4.1 and 4.2. The concept of the prototype is to provide the support to people who prepare for hospital visit in a several ways. First of all, tool provides possibility to plan trip to a hospital and to a specific place in a hospital so visitor does not have to worry about how he would navigate inside the hospital. Another way how to ease hospital visit preparation is to provide detailed information about hospital — all the visitor can look for at one place. Tool also provides function to make an appointment with a specific doctor or to a specific examination available in a hospital. This should reduce the waiting time spent in a hallway which was the one of the most painful issues mentioned during interviews. Last but not least tool provides interaction with other system users via user forum where visitor can find helpful tips and tricks and contribute with own experience.

Based on the user research and requirements, tasks can be divided into several subtasks. This hierarchy can be visualized in hierarchical task analysis (HTA) diagrams. The main task is to prepare for a hospital visit. This can be divided into several subtasks such as "Make an appointment", "Find out information about hospital", "Prepare navigation in hospital" or "Read tips and tricks from other visitors". To demonstrate how the task decomposition looks like the "Make an appointment" task decomposition is depicted in Figure 4.1.

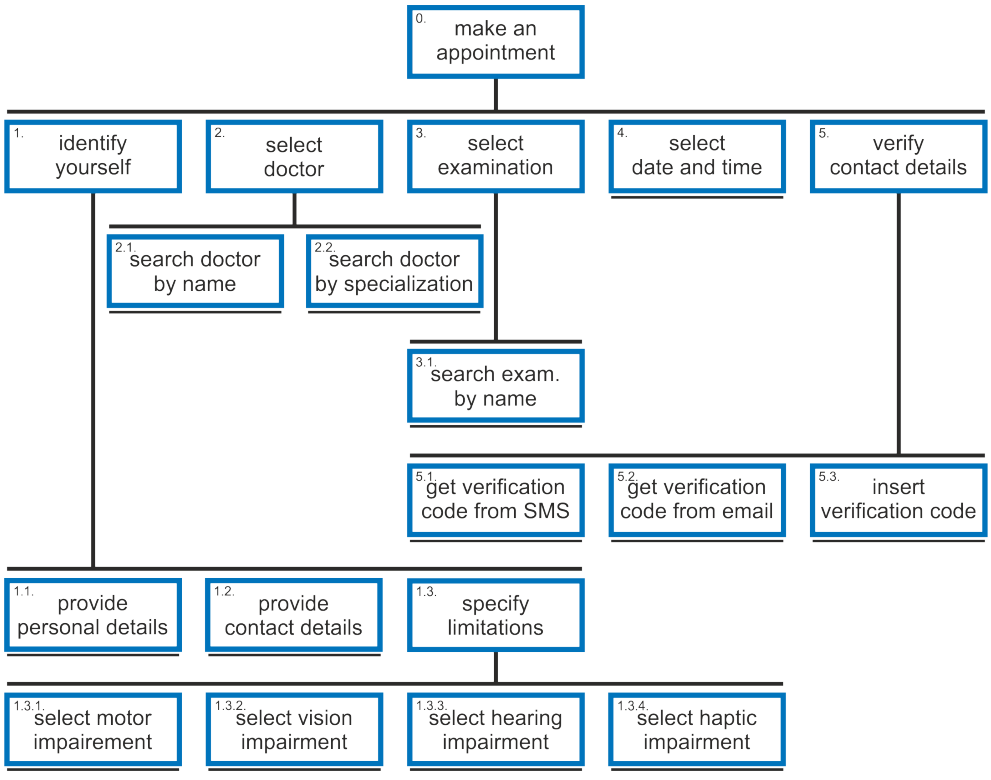

Figure 4.1. The HTA diagram with decomposition of the "Make an appointment" task.

Users interact with the system in different use cases. Those use cases can be represented by a plan of HTA. To demonstrate different usage scenarios of the system there are two possible plans.

1. Completely blind user who wants to make an appointment with a doctor. Assume that user know doctor's name and specialization.
   1.1. → 1.2. → 1.3.2. → 2.1. ∨ 2.2. → 4. → 5.1. ∨ 5.2. → 5.3.
2. A senior with injured ankle and worsen vision wants to make an appointment to an examination. Assume that user knows name of the examination.
   1.1. → 1.2. → 1.3.1. → 1.3.2. → 3.1. → 4. → 5.1. → 5.3.

One of the most important requirements is that the website should be simple, easy to understand and orientate in. That requires that there should be as little as possible information on the page. This is in contradiction with requirement that all necessary information for In-hospital navigation should be provided in advance such as personal information and information about limitations. Complexity of those forms requires to separate them into several steps according to the HTA diagram. Thus, the wizard design pattern [22] was used for user interface (UI).

4.3.1 Wizard design pattern

The wizard UI pattern is well known in the computer world. Almost every program installation, online store purchase or any more difficult task which can be broken down into dependable sub-tasks is usually designed as a wizard. User focuses in each step only on the one goal which is usually accomplish in very short time. User can go only one step back, one step forward or cancel whole task. One of the last steps is usually summary of all previous steps where user can review all inserted data. A preview of how complex task is decomposed into sub-tasks in prototypes is depicted in Figure 4.2. Each step is represented as separate web page in the prototypes where user has to fill-in/select from part of an information.

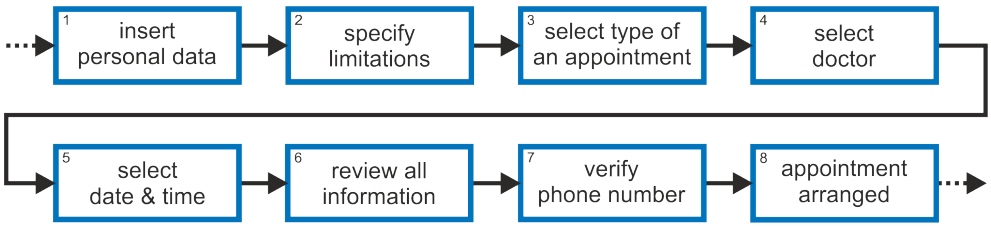

Figure 4.2. "I want to make an appointment with a specific doctor" task decomposed in sub-tasks in wizard UI design pattern.

The main advantage of the wizard is that complex task as "I want to make an appointment with a doctor" can be broken down in several shorter steps. That is perfect for visually impaired users as the website content is short and easy to navigate in. Also seniors prefer this "guide" system as they know where they are and how many steps they have to go through to get the desired result. Another advantage of the granularity is that inserted data can be validated in each step and it does not slow down user to correct mistakes in one long form instead of few fields.

The main disadvantage of the wizard is that it is not suitable for experienced users. Wizard forces user to go through all steps regardless the user previous experience with the system. This disadvantage was minimized by adding possibility to create a user account. Thus, user with created account can log in and skip some steps where information about user is required.

4.4 Mock-up

This Section describes creation of the very first designed solution. The mock-up is based on functional and system requirements stated in Section 4.1 and 4.2. The mock-up has been created with Balsamiq in version 3.3.6[1] within 30 day trial period. As a result for evaluation was created interactive PDF file. Mock-up does not cover all functionality. It employs only critical scenarios such as trip planning to hospital's specific ward to show the flow design. The main screen depicted in Figure 4.3 consists of big buttons which are easy to understand and clearly visible even for people with slightly impaired vision. Those buttons represents main functionality of the system. There is also "about" section which explains how the system can help to a visitor.

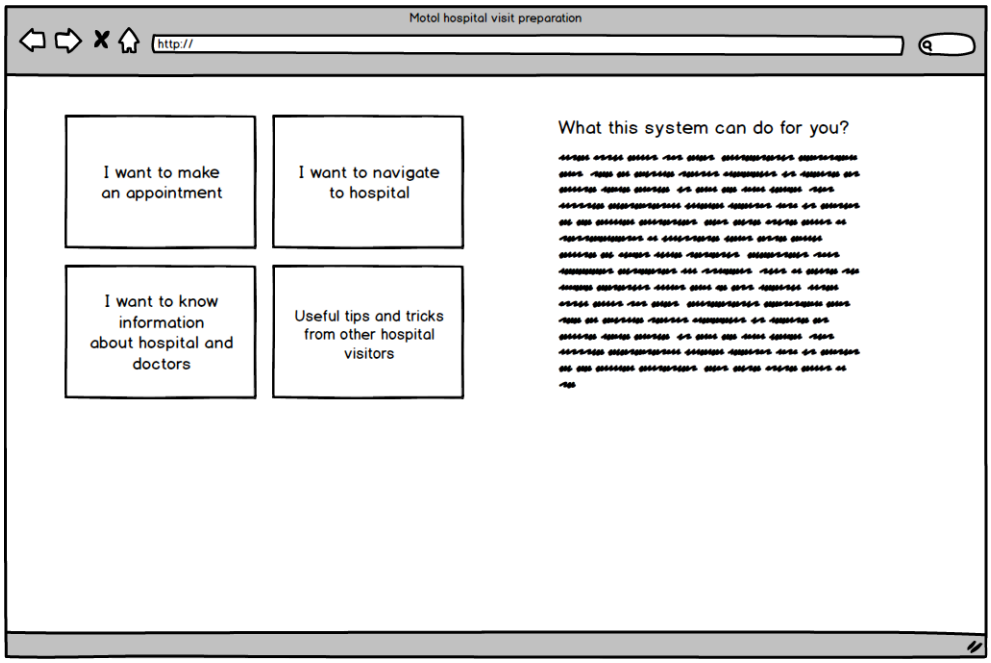

Figure 4.3. Main screen of the mock-up.

4.4.1 Use cases covered by prototype

Two main scenarios were selected to be implemented in mock-up version of prototype. Those scenarios were considered as critical and sufficient for the proof-of-concept evaluation.

Use case 4.1. *Make an appointment with a specific doctor*

- **Actors:** user, system
- **Description:** User wants to make an appointment with a specific doctor for a date and time, when doctor is available.
- **Main flow:**

1. On the main screen user clicks on "I want to make an appointment" button.
2. System displays screen with form for personal data input.
3. User fills in all personal data and contact information and clicks on "Continue to the step 2" button.
4. System displays screen with form for impairment specification.

[1] `https://balsamiq.com/`

5. User specifies impairments by picking options from drop-down lists and clicks on “Continue to the step 3” button.
6. System displays screen with menu for type of an appointment selection.
7. User clicks on “Search doctor by name” button.
8. System displays screen with list of all doctors sorted by last name alphabetically.
9. User clicks on desired doctor.
10. System displays screen with list of available days and times for an appointment.
11. User selects date and time and clicks on “Continue to the step 6” button.
12. System displays screen with summary of all inserted information.
13. User verifies all information and clicks on “Make an appointment” button.
14. System displays screen with input field for verification code and sends SMS message and email with verification code to the contact information specified in step 3.
15. User fills in verification code and clicks on “Confirm an appointment” button.
16. System displays screen with confirmation that appointment is arranged and send information about appointment to the contact information specified in step 3.

Use case 4.2. *Navigate to a specific ward*

- **Actors:** user, system
- **Description:** User wants to navigate to the specific ward.
- **Main flow:**

1. On the main screen user clicks on “I want to make an appointment” button.
2. System displays screen with form for personal data input.
3. User fills in all personal data and contact information and clicks on “Continue to the step 2” button.
4. System displays screen with form for impairment specification.
5. User specifies impairments by picking options from drop-down lists and clicks on “Continue to the step 3” button.
6. System displays screen with menu for choosing the destination type.
7. User clicks on “I want to visit specific ward” button.
8. System displays screen with list of all wards sorted alphabetically.
9. User clicks on desired ward.
10. System displays screen with form for “navigation to hospital” settings.
11. User fills in city and bus stop from where he or she wants to navigate, date, time, whether he or she wants to departure or arrive at filled in time and clicks on “Continue to the step 6” button.
12. System displays screen with summary of all inserted information.
13. User verifies all information and clicks on “Create navigation request” button.
14. System displays screen with input field for verification code and sends SMS message and email with verification code to the contact information specified in step 3.
15. User fills in verification code and clicks on “Confirm an appointment” button.
16. System displays screen with confirmation that navigation in hospital is prepared and provides link to the result of search for connection to the hospital from given place in step 11.
17. User clicks on “Link to the connection search result” link.

4.5 Lo-Fi prototype

This Section describes creation of the Low-Fidelity (Lo-Fi) prototype of the web application. The main concept remains the same as the testing of the mock-up has shown that the tool is usable.

The main difference between the mock-up described in Section 4.4 and the Lo-Fi prototype is that Lo-Fi prototype has been created as an actual web page. The prototype provides the same set of functionality and supports only few scenarios. It has been developed by using pure HTML5 and CSS3 in Sublime Text 3 editor[1]. The navigation among the pages was provided just by using links an buttons. CSS3 was used just to create buttons bigger with hover effects to be easier to recognize by seniors. The main page of the prototype is depicted in Figure 4.4. Due to testing with participants from Czech Republic the prototype has been created in Czech language. Pictures in this thesis are translated to English.

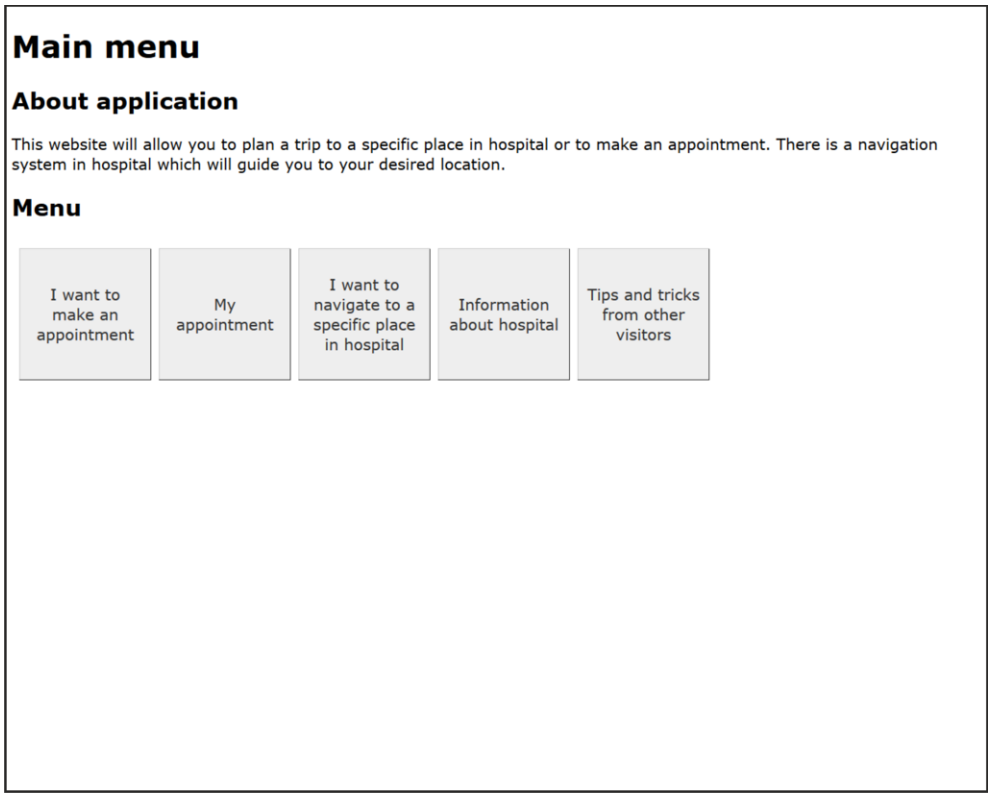

Figure 4.4. Main page of the Lo-Fi prototype.

Majority of findings from the testing of the mock-up summarized in Section 6.1.3 were resolved in the Lo-Fi prototype. All of them were reviewed some of them postponed to the next prototype iteration. For example finding with ID 3 was reviewed and postponed as there was only one participant mentioning that it might confuse someone. If the same issue occurs again with other participants it will be resolved. Finding with ID 10 was postponed to the next iteration as the navigation in long listings will be tested in the next prototype. As the prototype does not send actual verification code the findings with ID 11 was postponed as well.

The main goal of the prototype is to be able to evaluate the design with visually impaired participants and seniors. There were no special ARIA roles created to see how

[1] `https://www.sublimetext.com/`

visually impaired participants interact with regular page. However, the accessibility was still taken in mind during it's creation. The prototype does not support form validation as well as data persistence. All links and buttons are clickable and recognizable by screen reader but some of them leads to the same page as they are placed in. The reason is simple — the prototype supports only two main scenarios. Those false links had to be in the eyes of the screen reader rightful links so the visually impaired user would get the idea of the possibilities of the navigation in page.

4.5.1 Use cases covered by prototype

The set of use cases covered by the Lo-Fi prototype is based on use cases of the mock-up described in Section 4.4.1. There are two main scenarios considered as critical and sufficient to be able to evaluate very first implementation of the proposed design.

Use case 4.3. *Make an appointment with a specific doctor*

- **Actors:** user, system
- **Description:** User wants to make an appointment with a specific doctor.
- **Main flow:**

1. On the main screen user clicks on "I want to make an appointment" button.
2. System displays screen with form for personal data input.
3. User fills in all personal data and contact information and clicks on "Continue - by clicking you agree with personal data processing" button.
4. System displays screen with form for impairment specification.
5. User specifies impairments by picking options from drop-down lists and clicks on "Continue" button.
6. System displays screen with menu for type of an appointment selection.
7. User clicks on "Search doctor by name" button.
8. System displays screen with list of all doctors sorted by last name alphabetically.
9. User clicks on desired doctor.
10. System displays screen with list of available days and times for an appointment.
11. User selects date and time and clicks on "Continue" button.
12. System displays screen with summary of all inserted information.
13. User verifies all information and clicks on "Continue" button.
14. System displays screen with input field for verification code and sends SMS message and email with verification code to the contact information specified in step 3.
15. User fills in verification code and clicks on "Continue" button.
16. System displays screen with confirmation that appointment is arranged and send information about appointment to the contact information specified in step 3.

Use case 4.4. *Navigate to a specific ward from given location*

- **Actors:** user, system
- **Description:** User wants to navigate to the specific ward from given place.
- **Main flow:**

1. On the main screen user clicks on "I want to make an appointment" button.
2. System displays screen with form for personal data input.
3. User fills in all personal data and contact information and clicks on "Continue - by clicking you agree with personal data processing" button.
4. System displays screen with form for impairment specification.

5. User specifies impairments by picking options from drop-down lists and clicks on “Continue” button.
6. System displays screen with menu for choosing the destination type.
7. User clicks on “I want to visit specific ward” button.
8. System displays screen with list of all wards sorted alphabetically.
9. User clicks on desired ward.
10. System displays screen with form for “navigation to hospital” settings.
11. User fills in city and bus stop from where he or she wants to navigate, date, time, whether he or she wants to departure or arrive at filled in time and clicks on “Continue” button.
12. System displays screen with summary of all inserted information.
13. User verifies all information and clicks on “Continue” button.
14. System displays screen with input field for verification code and sends SMS message and email with verification code to the contact information specified in step 3.
15. User fills in verification code and clicks on “Continue” button.
16. System displays screen with confirmation that navigation in hospital is prepared and provides link to the result of search for connection to the hospital from given place in step 11.
17. User clicks on “Link to the connection search result” link.

Use case 4.5. *Navigate to a specific ward in hospital only*

- **Actors:** user, system
- **Description:** User wants to navigate to the specific ward in hospital only.
- **Main flow:**

1. On the main screen user clicks on “I want to make an appointment” button.
2. System displays screen with form for personal data input.
3. User fills in all personal data and contact information and clicks on “Continue - by clicking you agree with personal data processing” button.
4. System displays screen with form for impairment specification.
5. User specifies impairments by picking options from drop-down lists and clicks on “Continue” button.
6. System displays screen with menu for choosing the destination type.
7. User clicks on “I want to visit specific ward” button.
8. System displays screen with list of all wards sorted alphabetically.
9. User clicks on desired ward.
10. System displays screen with form for “navigation to hospital” settings.
11. User clicks on “I want to skip this step and navigate only inside the hospital building” button.
12. System displays screen with summary of all inserted information.
13. User verifies all information and clicks on “Continue” button.
14. System displays screen with input field for verification code and sends SMS message and email with verification code to the contact information specified in step 3.
15. User fills in verification code and clicks on “Continue” button.
16. System displays screen with confirmation that navigation in hospital is prepared and provides link to the result of search for connection to the hospital from given place in step 11.
17. User clicks on “Link to the connection search result” link.

4.6 Hi-Fi prototype

This Section describes creation of the High-Fidelity (Hi-Fi) prototype of the web application. The main concept remains the same as the testing of the Lo-Fi prototype has shown that the tool is usable and there were no critical issues.

The main difference between the Lo-Fi prototype described in Section 4.5 and the Hi-Fi prototype is that Hi-Fi prototype has revamped design. The skeleton of the page is based on the Lo-Fi prototype and improved with many elements and attributes for better accessibility. The design of the page was created by using Bootstrap framework with Accessibility plugin for Bootstrap. The first improvement is form validation. As the prototype contains several forms it is crucial to prevent errors and if they occur, provide easy and accessible recovery. Data are validated by JavaScript which also sets focus to elements that need attention. Overall design remained clean and simple. This is important mainly for seniors. The main page of the prototype is depicted in Figure 4.5. Due to testing with participants from the Czech Republic the prototype has been created in Czech language. Pictures in this thesis are translated to English.

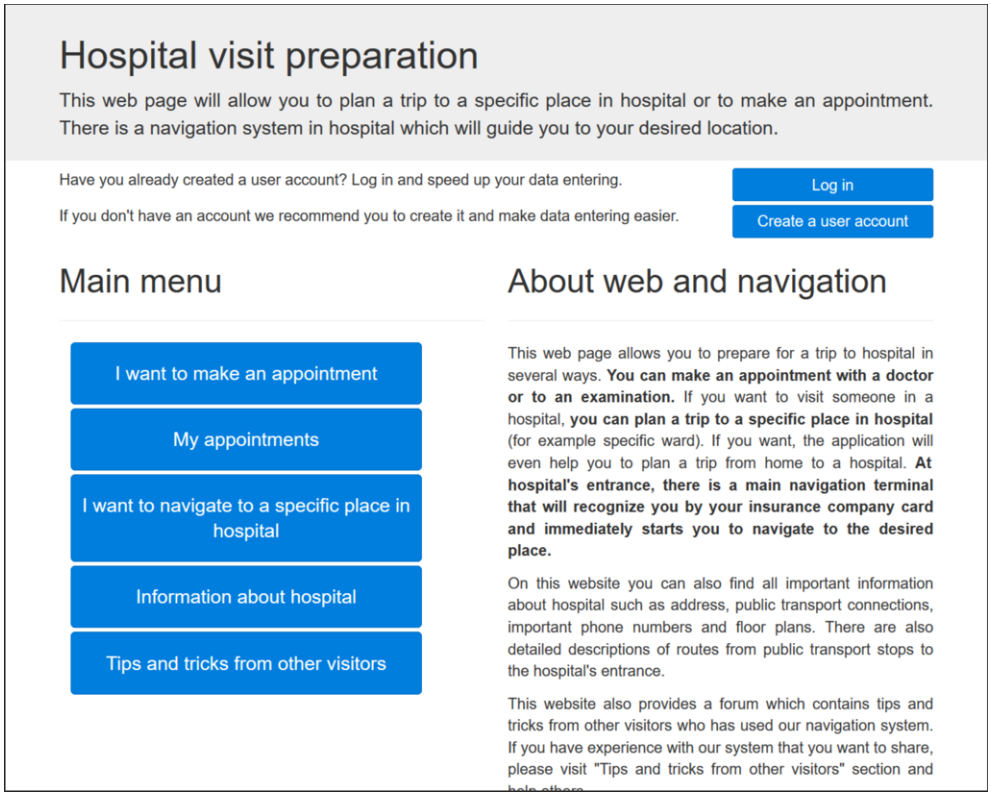

Figure 4.5. Main page of the Hi-Fi prototype.

The next main improvement is data persistence. For the purpose of the prototype Session Storage available in internet browsers was used for data persistence. Application logic was handled by JavaScript only. Data used in prototype (doctors, available hours for appointment, examinations) were made up and dynamically placed in the page by JavaScript. As the Session Storage was used to persist data it is important to say that all data were lost when browser was closed. It was sufficient for the prototype and even better for testing — participants did not have to worry about inserting their personal information as they were lost at the end of the test.

The last main improvement is the support of user accounts. Prototype allows user to create a user account to make data entering faster the next time he or she will use

the system. Also, the user account can be used to easily access all already arranged appointments. As the concept of user accounts might not be known to all users — especially to seniors — it was necessary to provide access to all already arranged appointments without the user account. When user makes an appointment one of the steps is to verify contact details (mandatory phone number, optional email) by entering verification code that has been sent to them. Thus, we can assume that if user has successfully arranged an appointment the system has valid contact details. Then, if user wants to access his or her appointments he or she just enters the phone number and uses one-time access code that system has sent. The phone number is used to distinguish to whom the appointment belongs.

It is important to say that the prototype does not send actual verification code to the phone as this service is paid and not necessary for prototyping. During the test SMS messages with the code were send to participants by moderator to simulate real scenario.

Almost all findings from the previous testing of Lo-Fi prototype summarized in Section 6.2.2 were resolved in Hi-Fi prototype. All of them were reviewed and one of them — finding with ID 8 — postponed to the next iteration. The reason is that we should verify if the same issue occurs again in the next iteration of testing. Fixing this issues requires adding heading elements on the place they should not semantically be. Postponed findings from mock-up testing were also successfully resolved in Hi-Fi prototype.

4.6.1 Use cases covered by prototype

The set of use cases covered by the Hi-Fi prototype is based on use cases of the Lo-Fi prototype described in Section 4.5.1. As those use cases are supported also by Hi-Fi prototype only new use cases are listed in this Section.

Use case 4.6. *Create a user account*

- **Actors:** user, system
- **Description:** User wants to create new user account to make easier access to his or her appointments.
- **Main flow:**
  - *Precondition:* User is not logged in.

1. On the main screen user clicks on “Create a user account” button.
2. System displays screen with form for personal data input.
3. User fills in all personal data and contact information and clicks on “Continue - by clicking you agree with personal data processing” button.
4. System displays screen with form for impairment specification.
5. User specifies impairments by picking options from drop-down lists and clicks on “Continue” button.
6. System displays screen with form for username and password input.
7. User fills in username and password and clicks on “Create a user account” button.
8. System displays dialog that informs user about successful account creation.
9. User clicks on “Continue” button.
10. System creates an account, logs user in and displays the main screen with information that user is logged in.

- **Alternative flow:**
  - *Precondition:* User is not logged in.

1. On the final screen of making an appointment user clicks on “Create a user account” button.
2. System displays screen with form for username and password input.
3. User fills in username and password and clicks on “Create a user account” button.
4. System displays dialog that informs user about successful account creation.
5. User clicks on “Continue” button.
6. System creates an account, logs user in and displays the main screen with information that user is logged in.

Use case 4.7. *Log in to a user account*

- **Actors:** user, system
- **Description:** User wants to log in to his or her user account.
- **Main flow:**
  - *Precondition:* User has user account created.

1. On the main screen user clicks on “Log in” button.
2. System displays screen with form for username and password input.
3. User fills in username and password and clicks on “Log in” button.
4. System logs user in and displays the main screen with information that user is logged in.

- **Alternative flow:**
  - *Precondition:* User has user account created.

1. On the personal information screen user clicks on “Log in and fill in personal data automatically” button.
2. System displays screen with form for username and password input.
3. User fills in username and password and clicks on “Log in” button.
4. System logs user in and displays the personal information screen with all personal data filled in from account.

Use case 4.8. *Log out from user account*

- **Actors:** user, system
- **Description:** User wants to log out from his or her user account.
- **Main flow:**
  - *Precondition:* User is logged in.

1. On the main screen user clicks on “Log out” button.
2. System logs user out and displays the main screen.

Use case 4.9. *Manage my appointments*

- **Actors:** user, system

- **Description:** User wants to display/edit some of his or her already arranged appointments.
- **Main flow:**
  - *Precondition:* User has at least one appointment arranged and is logged in.

  1. On the main screen user clicks on "My appointments" button.
  2. System displays the list of user's appointments.
  3. User click on the button labeled by the appointment he or she wants to display/edit.
  4. System displays screen with appointment details.
  5. User makes necessary changes (change of personal information, limitations, date and time of an appointment, target of an appointment) and clicks on "Save changes" button.
  6. System saves changes and displays the main screen.

- **Alternative flow 1:**
  - *Precondition:* User has at least one appointment arranged and has created account.

  1. On the main screen user clicks on "My appointments" button.
  2. System displays screen with form for username and password input.
  3. User fills in username and password and clicks on "Log in" button.
  4. System displays the list of user's appointments.
  5. User click on the button labeled by the appointment he or she wants to display/edit.
  6. System displays screen with appointment details.
  7. User makes necessary changes (change of personal information, limitations, date and time of an appointment, target of an appointment) and clicks on "Save changes" button.
  8. System saves changes and displays the main screen.

- **Alternative flow 2:**
  - *Precondition:* User has at least one appointment arranged and does not have account.

  1. On the main screen user clicks on "My appointments" button.
  2. System displays screen with form for username and password input.
  3. User clicks on "Log in without user account" button.
  4. System displays screen with form for phone number.
  5. User fills in phone number and clicks on "Continue" button.
  6. System displays screen with input field for entry code and sends SMS message with entry code to the phone number.
  7. User fills in entry code and clicks on "Continue" button.
  8. System displays the list of user's appointments.
  9. User click on the button labeled by the appointment he or she wants to display/edit.
  10. System displays screen with appointment details.
  11. User makes necessary changes (change of personal information, limitations, date and time of an appointment, target of an appointment) and clicks on "Save changes" button.

12. System saves changes and displays the main screen.

Use case 4.10. *Manage appointment's task list*

- **Actors:** user, system
- **Description:** User wants to display/edit appointment's tasks.
- **Main flow:**
  - *Precondition:* User has appointment detail displayed.

1. User makes necessary changes (addition of new task, marking task as done) and clicks on "Save changes" button.
2. System saves changes and displays the main screen.

4.7 Final design

This Section describes creation of the final design of the web application. Regarding the visual design there were no major changes as the testing of the Hi-Fi prototype has shown that the tool is usable, intuitive and there were no critical issues.

The main changes were on the back-end of the web application. The most important change between the Hi-Fi prototype described in Section 4.6 and the Final design is that the persistence of data is handled by database. The Session Storage used in Hi-Fi prototype as a persistence layer is now used just for maintaining data important for a session such as logged in user. The web application has also completed all sections of the page such as "Information about hospital" and "Tips and tricks from other visitors".

The web application also provides REST API for database that can be used for integration with other components of the navigation system. For example the main terminal can make a JSON request to the web application about the user that has just scanned the insurance company card. REST service returns all information about the user such as limitations. If user has also prepared appointments they can be requested by terminal as well. Data used in final prototype (doctors, available hours for appointment, examinations) were made up for the purpose of showing design. More information about implementation of the prototype can be found in Chapter 5.

As the service for sending SMS messages is paid it was not included in final design of web application. In future, it will be possible to add functionality by using external service which can be called within the web application. System does not send SMS messages so the validation of those fields requires only non-empty field.

All findings from the testing of Hi-Fi prototype summarized in Section 6.3.2 were resolved in final design. Majority of the were solved by rephrasing labels and adding descriptions to fields. There were also several improvements mentioned during testing by participants. One of them was to skip first two steps — inserting personal information and limitations — if user is logged in. This is also handled in the final prototype. The next improvement proposal was to add location information to the SMS summary message. As the system does not actually sends SMS messages it is postponed to future development.

4.7.1 Use cases covered by prototype

The set of use cases covered by the final prototype is based on use cases of the Hi-Fi prototype described in Section 4.6.1. As those use cases are supported also by final prototype only new use cases are listed in this Section.

Use case 4.11. *Display information about hospital*

- **Actors:** user, system
- **Description:** User wants to display information about the hospital.
- **Main flow:**

1. On the main screen user clicks on "Information about hospital" button.
2. System displays screen with information about the hospital.

Use case 4.12. *Display tips and tricks from other visitors*

- **Actors:** user, system
- **Description:** User wants to display tips and tricks from other visitors.
- **Main flow:**

1. On the main screen user clicks on "Tips and tricks from other visitors" button.
2. System displays screen with tips and tricks from other visitors.

Use case 4.13. *Add new tip to the visitor's forum*

- **Actors:** user, system
- **Description:** User wants add a new tip as he already has an experience with navigation system.
- **Main flow:**
  - *Precondition:* User is logged in.

1. On the main screen user clicks on "Tips and tricks from other visitors" button.
2. System displays screen with tips and tricks from other visitors.
3. User fills in the text of the new message and clicks on "Add new tip".
4. System saves the new tip and displays it along with other tips and tricks from other visitors.

4.8 Summary of the design

This Chapter described evolution of design of the tool supporting hospital visit preparation. Each prototype has been described with the set of supported use cases. The very first design — mock-up — was based on the user research described in Chapter 3. Next designs — Lo-Fi, Hi-Fi and Final design — were influenced by results of the evaluation of the previous prototypes. Thus, with respect to UCD approach every design decision was based on the usability testing with target audience. Usability tests with target audience ensured that findings were relevant as they were based on user's experience. The designed solution has shown to be very intuitive, usable and welcomed by participants from target audience. The next Chapter 5 will discuss details about the implementation of prototypes.

Chapter 5
Implementation

In this Chapter is described implementation of created prototypes. This chapter focuses on the interesting implementation improvements regarding accessibility of the front-end. Especially on the parts of the web which is not visible to regular user but is important for screen readers. It also describes the architecture of the web application's back-end.

5.1 Used technologies

- *Front-end* of the application was created as a set of HTML pages with JS and Bootstrap[1] framework in version 3 for styling. Additional Bootstrap Accessibility Plugin[2] was added as well as jQuery[3] library as it was required by the plugin. The Lo-Fi and Hi-Fi prototypes were created by using Sublime Text[4] text editor in version 3. The final design of web application's front-end was created in IntelliJ IDEA Ultimate[5] in version 15.0.4. The license was provided by CTU for educational purposes. HTML pages from Hi-Fi prototype were rewritten to JSP as the path to the REST API was created dynamically and injected to the page when application was deployed. For temporary data persistence on client's side Session Storage was used. For future development is important to save data more securely for example to use server-side session to store sensitive data and encrypt communication with back-end.
- *Back-end* of the application was created in Java language in version 8. The Jersey[6] framework was used to implement REST API. The back-end was created for final design of web application and integrated with front-end in one Java EE project. For development also IntelliJ IDEA Ultimate was used with GlassFish Server[7] in version 4.1 to be able to deploy the application. The SQLite database was used as persistence layer. Communication with database was handled by Hibernate[8] framework.

The application's logic was driven mainly by the client's JS to separate the front-end and back-end. This is important to be able to change or rewrite one of the modules for future development of the navigation system and to provide better integration in the final architecture.

5.2 Accessibility improvements

To create good accessible web it is important to adjust implementation of the HTML and JS to provide screen reader users same context as sighted users have. The first

[1] http://getbootstrap.com/
[2] https://paypal.github.io/bootstrap-accessibility-plugin/
[3] https://jquery.com/
[4] https://www.sublimetext.com/
[5] https://www.jetbrains.com/idea/
[6] https://jersey.java.net/
[7] https://glassfish.java.net/
[8] http://hibernate.org/

problem was how to navigate visually impaired users in long listings of items such as doctors. To provide ability to jump in the list the navigation section with "letter" was included. However, this letter labeling makes sense for sighted user but visually impaired users do not have context. On top of that, standalone letters are read by screen reader really bad — many of them are not recognizable. Following snippet of JS contains 3 accessibility features.

```
var letters = [["A", "Á"], ["F", "eF"], ["M", "eM",], ["T", "Té"]];

for (var i = 0; i < letters.length; i++) {
  var letterLink = document.createElement("a");
  letterLink.setAttribute("role", "button");
  letterLink.setAttribute("class", "btn btn-primary");
  letterLink.setAttribute("href", "#" + letters[i][0]);
  letterLink.setAttribute("onclick",
    'document.getElementById("' + letters[i][0] + '").focus();');

  letterLink.innerHTML = '<span aria-hidden="true" role="presentation">'
    + letters[i][0] + '</span><span class="sr-only">Letter '
    + letters[i][1] + '</span>';

  btnGroup.appendChild(letterLink);
}
```

The first one is that letters has to be read in human acceptable form as screen readers do not read single letters well. So for example phonetic transcription of letter "F" in Czech is "eF". The second feature is setting focus on the heading with desired letter. Setting anchor link is not sufficient in all browser and for all screen readers so it is necessary to programatically set focus on element as well. Note that focus can be set programatically only on elements which are tabbable such as buttons, links and input field. Thus, to set focus on heading it is necessary to specify attribute `tabindex` with value -1. The third feature is labeling of button for both sighted and screen reader users. Screen readers will exclude the element with `aria-hidden` attribute — which is standalone "F" letter we want to show to sighted users only. On the other hand, element with class `sr-only` will be read by screen readers only — it contains phonetic transcription "Letter eF". Additional improvement was placement of button that allows user to return to the navigation section of the page. This link has intentionally role of the button to not to be displayed in the list of links which screen reader users sometimes use. Only doctors remains as link so they can be easily listed by this shortcut and searched in.

Similar improvement was also made when tasks — that can be created for every appointment — were implemented. Each task is displayed in a row consisting of 3 columns. If the task is marked as done, there is an information about that in the first column. For visually impaired users with the context of the number of task and with hidden "checked" icon. The second column contains the text of the task. Also, for visually impaired users there is a context prefix before the text. In the third column is a button for marking task as done. For visually impaired users was added also number of the task and hidden "check mark" icon. The comparison of how tasks are displayed to sighted user and to a screen reader is depicted in Figure 5.1.

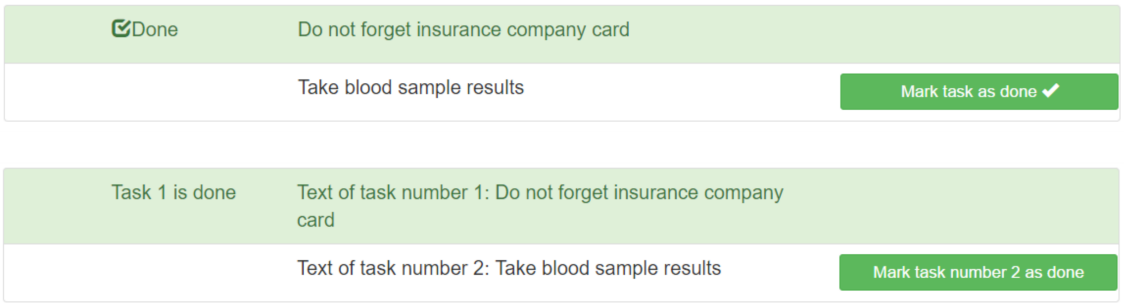

Figure 5.1. Comparison of how tasks are perceived by the sighted and screen reader users.

One of the most important implementations regarding accessibility was to provide accessible modal dialog. These dialogues were displayed in case of validation failure or action success. The example of validation error dialog is depicted in Figure 5.2. The dialog was selected as modal to attach the attention of the user — especially seniors. The background of the page is faded so user's focus is set to the dialog. The focus is also set programatically by JS so screen reader starts to read the dialog contents. Interesting is that according to accessibility guidelines modal dialog should be always described by `described-by` attribute. It makes sense to mark description as the dialog's heading. It that case screen reader reads the heading twice which is really uncomfortable for screen reader user. This has been solved by marking heading as `aria-hidden`. Thus, it was read as part of dialog description immediately and displayed for sighted users but not read again as heading. There is also information for screen reader users only that dialog can be closed by pressing button at the end of the dialog. Dialog can be also dismissed by clicking on the background around the dialog.

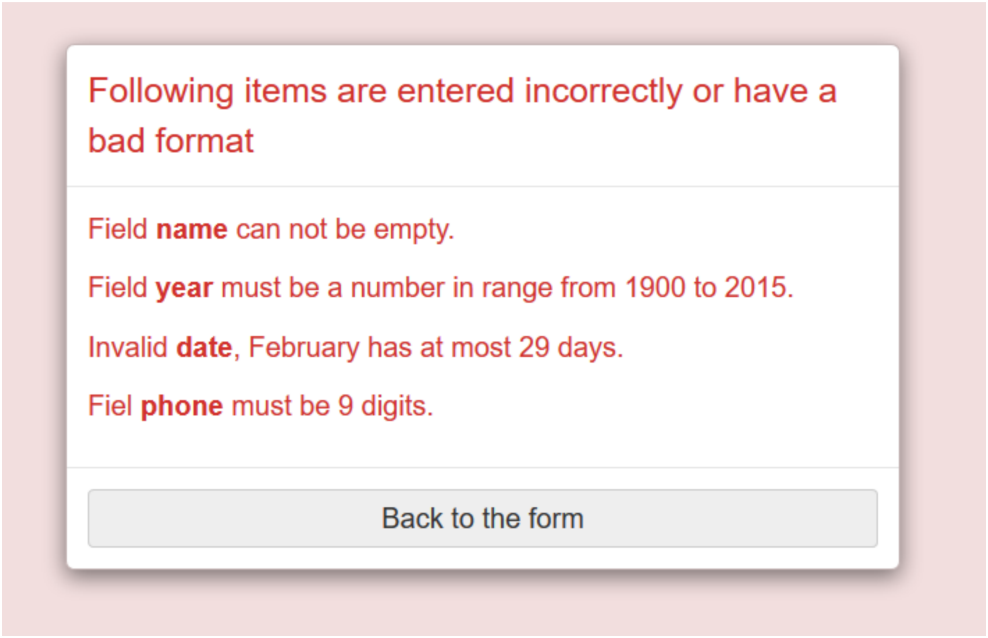

Figure 5.2. Validation failure modal dialog with information what went wrong.

5.3 REST back-end

The back-end provides REST API that can be used by any module of the navigation system. For the purpose of the prototype it was designed to store just data about the visitor and his or her appointments or navigation requests. It also stores data that are used by hospital visit preparation application such as tasks a tips from other visitors. The REST API was chosen to have those modules separated so they can be replaced or used separately in the final version of the overall navigation system.

The system works with several entities. Entities with relations are depicted in Figure 5.3 in form of Entity-relationship diagram. Entities are annotated by using Java Persistence API. Thus, the database model is created or updated automatically by Hibernate. The `Target` entity is an abstract entity that is actually stored in one database table. Type of the object is determined by discriminator value that is saved in separate column. Communication is also handled by using Hibernate and Criteria API for specifying selection queries. Program than works with concrete instances of entities. For each entity is created at least one entity contract class. These classes represent objects that are consumed or produced by the REST API. Those contracts are mapped to entities that are then stored in the database.

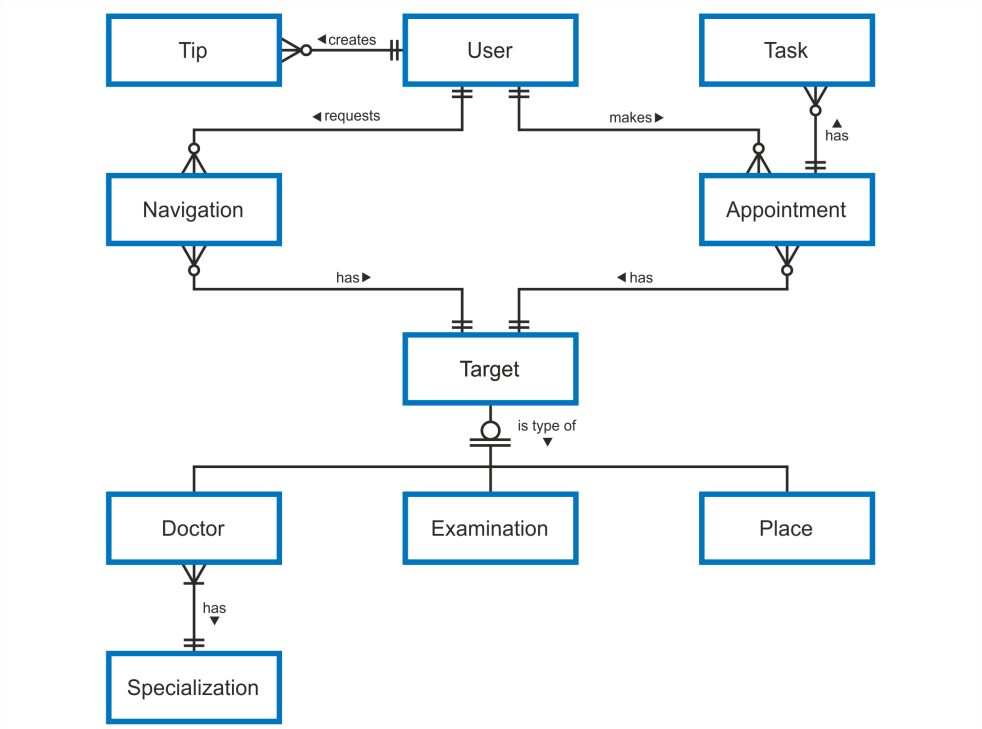

Figure 5.3. Entity-relationship diagram of entities used in the application.

For each entity the resource class is created. Those classes contain methods that are annotated according to the HTTP method they are bound to. Each resource class is annotated by `@Path` annotation which specifies the path to the resource. Each method is then annotated by method such as `@POST` and other parameters such as `@QueryParam` or `@PathParam`. All methods are annotated to consume JSON payload. Some methods are also annotated by custom `@Secured` annotation. This annotation provides basic security of endpoints.

Every request that is made on the secured endpoint is filtered by `AuthFiler` class that passes authorization header of the request to `AuthService` class. This class then looks

up the user with given credentials in database. If user does not exists the unauthorized status is returned. Further security is then handled in each method during validation such as that user with valid credentials cannot modify the appointment of another user. For the purpose of the prototype authorization header with username and password encoded in Base64 was selected. For future development the security has to be improved by using more advanced authorization method such as OAuth.

The overview of all entity resources and their endpoints is depicted in Table 5.1. REST API is accessible on this path `http://{hostname}/service` where the endpoint path is appended at the end of this path. Each endpoint has specified HTTP method, path and brief description. Methods that require authorization header are marked with `(*)`. Methods marked with `(+)` are intended to use only internally by the proposed system — the security has to be added according to future development.

method	path	description
POST	/users	creates new user
PUT(*)	/users/{*user id*}	updates existing user
GET(*)	/users/{*user id*}	returns user's data
GET(*)	/users/login(?phone={*phone number*})	returns user's ID
GET(+)	/users/login/internal	returns user's ID
POST	/appointments	creates new appointment
PUT(*)	/appointments/{*appointment id*}	updates existing app.
GET(*)	/appointments/{*appointment id*}	returns appointment's data
GET(*)	/appointments?user={*user id*}	returns all app. for user
POST	/navigations	creates new nav. request
GET(*)	/navigations?user={*user id*}	returns all nav. for user
POST(*)	/doctors	creates new doctor
GET	/doctors?sort={*name/spec*}	returns all doctors sorted by name or specialization
POST(*)	/examinations	creates new examination
GET	/examinations	returns all examinations
POST(*)	/places	creates new place
GET	/places?type={*ward/other*}	returns all places with type
POST(*)	/tips	creates new tip
GET	/tips	returns all tips

Table 5.1. Overview of REST API endpoints with paths and descriptions.

Entity management methods that are not listed in table were handled by manipulating database directly. All methods will be added in future development according to navigation system architecture requirements.

Chapter 6
Evaluation

In this Chapter is described evaluation of all prototypes that has been created and presented in Chapter 4. Appropriate evaluation method has been selected for each prototype. For the first prototype — mock-up created as an interactive PDF file — was selected preliminary usability evaluation with one participant and UI heuristic evaluation. For next prototypes — Lo-Fi and Hi-Fi — was selected evaluation in form of usability tests. The final design of the web application was also tested by suitable software testing method. Following Sections describe the setup, course and test results that affect creation of the next prototype.

6.1 Mock-up

This Section describes evaluation of the very first designed solution. Detailed description of the prototype can be found in Section 4.4. The goal of the preliminary test is to verify the concept idea. As this is a very first design it is important to discover potential design bugs – in this phase of development is really easy to fix them. Preliminary test consists of two parts. The first part is an informal usability test with one healthy participant not from target group. The goal of the first test is to verify the proposed workflow of an app. The second part is a heuristic evaluation of a mock-up. The goal of the second test is to reveal mistakes in interaction design that may confuse or even deter some users.

6.1.1 Informal usability test

The first test consists of two main scenarios based on use cases from Section 4.4.1. Both scenarios support only positive walk-through so there are no error states involved. As there are several forms which user has to fill in the prototype is designed to fill in all information by tapping on any form's field.

- *The first tested scenario* is to make an appointment with MUDr. Jan Novák on Friday 22.1.2016 at 14:00. Imagine, that you are completely blind and because of diabetes you are unable to read braille.
- *The second tested scenario* is to navigate to the hospital's neurological ward. Imagine, that you use a wheelchair and that you have hearing ability reduced by 50%. You want to navigate from Opatov, Prague to the Motol Hospital. You have to be there 21.1.2016 at 11:15.

Participant was a 29 year old sighted man. Participant has been seated at the office desk. In front of him there was a computer with prepared mock-up as an interactive PDF file open in full screen mode. Participant had access to the computer mouse only. Moderator has been seated by the participant's side to observe the testing process. Once participant has been seated, moderator started to explain the goal of test. Participant has been familiarized with the In-hospital navigation system and it's parts. Participant has been assured that if something goes wrong it is not his fault but it is fault of the

tested system. Participant has been asked to think aloud and comment everything he does. Once participant felt ready, the test has begun. Moderator told participant what he should achieve f.e. *"You want to make an appointment with MUDr. Jan Novák on Friday 22.1.2016 at 14:00."*. Moderator observed participant's behavior and wrote down all findings.

The *first tested scenario* participant started without problems. At the first step — insert personal information — he had one comment about the "Full name" input field. He would prefer separated input field for name and surname. The first confusion was few steps further on the review screen. Participant wanted to change the appointment details and he was confused that the application did not remember his choice of the appointment's date and hour. This was caused by the nature (simplicity) of the prototype, so it is not considered as an issue. Participant's last commend was at the end of the first test. He was confused about which code he should enter in the hospital — the one he used one step back during verification or the other one described at the final screen (Figure 6.1).

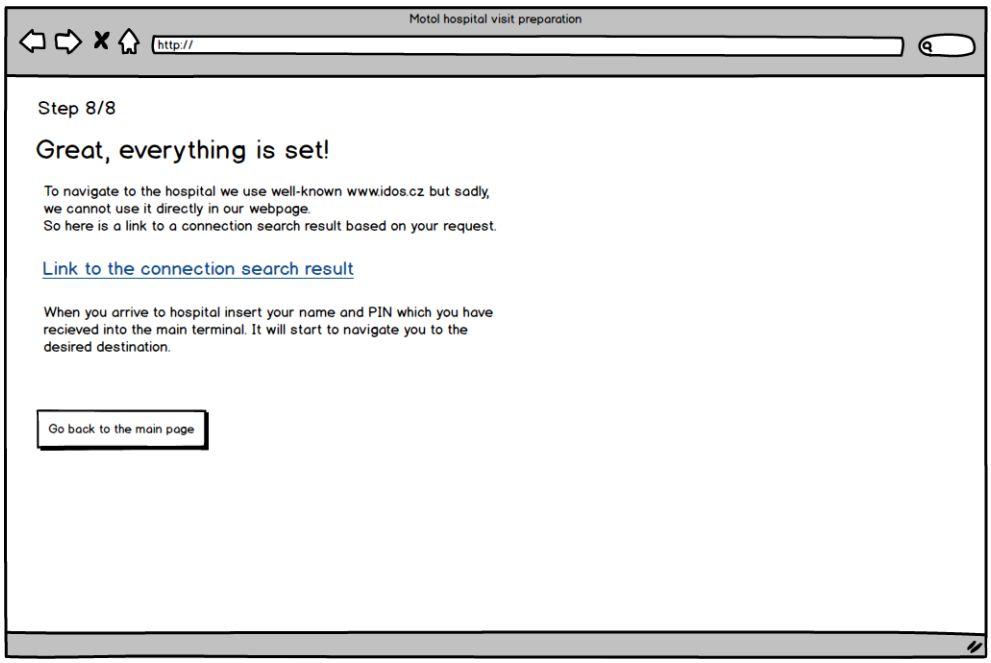

Figure 6.1. Navigation to hospital final screen of the mock-up.

The *second tested scenario* participant also started without problems. Participant had a comment about labels of navigation buttons. He would just label them as "Previous" and "Next". Participant said it is confusing to have step numbers on button labels as they change all the time and does not give any valuable information for him. Another problem was when the participant was on information review screen. He wanted to change the origin of navigation. Button "Change navigation details" redirected him to the page where final destination is specified depicted in Figure 6.2.

Participant expected to be redirected to the page with navigation settings (Figure 6.3). Participant's next comment was about the formulation of verification screen introduction sentence. He did not understand why he has to fill in some code to confirm what he has just set. Participant would rephrase it in a way that this step is important for phone number/email verification. The last comment was about the final screen of navigation (Figure 6.1). Participant expected that he would see connections embedded in the application's page — not as a link to another page. This is a problem due to

legal restrictions of the IDOS service[1]. The only way how to use this service was to provide prepared link for search results.

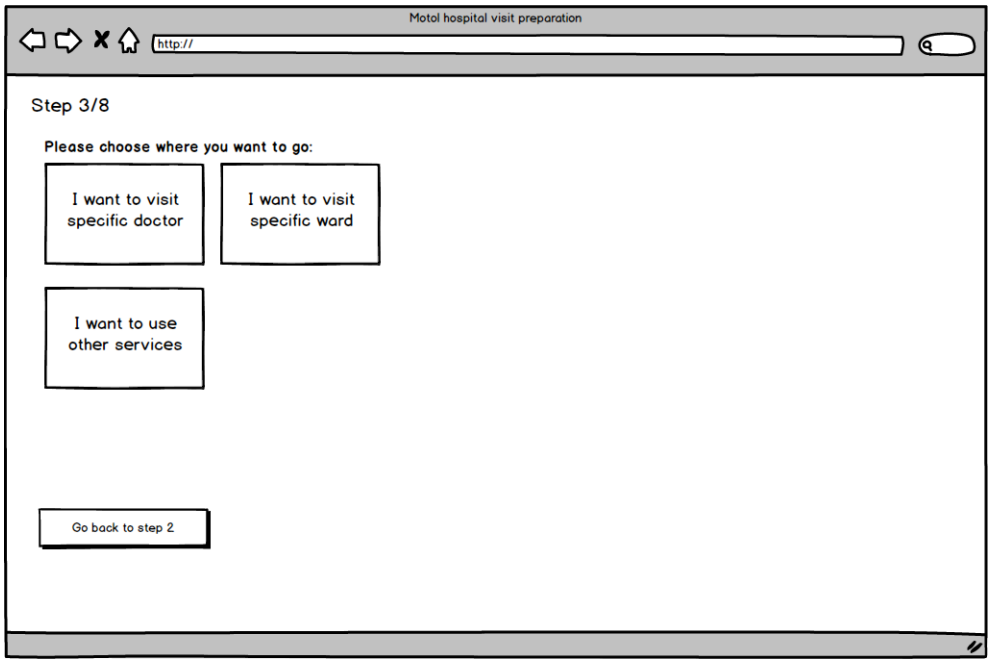

Figure 6.2. Navigation destination screen of the mock-up.

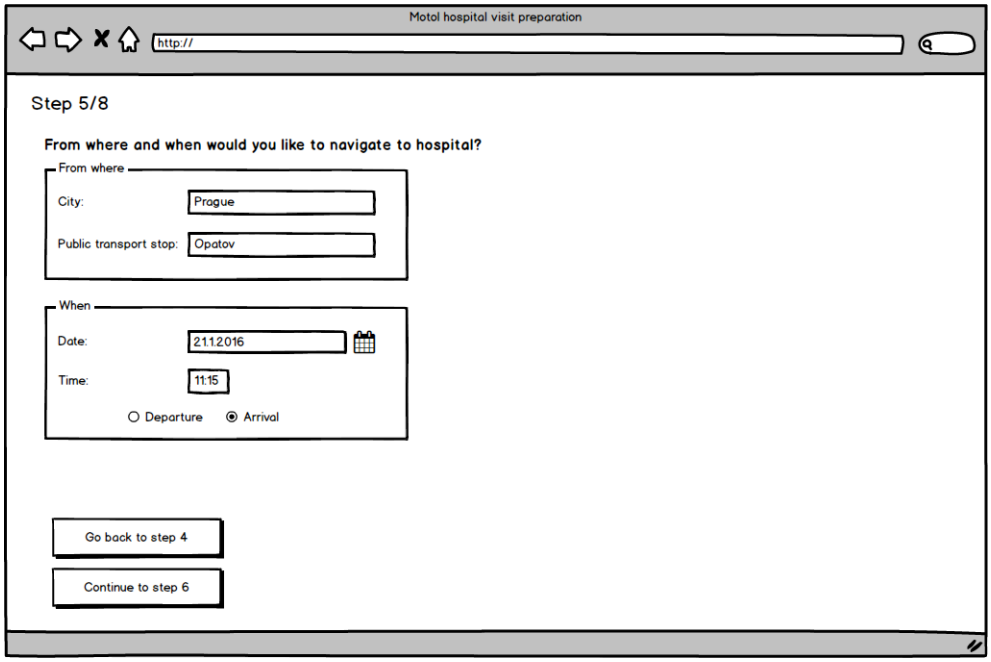

Figure 6.3. Navigation to hospital setup screen of the mock-up.

[1] `http://www.chaps.cz/files/idos/IDOS-API.pdf`

6.1.2 Nielsen's heuristic evaluation

The second test is Nielsen's heuristic evaluation originally presented by Nielsen and Molich [23] and later rephrased by Nielsen to 10 basic principles [24]. Evaluation is done by an evaluator which is familiarized with the domain of the system by looking at the UI and trying to come up with an opinion about what is good and what is bad about an interface. The evaluator goes through the UI of an application and in each state evaluates all 10 principles. Due to simplicity and scope of the prototype there was only one evaluator involved. Some the problems were already discovered by the first informal usability test.

1. *Visibility of system status*
   The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
2. *Match between system and the real world*
   The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
3. *User control and freedom*
   Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
4. *Consistency and standards*
   Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
5. *Error prevention*
   Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
6. *Recognition rather than recall*
   Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
7. *Flexibility and efficiency of use*
   Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
8. *Aesthetic and minimalist design*
   Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
9. *Help users recognize, diagnose, and recover from errors*
   Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
10. *Help and documentation*
    Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

6.1.3 Test results

Both tests has shown presence of some problems. Findings from each test are summarized in separate tables. Each finding has defined ID, priority, description and improvement proposal. However, tested design has shown to be usable a understandable as there were no findings categorized with the Priority 1.

Priorities are defined as follows:

- *1 (high)* – Defect makes system unusable, has to be fixed.
- *2 (medium)* – Defect makes system usage uncomfortable and confuses user, should be fixed.
- *3 (low)* – Defect makes system usage little confusing, should be reviewed and probably fixed.

Summary of all findings from the first test — informal usability test — is shown in Table 6.1.

ID	priority	problem description	improvement proposal
1	3	one input field for full name	separate full name input in two input fields (name, surname)
2	2	it is not clear which code is used for what (verification code vs. PIN code)	explain better difference between these codes or come up with another way how to authenticate the visitor at the hospital
3	3	labels of navigation buttons are confusing as they contains step numbers (which changes all the time)	change label of navigation buttons
4	2	"Change navigation settings" button redirects only to the beginning of the navigation setup	add a new button to the information review screen which enables option to change just origin and date of the navigation
5	2	it is not clear why user has to insert verification code	rephrase introduction sentence on the verification screen — explain why it is important to verify phone number/email
6	2	connections to the hospital are provided as a link to other website	embed/integrate IDOS search engine in web application

Table 6.1. Overview of all findings revealed by informal usability test with priorities and improvement proposals.

Summary of all findings from the second test — heuristic evaluation — is shown in Table 6.2.

ID	priority	broken principals	problem description	improvement proposal
7	2	4	complex personal identification number input field format	field should be separated into two fields by the slash character as users are used to it
8	2	3	on all pages is missing option to escape at the beginning	add a button to each page which leads to the main page
9	2	2, 4	limitations are presented more like handicaps — user with broken leg will not choose any of the motor impairment options and will be navigated by stairs	rephrase the limitations to match the real world situations
10	2	7	search among long list of doctors will be uncomfortable	provide an option to search/jump in long listings
11	2	3, 9	if verification code does not arrive there is no option to resend it	provide a “resend” code option
12	2	5, 10	user might not be able to finish if he has not current access to phone/email	inform user at the beginning that he or she will need a phone/email to finish the task
13	3	2, 10	at the end of the navigation user migh be confused what to do in hospital with terminal	add more information or info-graphics how identification works with terminal
14	2	3	if user wants to navigate only in hospital building he or she has to choose the origin of navigation to proceed	add option to skip the outdoor navigation to the hospital

Table 6.2. Overview of all findings revealed by heuristic evaluation with priorities and improvement proposals.

6.2 Lo-Fi prototype

This Section describes evalation of the second design — Lo-Fi prototype. Detailed description of the prototype can be found in Section 4.5. The goal of the evaluation is to verify accessibility of the designed elements and overall workflow with target audience.

6.2.1 Usability test

The best way how to evaluate designed solution is to perform a usability test with the target group. The main goal of the usability test is to verify the concept with target audience and reveal issues in current design and implementation.

- **Setup**

  Testing took place at CTU - FEL at Karlovo náměstí in Prague. There were 3 senior participants and 3 visually impaired participants involved in the test. Each participant spent at most one hour in the lab. After the participant's arrival, he or she was seated behind an office desk. On the desk was a laptop (Acer 15.6", Windows 10 64bit) with external classic keyboard attached to the computer. That was important especially for visual impaired users as they need buttons with high profile to be able to use keyboard efficiently. On the laptop was installed JAWS 16 screen reader in demo version which provides 40 minutes of free use. Each participant had opportunity to adjust JAWS settings before the test such as speed of the reading. After this period computer must be restarted to be able to run JAWS again.

  Moderator has been seated by the participant's side to observe the testing process. Once participant has been seated, moderator started to explain goal of the test. Participant has been familiarized with the In-hospital navigation system and it's parts. Participant has been assured that if something goes wrong it is not his fault but it is a fault of the tested system. Participant has been asked to think aloud and comment everything he or she does. Once participant felt ready, the test has begun. At the beginning of the test the prototype's main page was opened in the Mozilla Firefox version 46 and JAWS screen reader was activated.

- **Participants**

  1. The 1^{st} *participant* was 40 year old visually impaired woman. She lives in Prague. She has lost her sight in time. She is categorized as 4 – practically blind. She uses computer on daily basis. She uses JAWS as her primary screen reader. She cannot read braille.
  2. The 2^{nd} *participant* was 68 year old visually impaired woman. She lives in Prague. She has lost her sight in time. She uses computer but she does not user JAWS as a screen reader – she uses SuperNova screen reader from Dolphin. She can read braille.
  3. The 3^{rd} *participant* was a 51 year old visually impaired man. He lives in Prague. He is completely blind since he was born. He uses computer very often. He also teaches computer skills other visually impaired individuals so he is professional user. He uses JAWS and also other screen readers. He is advanced user so he knows a lot of shortcuts. He can read braille.
  4. The 4^{th} *participant* was a woman, 72 year old senior. She lives in Loket. She uses computer once a week as she does not have one. She uses computer mainly for browsing internet and writing documents. She uses glasses but mainly for reading.
  5. The 5^{th} *participant* was a man, 69 year old senior. He lives in Karlovy Vary. He uses computer almost every day for browsing internet, managing pictures, writing

documents and emails. He uses glasses — one pair for reading and other that he has to wear all day.

6. The *6th participant* was a woman, 68 year old senior. She lives in Karlovy Vary. She uses computer occasionally for browsing internet. She uses glasses for long distances.

- **Tested scenarios**

  There were two test scenarios. All information provided for the test scenario were repeated during the test according to the participant's needs. A verification code used for verifying contact information was told to the participant by moderator.

1. *Imagine that you want to make an appointment with MUDr. Jan Novák — he is neurologist. You have free time only 8.3. at 15:00. You have injured ankle so you have problems with walking. You have insurance company number 209 — Změstnanecká pojišťovna Škoda.*
2. *Imagine that you want to navigate to the hospital to the ward of nuclear medicine. You live in Prague - Opatov and you want to be in hospital 10.3. at 11:00. You have insurance company number 205 — Česká průmyslová zdravotní pojišťovna.*

- **Testing process**

  The **1st participant** started with the first scenario without problems. The first problem occurred on the page where personal data should be inserted. The page is depicted in Figure 6.4. She complained about the fact that the system requires personal information at the very first page before selecting doctor. Also, the amount of required information surprised her. She does not like to give personal identification number to anyone. Obviously, she had problem with that in the past.

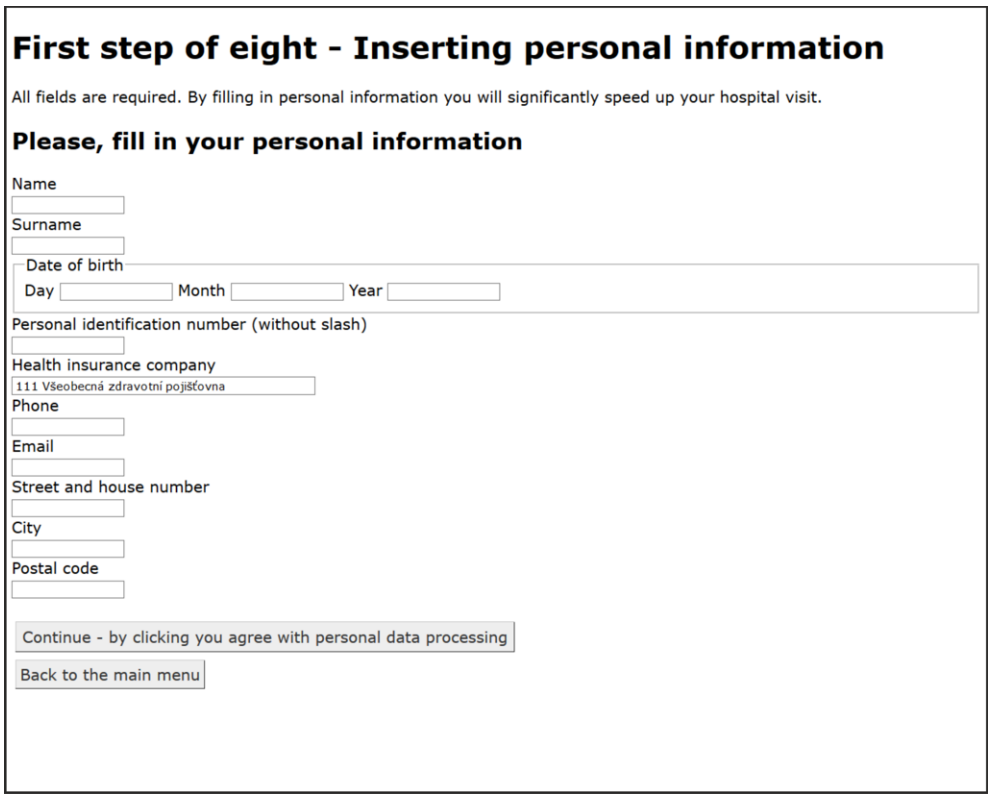

Figure 6.4. Personal information input page of the Lo-Fi prototype.

The next problem was on the page where user's limitations are specified. She did not connect the fact that if she has an injured ankle she should specify that as movement limitation. She chose the correct doctor by using CTRL + F shortcut. She selected the date and time without any problem. She complained a little bit about the amount of information on the page where all data are summarized. As these information were placed in the table it was harder for her to go through it. The verification and final screen were without problems.

The second scenario also started without problems. She associated correct button with an action. She mentioned again problem with the amount of personal data required. On the page where she should choose the target place for navigation she was confused by labeling of the buttons and title. The title text said "Please choose a place where you want to navigate" but the button label was "I want to visit specific doctor". Despite this mistake in consistency she chose correct button to proceed. Next problem occurred on page where navigation settings are specified. The page is depicted in Figure 6.5. She did not notice the traffic information displayed. It was probably caused by the placement of the "Continue" button. Once she filled in the form and jumped on the "Continue" button she pressed it.

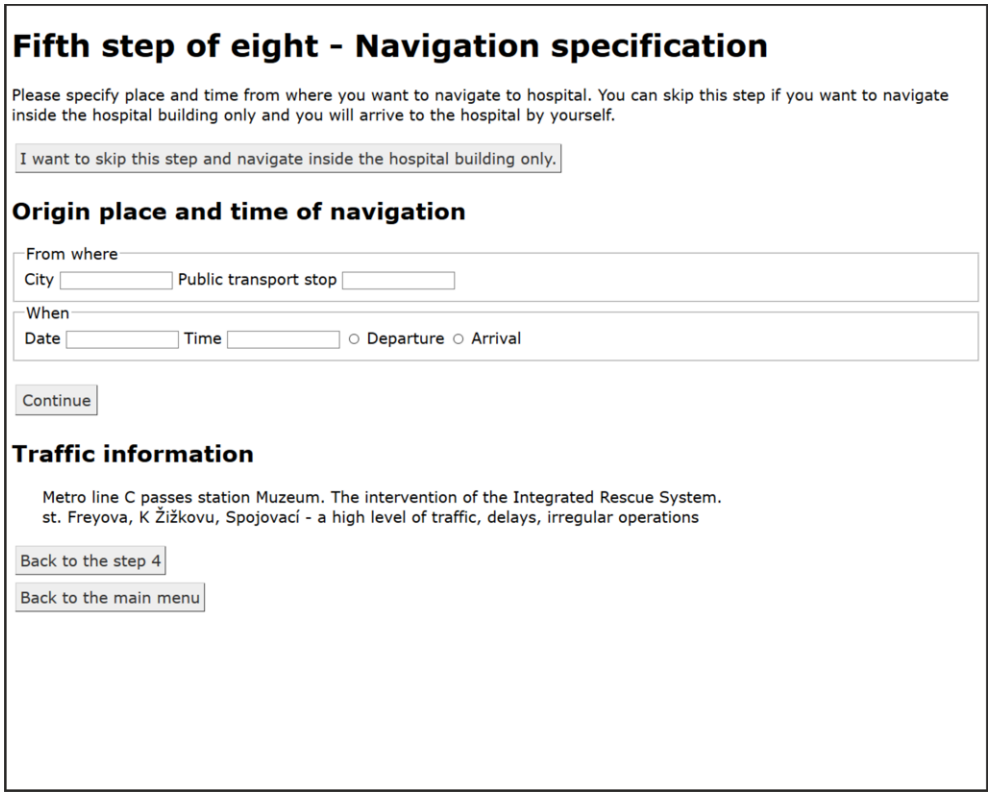

Figure 6.5. Navigation specification page of the Lo-Fi prototype.

At the end of the test she expected that in real scenario the link on the search result will be also sent to her mobile phone. Despite those findings she found the idea and prototype usable and intuitive.

The **2nd participant** was not used to the JAWS screen reader. During the reading of the main page she had to figure out how the JAWS reads the page. After a while she adjusted to the JAWS and was able to continue in test. She used the punctuation marks in date of birth. It was not a problem during the test as there was no validation of the input field. This was intentional — it is important to find out which formats

people will use and support the widest range of them to prevent errors. The next problem occurred while she was filling in some input field and browser whispered her some values for the field. It confused her a lot. While she was choosing the date and time of an appointment she was little confused at the beginning. She thought that there is equal number of free hours for each day so she pressed arrow multiple times to get to the next day.

The second scenario also started without problems. She had a comment about the personal identification number. She found it redundant as she already typed the date of birth. Next problem occurred on the page where wards were listed. She expected that she had to press the ENTER key on the header to access the actual list of wards. After a while she managed to find the desired ward. We can assume that this problem occurred due to lack of attention because screen reader clearly read the header with prefix "header ...". She also skipped the traffic information due to the same reason as the first participant.

The **3rd participant** was experienced user so he started without any problems. At the personal information page ha hesitated a while about the format of the date but he tried it and it passed so he was satisfied. He used format of two digits for both day and month. He would welcome more information about the required formats of the field. He also skipped the title text on this page so he was not sure about what field are required. He would expect "$*$" sign a the beginning of the label. He would also appreciate an information here saying that the phone or email is required to finish the task. When he was selecting limitations he would merge the first two options "I avoid stairs" and "I use crutches" of movement limitation to the one as he did not know what to choose if he is supposed to have injured ankle. The last recommendation was about the page where date and time of an appointment should be selected. He suggested to make days which are implemented as a `<legend>` element also mark as headers. Experienced screen reader users often use shortcuts to jump form header to header.

The **4th participant** started the first scenario without problems. The first complaint was about the size of the letters in the input fields. Otherwise, the font of surrounding text (20 pixels) was commented as sufficient. Next problem occurred on the page for the limitations specification. She had no idea what "haptic" means. Despite those problem she was able to successfully complete the task.

The second scenario also started without problems. The first problem was on the page where navigation settings are specified. The page is depicted in Figure 6.5. She did not understand what "Departure" and "Arrival" means. She had question about the time of arrival. If it is time of arrival to the hospital or to the desired ward. She would suggest to at least add information about the estimated time needed to get from the hospital's front door to the target location. But she found prototype very useful and intuitive.

The **5th participant** started the first scenario without problems. The first comment was about the number of personal information required. He would suggest to leave just name, surname, insurance company, date of birth and phone/email. On the next page, where limitations are specified, he suggested to rephrase the movement limitations to more friendly format. Also, he did not know what does the "haptic" means. At the end of the first scenario he was little bit confused. He would replace the phrase "... scan the insurance company card ..." with "... swipe/attach the insurance company card ...".

The second scenario also started without problems. He suggested to be able to create a profile so he would not have to insert all personal information again. When he was entering date and time he used dots at the end as a separator. When he was filling in the navigation settings he misunderstood the "Departure" and "Arrival" options. He also comments that the code insertion might be too complex for some seniors. He said the prototype is nice but that is might be too complicated for some seniors.

The **6th participant** started the first scenario without problems. The first problem occurred while she was selecting limitations. She had no idea what does the "haptic" means. Also the text inside the form input fields is too small. Next problem occurred while she was selecting date and time of an appointment. She had problems to hit the radio button as she did not know she can click even on the label of the button to check it. She would suggest to make those button bigger. At the end of the scenario she did not read the final instructions properly so she would not know what to do in the hospital.

The second scenario also started without problems. It was clear during the test that she almost always skipped the informative text below the title. While she was writing a date for the navigation she used "-" as a separator. She also did not understand the meaning of the "Departure" and "Arrival" options. She found prototype nice but sometimes too complicated for her. She would also increase the size of the font. However, she enjoyed the testing.

6.2.2 Test results

The usability test has shown presence of some problems. Findings from each participant are summarized in on table. Each finding has defined ID, priority, description and improvement proposal. However, tested prototype has shown to be usable, understandable and intuitive as there were no findings categorized with the Priority 1.

Priorities are defined as follows:

- *1 (high)* – Defect makes system unusable, has to be fixed.
- *2 (medium)* – Defect makes system usage uncomfortable and confuses user, should be fixed.
- *3 (low)* – Defect makes system usage little confusing, should be reviewed and probably fixed.

Summary of all findings from the usability test is shown in Table 6.3.

ID	priority	problem description	improvement proposal
1	2	too much information required	leave only necessary personal information and certainly avoid the personal identification number
2	2	users does understand the movement limitation options	rephrase the options to match the real situations in more user friendly language
3	3	summary information are in table which is harder to orientate in	provide summary in another format then in the table
4	2	traffic information skipped	move traffic section between the last input field and "Continue" button
5	2	date format not specified properly	accept several versions of formatting or specify desired format in label
6	2	browser's input field whispering confuses visually impaired	turn off whispering for all input fields
7	3	required input field are not marked	add an "∗" sign at the start of label of each required field
8	3	days are not accessible by any shortcut on date and time page	make days also a headers so they can be found easily by screen reader's shortcuts
9	2	seniors does not know what "haptic" means	hide this limitation completely when none or small vision impairment is selected
10	3	font size inside the input field is too small	make the font of the input fields the same size as the other text in page
11	2	seniors does not understand to "Departure" and "Arrival" options	rephrase those options to be easily understandable
12	3	explanation of what the user should do at the hospital is not clear	rephrase those instructions and make them more visible in page
13	3	radio input buttons are too small	increase the size of the radio buttons so they are easier to be clicked

Table 6.3. Overview of all findings of the Lo-Fi prototype revealed by usability test with priorities and improvement proposals.

6.3 Hi-Fi prototype

This Section describes evaluation of the third design — Hi-Fi prototype. Detailed description of the prototype can be found in Section 4.6. The goal of the evaluation is to verify accessibility of the whole prototype and verify that design is suitable for seniors. Again, the usability test was selected for evaluation as it shows how the target group interacts with the system.

6.3.1 Usability test

The best way how to evaluate designed solution is to perform a usability test with the target audience. The main goal is to verify that changes in visual design did not affect the accessibility of the application. Also it is important to verify that seniors can connect actions with correct GUI elements. The last main goal is to test the concept of user accounts. It is important to verify that users understand it and are willing to use it.

- **Setup**

  Testing took place at CTU - FEL at Karlovo náměstí in Prague. There were 7 senior participants and 7 visually impaired participants involved in the test. Each participant spent at most one hour in the lab. After the participant's arrival, he or she was seated behind an office desk. On the desk was a laptop (Acer 15.6", Windows 10 64bit) with external classic keyboard attached to the computer. That was important especially for visual impaired users as they need buttons with high profile to be able to use keyboard efficiently. On the laptop was installed JAWS 16 screen reader in demo version which provides 40 minutes of free use. Each participant had opportunity to adjust JAWS settings before the test such as speed of the reading. After this period computer must be restarted to be able to run JAWS again.

  Moderator has been seated by the participant's side to observe the testing process. Once participant has been seated, moderator started to explain goal of the test. Participant has been familiarized with the In-hospital navigation system and it's parts. Participant has been assured that if something goes wrong it is not his fault but it is a fault of the tested system. Participant has been asked if it is possible to send him or her SMS messages during the test. Moderator explained that the system will send SMS messages to the user in future. As it is not implemented the Wizard of Oz[1] approach was used — prepared SMS messages were sent by a moderator during the test. Participant has been asked to think aloud and comment everything he or she does. Once participant felt ready, the test has begun. At the beginning of the test the prototype's main page was opened in the Mozilla Firefox version 46 and JAWS screen reader was activated.

- **Participants**

  1. The *1st participant* was a woman, 75 year old senior. She lives in Prague. She uses computer once daily. She uses computer mainly for browsing internet and writing documents. She uses Mozilla Firefox, Google Chrome and also Internet Explorer for internet browsing. She uses glasses as she has 5.5 diopters.
  2. The *2nd participant* was a woman, 78 year old senior. She lives in Prague. She uses computer almost daily. She uses computer mainly for browsing internet and

[1] `https://en.wikipedia.org/wiki/Wizard_of_Oz_experiment`

managing pictures. She uses mainly Google Chrome for internet browsing. She does not use glasses.

3. The *3rd participant* was a woman, 69 year old senior. She lives in Prague. She uses computer almost every day for browsing internet, managing pictures, writing documents and emails. She uses mainly Mozilla Firefox for internet browsing. She uses glasses for reading.
4. The *4th participant* was a man, 84 year old senior. He lives in Prague. He uses computer almost every day for browsing internet, managing pictures and emails. He does not have favorite internet browser. He uses glasses but mainly for reading.
5. The *5th participant* was a woman, 72 year old senior. She lives in Loket. She uses computer once a week as she does not have one. She uses computer mainly for browsing internet and writing documents. She uses mainly Internet Explorer for internet browsing. She uses glasses but mainly for reading.
6. The *6th participant* was a man, 69 year old senior. He lives in Karlovy Vary. He uses computer almost every day for browsing internet, managing pictures, writing documents and emails. He uses mainly Internet Explorer but sometimes also Google Chrome for internet browsing. He uses glasses — one pair for reading and other that he has to wear all day.
7. The *7th participant* was a woman, 68 year old senior. She lives in Karlovy Vary. She uses computer occasionally for browsing internet. She uses Internet Explorer only as it is the only browser she knows. She uses glasses for long distances.
8. The *8th participant* was 31 year old visually impaired man. He lives in Prague. He is visually impaired since he was born. He is categorized as 4 – practically blind. He uses several screen readers but preferably NVDA[1] and Window-Eyes[2]. As he is an advanced user he uses the fastest speed of reading and several shortcuts. He can read braille.
9. The *9th participant* was 40 year old visually impaired woman. She lives in Prague. She is completely blind from birth. She uses computer on daily basis. She uses mainly JAWS screen reader. She can read braille.
10. The *10th participant* was a 66 year old visually impaired woman. She lives in Prague. She has lost her sight in time. She is categorized as 4 – practically blind. She uses computer on daily basis. She uses JAWS as her primary screen reader. She cannot read braille.
11. The *11th participant* was 28 year old visual impaired woman. She lives in Prague. She is completely blind from birth. She uses computer on daily basis. She uses mainly JAWS and Window-Eyes careen readers. She can read braille.
12. The *12th participant* was 30 year old visually impaired woman. She lives in Prague. She is practically blind from birth. She uses computer on daily basis. She uses the fastest speed of reading in screen reader. She uses JAWS and NVDA. She prefers JAWS for the internet browsing. She can read braille.
13. The *13th participant* was 25 year old visually impaired woman. She lives in Prague. She is completely blind from birth. She uses computer on daily basis. She uses mainly JAWS as a screen reader. She uses the fastest speed of reading in screen reader. She can read braille.
14. The *14th participant* was 39 year old visually impaired man. He lives in Prague. He is completely blind and he has lost his sight in time. He uses computer on daily basis. He uses mainly JAWS screen reader. He theoretically can read braille but in

[1] `http://www.nvaccess.org/`
[2] `http://www.gwmicro.com/window-eyes/`

practice he does not use it. He studied information technologies for several years so he is a professional user with technical knowledge of how the website works.

- **Tested scenarios**

  There were 3 main scenarios tested. All information provided for the test scenario were repeated during the test according to the participant's needs. Some scenarios had several sub-tasks to force participant for example go back and changed entered information. Verification and entry codes used for verifying contact information and one-time entry to "My appointments" section were sent in SMS message to the participant by moderator.

  1. *Imagine that you want to make an appointment with doctor Martin Kemr — he is an orthopedist. You have free time only at Friday 8.4. in the morning. You have injured ankle so you have problems with walking.*
     - Message with verification code: `Your verification code is: m3d5`
     - Message with appointment confirmation: `Confirmation of the appointment. Friday 8.4.2016 at HH:MM, MUDr. Martin Kemr, orthopedist`
  2. *Imagine that you have just remembered that you already have something that day in the morning. You want to change the time of an appointment to the evening.*
     - Message with one-time entry code: `Your entry code is: v21a`
     - When participant changes time: *You must not forget to take your blood results for the appointment. You want to note it.*
     - When participant adds new task: *You have your insurance company card already prepared so you know you won't forget it.*
  3. *Imagine that you want to visit your friend in the hospital. She is at Department of internal Medicine of Motol hospital. You have never been to Motol hospital and you want to find a route from home. You live in Prague at Pankrác. You want to visit her 30.4. and your want to be there at half past two.*
     - When participant is on the summary screen: *You have just realized that you have to arrange something at Budějovická the same day. You want to change the origin of navigation to Budějovická.*
     - Message with verification code: `Your verification code is: 23pr`

- **Testing process**

  The **1st participant** started the first scenario without problems. She tried to log in but she realized that she did not have an account. She created one and continued as logged in user. First problem was that on the summary screen. She thought that appointment in already made. She did not notice the "Continue" button as it was hidden and she had to scroll down. But she realized that when she scrolled down to find how she can get back to the main page. At the beginning of the second task she was logged in so she immediately saw the list of appointments. When she changed the time of an appointment she was not sure if the change applied. She recommended to make changes more visible, to give more feedback. While she was working on the third task she entered wrong data in form for navigation data. Validation failed and modal dialog appeared. She understood the instructions but she would change the label of escape button from "Close" to "Back" or "I understand". While she was filling the form she also wrote the bus stop name in "City" field. At the end the moderator asked her what she thinks about the user account and skipping first two

steps while she is logged in. She liked the idea but also warned that there has to remain an option to change those information on summary page. She also liked SMS messages, she had no comments about the format of the message. She also mentioned that system like this is really needed and not just in hospitals.

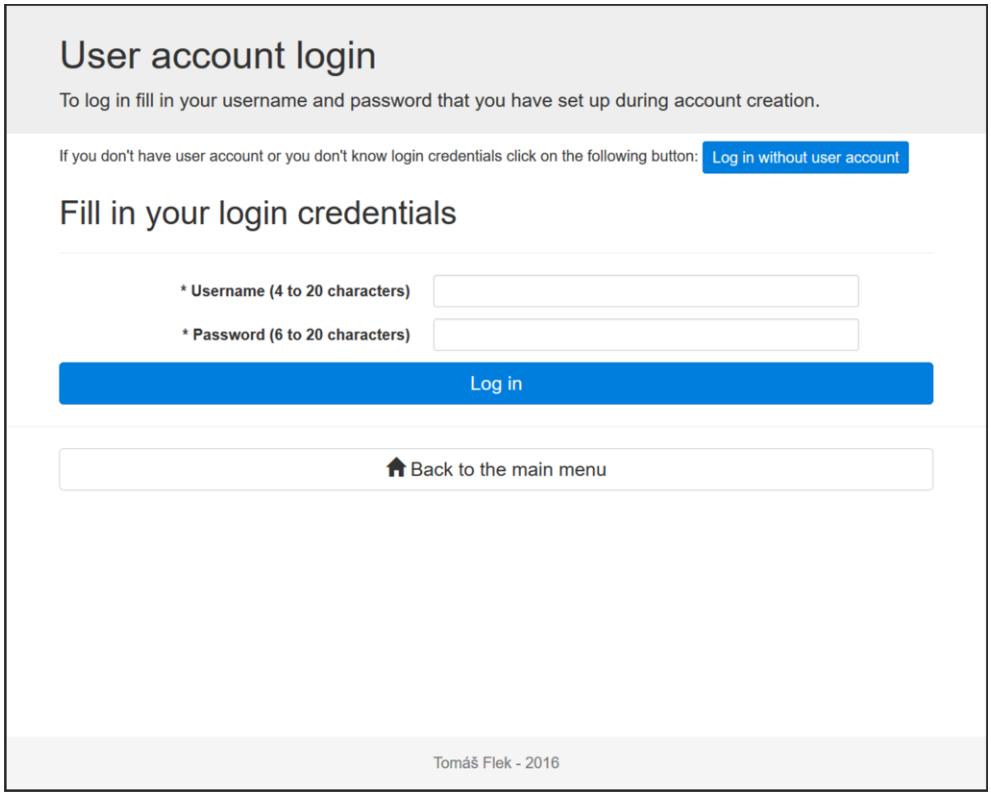

Figure 6.6. Account login page of the Hi-Fi prototype.

The **2**nd **participant** finished the first scenario without problems. However, she did not use the user account. The first problem was she she was trying to display her appointments. She did not have an account so she had to access them via phone number and SMS code. The problem was that she did not notice the "Log in without user account" button (Figure 6.6). She would make it bigger. After a while she noticed the button and successfully accessed the appointment to edit. When she started the third task she realized that she will have to insert all information again so she created an account. She also responded that she would prefer to skip first two steps while she is logged in. While she was filling in the navigation form she also wrote the name of the bus stop to the "City" field. She had no comments about the SMS message format.

The **3**rd **participant** had no problems with the first scenario. She just commented user accounts that she did not like it. Probably, she had bad experience with user account before. She just continued without it. During the second scenario she successfully found the button for entering without user account and changed the appointment's time. During the third scenario she made a mistake in date input field on navigation settings page. She did not understand the message "Date must be in format DD.MM.". She did not know what DD.MM. stands for but when she closed the dialog and noticed that the date field is red she corrected it (Figure 6.7). When she was going to change the origin of navigation she noticed the button with label "Change target location". She did not know what it means and suggested to change

the label to "I want to go somewhere else". She had no comments about the SMS message format.

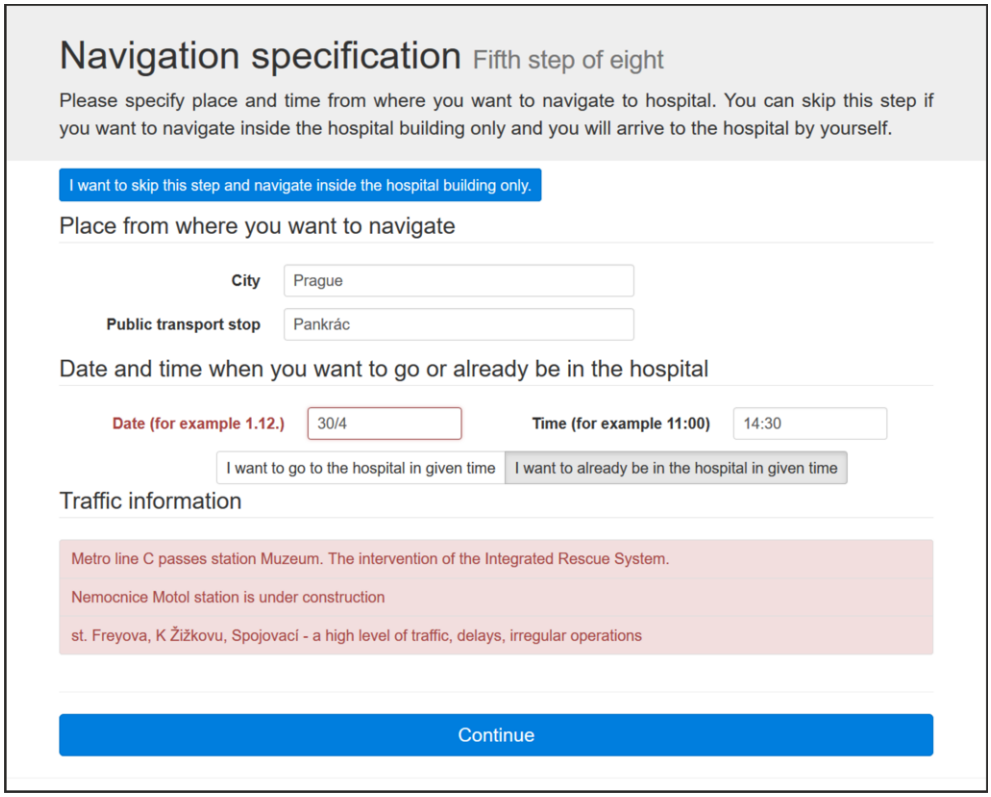

Figure 6.7. Navigation specification page of the Hi-Fi prototype.

The **4th participant** started the first scenario without the problem. The first hesitation was about the verification code. He did not know if he had to enter the code in capitals or if it does not matter. In the second scenario he did not know how to access to the appointment if he did not want to create an account. He did not notice the button for access without the user account (Figure 6.6). He thought that some seniors might have problem with SMS messages and verification codes — it is too complex he said. However, he finished the second scenario without big problems. During the third scenario he wrote bus stop name into the "City" field and also a year into the "Date" field on the navigation specification screen. When validation failed he successfully corrected mistakes and continued in the task. He managed work with SMS messages but he again mentioned that is might be too complex for some seniors.

The **5th participant** started the first scenario without problems. At the end of the first scenario she decided to create a user account as the text recommended it. She successfully managed the edition of the appointment and tasks in the second scenario. In the third scenario she also wrote the name of the public transport stop into the "City" field. The only comment was about the final screen of the navigation/appointment creation. There is just "Back to the main menu" button but was not sure if she wanted to go there. She suggested to change the label of the button to something like "Finish". She has no problem with SMS messages and she also managed to work with user account. She liked the system and she found it very useful.

The **6**th **participant** had no problem with the first task. The only comment was about the verification code. He thought that it might be too complex for other seniors. At the end of the first scenario he created an account. Thus, the second scenario was also without problems as he entered appointments right away. While he was confirming phone number in the third scenario he first thought that he has to use the same code from the first scenario. When the SMS mesage arived he understood and entered the correct code. Despite the comments about the SMS messages he found the system very useful and intuitive.

The **7**th **participant** had no problem with the first task. She decided not to create an account as she is not used to use them. She successfully accessed appointments via phone number and SMS message enter code. She found tasks very useful. While she experience the validation error in the third scenario she was confused about the "Close" button. She thought that it will close the whole page. She suggested to change the label of the button.

The **8**th **participant** no problems during the whole test. As he was an advanced user and did not read whole site but just headers and tabbable content like links, buttons and input fields, he skipped the information how doctors are sorted in list. The page with doctors listing is depicted in Figure 6.8. He expected doctors are sorted by first name. He would also remove all titles from names ("MUDr.") as it confused him a little. While he was filling in the date of birth he did not know exact format but tried it and it passed the validation. While he was changing the origin of navigation in the third scenario he complained that the radio button did not remember the state — there was a bug in implementation. He really liked the website. He said it is very intuitive. He would suggest to skip the first 2 steps when he is logged in as there will remain possibility to change information later. SMS message verification did not surprise him — he would expect this behavior as it is hospital system.

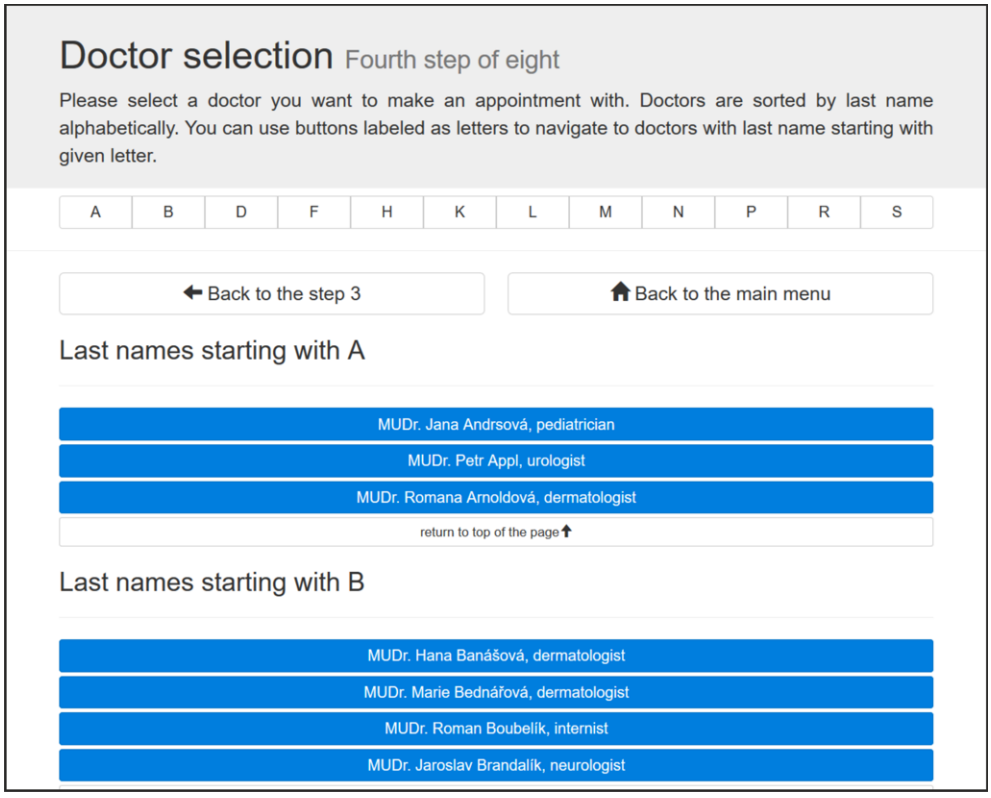

Figure 6.8. Doctor selection page of the Hi-Fi prototype.

The **9th participant** started the fist scenario without problems. She was confused about sorting of doctors. She thought that they are sorted by first name as she skipped the information in the page header. She used navigation letter to move in the list. While she was working with tasks she expected that hitting ENTER on the task will mark it as done. Later she noticed that there is a button for that and she used it. Sadly, she consumed a lot of time on the list with doctors where she tried to find the doctor in several ways. Because the lack of the time she was not able to start the third scenario. She was not used to use JAWS with given setup and with given keyboard so she was slower than usual. She said she would use the account in future if she will use the service more than just once. She would also skip the first 2 steps when she is logged in but there had to be possibility to change information later. She did not have problem with SMS message. Format of the message was OK.

The **10th participant** started the first scenario without problems. The first problem occurred on the page where doctors were listed (Figure 6.8). She did not understand the concept of the letters that helps with navigation in long listing. The main reason why she was confused was that she was not focused on the test and she was still commenting unimportant things while the screen reader read the page content. On summary screen, she would suggest to change the label of the button "Change appointment's target" to the "Change appointment's purpose" which will be more understandable. She was used to use the special curved keyboard so she had really big problems with typing. Also, she was not focused during the whole test. She did not try to achieve a goal of the task but she was thinking about all improvements she would do on each page. Majority of comments were caused by not listening to the screen reader. She managed to achieve only the first task in time dedicated to the session. She was OK with SMS format and it did surprised her.

The **11th participant** completed the first scenario without problems. She really liked the confirmation SMS message with appointment summary. While she was working with tasks in the second scenario she had problem with JAWS form mode. This mode caused that button that is placed right after the form was skipped by screen reader. That was the reason why she clicked on "Save changes" instead of "Add to tasks" button (Figure 6.9). She also experienced the bug with not remembering the choice of radio button in the third scenario. She was suggesting to skip first 2 steps while using account. She would use it when she will make another appointment. She said that whole website is cool and she really liked it. SMS messages was OK. She would suggest to avoid letters F, B and D in code as they are hard to distinguish when they are read.

The **12th participant** started by creating a user account. She is used to use it and she followed the recommendation to create it. The first problem was on the personal information page while she was entering phone number. There was not format specified so she wrote number with international prefix. She recommended to specify the number format. She commented the page with doctor's listing clear and simple. As she was logged in she directly accessed the appointment to edit. She used "Save changes" instead of "Add to tasks" button (Figure 6.9). She blamed the form mode of JAWS. It sometimes skips the button which is present right after the input field. She would suggest to save changes in the moment when they are made. She would suggest to skip first 2 steps when she is logged in. SMS message did no surprise her. She found website useful, clear and simple. She would not add any tabbable content as it would be more "chatty" than it has to be.

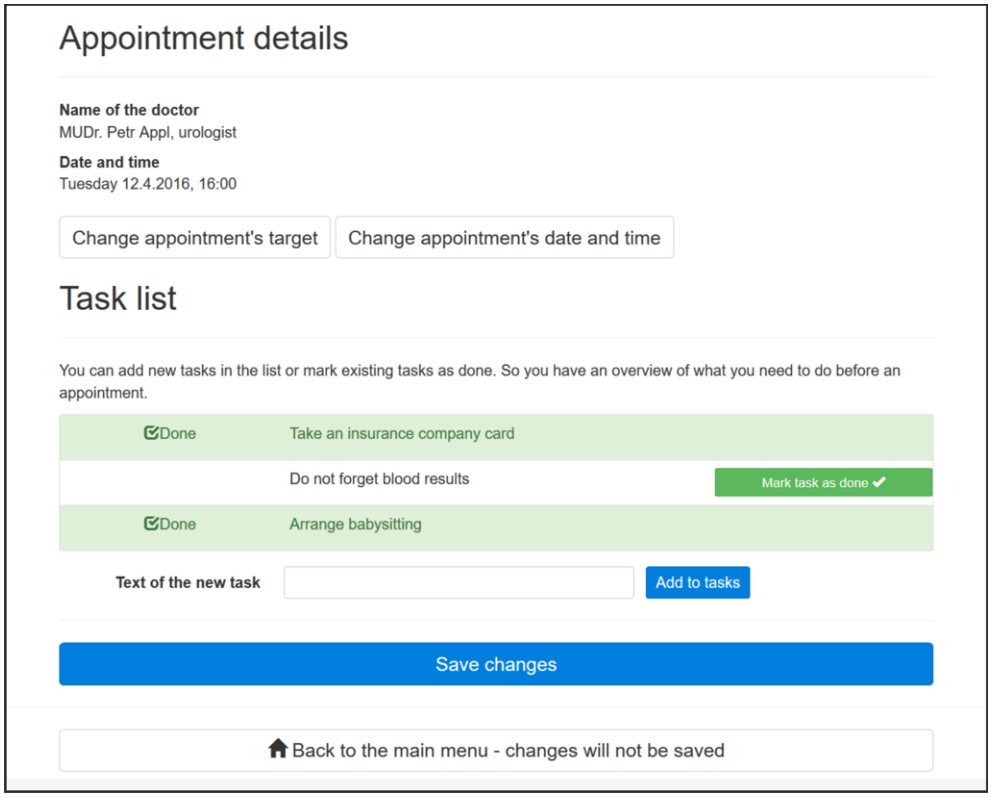

Figure 6.9. Appointment details page with tasks of the Hi-Fi prototype.

The **13th participant** also started by creating a user account. She hesitated a little about he format of the month in the date of birth (number or text). She successfully used navigation letters to find the doctor she was looking for. She really liked the idea of reminding the appointment one day in advance. While she was doing the third task she notices the traffic information and she really liked it. She would skip the first 2 steps when she is logged in. SMS message were OK, she would expect something like this from the hospital system. She really liked the website. She said it is intuitive and not very chatty.

The **14th participant** started the first scenario without problems. His first complaint was about missing link to the Personal information processing agreement. He also missed the information about the format of the date of birth field and format of the phone number. He did not understand the concept of the navigation letters. Despite that he was able to find desired doctor by search in a page. When he was choosing time of an appointment he would suggest to make legends as headings to make them easier to find. He would also suggest to select a day and then time. He liked the radio buttons as it is easy to continue by hitting enter. He suggested to add the information about the location of an appointment in the summary SMS message. At the end of the first scenario he created an account. In the second scenario, he did not understand the concept of the tasks. He would suggest to rename “tasks” to “notes” and add possibility to add them while creating an appointment. He would skip the first 2 steps when he is logged in. He also suggested to use only digits in SMS codes. It is hard to distinguish for example P and B letters. He really liked the page and found it usable.

6.3.2 Test results

The usability test has shown presence of some problems. Findings from each participant are summarized in one table. Each finding has defined ID, priority, description and improvement proposal. However, tested prototype has shown to be usable, understandable and intuitive as there were no findings categorized with the Priority 1. Participants liked the design and found the tool very useful.

Priorities are defined as follows:

- *1 (high)* – Defect makes system unusable, has to be fixed.
- *2 (medium)* – Defect makes system usage uncomfortable and confuses user, should be fixed.
- *3 (low)* – Defect makes system usage little confusing, should be reviewed and probably fixed.

Summary of all findings from the usability test is shown in Table 6.4.

6.4 Final design

This Section describes evaluation of the last prototype. Detailed description of the prototype can be found in Section 4.7. The goal of the evaluation was to evaluate an implementation of the prototype. The user interface and interaction has been successfully evaluated on Lo-Fi and Hi-Fi prototypes by usability tests with target group.

6.4.1 Accessibility validation

To statically verify accessibility of the web application the WAWE[1] tool was used. The tool loads the website and shows the problem marked on the your page preview. Each page and state of the application was manually checked with the tool and results evaluated. It is important to say that there were no validation errors found. There were only few alerts. The first alert was about the use of justifying text to block. The second was about several links that have the same target. This was intended as the list of doctors is made as list of link leading to the next step. The website was also validated with Markup Validation Service[2] for HTML in version 5.

The result was not surprising as the guidelines of creating good accessible web discussed in Section 2.3.1 were followed. Also, discussions with visually impaired participants during usability tests helped a lot. They have rich experience with using screen readers so they could provide important insight of how they perceive web.

6.4.2 Unit tests

The REST back-end of the web application was evaluated by using REST-assured[3] framework. It provides build in support for parsing and validation of JSON payloads which are consumed and produced by back-end. Tests cover all endpoints that are used by front-end or will be used by other parts of the navigation system.

Tests are sorted in classes according to endpoints. Each test forms a request with custom JSON payload if it is necessary and then sends it to the endpoint. Based on the scenario the response status code is checked and if some payload should be returned it is parsed and validated. Tests are included in the web application's project and can be executed manually.

[1] `http://wave.webaim.org/`
[2] `https://validator.w3.org/`
[3] `https://github.com/jayway/rest-assured`

ID	priority	problem description	improvement proposal
1	3	change in appointment is not visible on the first sight	add some form of feedback that change was successful
2	2	label of close button in modal dialog confuses users	change label to “Back on the form”
3	2	users are filling in bus stop name in city field	remove the city field and provide this service just for Prague for now
4	2	button for login without user account is easily overlooked	increase the button size and position to make it more visible
5	2	“DD.MM.” is not familiar to seniors	rephrase error message and show exact date format example
6	3	users do not understand “Change appointment target” label	rephrase this button label
7	3	users are not sure about the format of code (capitals or small letters)	change alphanumerical code to just numerical — is is easier to read by screen reader
8	3	date field on navigation specification page does not accept year	accept also format with year in the date
9	2	users are confused about the sorting of doctors	remove “MUDr.” from names and start with surname
10	3	date of birth input fields are missing format hint	add description of the requested format for all fields
11	2	radio button group does not remember state when page is leaved	fix bug
12	2	phone input field is missing format hint	add description of the requested format for the field
13	2	users do not like entering all information again while they are logged in	when user is logged in skip first two steps
14	3	dates available for appointment are not easily accessible by screen reader’s shortcuts	make legends also headings

Table 6.4. Overview of all findings of the Hi-Fi prototype revealed by usability test with priorities and improvement proposals.

Chapter 7
Conclusion

The aim of this thesis was to provide a tool that will help specific user groups — seniors and visually impaired — prepare for a hospital visit. That was achieved by designing and developing a web application which will be integrated into the In-hospital navigation system.

The domain of indoor navigation systems suitable for hospitals and hospital visit preparation was analyzed in Chapter 2. Several existing solutions were presented as well as compared to the proposed In-hospital navigation system [1–2] being developed at CTU. The analysis has also shown that there are only few possibilities of how people can prepare for a hospital visit.

The user research described in Chapter 3 was conducted with participants from target audience. It showed that people do have problems with navigation in hospitals and that a hospital visit is stressful. The research also proves that people are not used to getting prepared for a hospital visit in advance and what the main reasons for visiting hospitals are. The requirements for the tool have been based on the results of the user research.

Several prototypes were designed by employing the UCD approach. The design process is described in Chapter 4. The first prototype was based on the user research results. The next prototypes were designed with respect to evaluation results of the previous prototypes. The evaluation of each prototype is described in Chapter 6. *Each prototype was evaluated* by the usability test with the target audience. The usability tests ensured that findings were relevant as they were based on target user's experience.

The designed solution was implemented iteratively with each prototype creation. The final design of the tool was implemented as a standalone fully accessible web application with exposed REST API providing data access for the other parts of the navigation system. The implementation described in Chapter 5 was also focused on accessibility for visually impaired users and seniors.

The designed solution meets all the requirements stated at the beginning of this thesis. The most important fact is that the developed web application was found very intuitive, simple and usable by the majority of participants.

7.1 Future work

The next step is to improve the implementation especially in the security area and perform usability testing of the whole navigation system integrated in a real indoor environment. To be able to do that it is necessary to deploy the web application in a cloud environment. Once the test is performed and all findings are resolved the web application should be fully integrated with the back-end of the In-hospital navigation system. The last step is to deploy the navigation system in an existing hospital for commercial use.

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Appendix A
Specification

Czech Technical University in Prague
Faculty of Electrical Engineering

Department of Computer Science and Engineering

DIPLOMA THESIS ASSIGNMENT

Student: **Bc. Tomáš Flek**

Study programme: Open Informatics
Specialisation: Software Engineering

Title of Diploma Thesis: **Supporting hospital visit preparation for specific user groups**

Guidelines:

Perform user research of hospital visitors, focus on visually impaired and seniors. Focus on reasons to visit a hospital and information handover regarding indoor navigation. Perform an analysis of comparable solutions (SoA analysis) and suitable development methods and tools.
Design a solution that will support hospital visitors with visit planning and information exchange corresponding to a hospital visit. Focus on handover of information necessary for indoor navigation planning and personalization, including information necessary for user interface adaptation. Use user centered design (UCD) approach.
Implement designed solution with respect to the needs and preferences of the target user audience. Integrate the implementation with other components of the in hospital system being developed.
Evaluate developed solution using suitable UI evaluation methods. Evaluate the implementation using SW testing methods (e.g. unit testing).

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Prague, January 15, 2016

Appendix B
Abbreviations

To simplify the text, some abbreviations were used. Here can be found the whole list.

UCD	User Centered Design
SoA	State of the Art
VI	Visually Impaired
ARIA	Accessible Rich Internet Applications
HTML	HyperText Markup Language
JS	JavaScript
CSS	Cascading Style Sheets
REST	Representational State Transfer
API	Application Programming Interface
JSON	JavaScript Object Notation
JSP	JavaServer Pages
HTA	Hierarchical Task Analysis
UI	User Interface
UC	Use Case
GUI	Graphical User Interface
Lo-Fi	Low-Fidelity
Hi-Fi	High-Fidelity
PDF	Portable Document Format

Appendix C
CD Content

At the CD are located source files of prototypes and software required to be able to execute them. All necessary programs can be downloaded for free.

This document was typeset in plainTEX using CSplain[1] for a few Czech characters and the CTUstyle[2] template by Petr Olšák. To be able to execute the source code it is necessary to download TEX document production system — for example TeX Live[3].

The attached CD has following structure:

- **Prototypes**
  - **Final prototype**
  - **Hi-Fi prototype**
  - **Lo-Fi prototype**
  - **Mock-up**
- **Required software**
  - **GlassFish** in version 4.1
  - **Java** JRE in version 8
- **Text of this thesis**
  - **PDF** version of this thesis
  - **TEX** source code of this thesis

[1] http://petr.olsak.net/csplain.html
[2] http://petr.olsak.net/ctustyle.html
[3] https://www.tug.org/texlive/