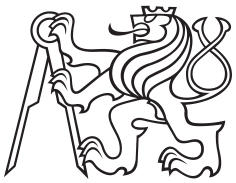
Master Thesis



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F3

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Tourist Navigation with Accessibility Data Crowdsourcing

Tourist Navigation and Crowdsourcing

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Field of study: Open Informatics
Subfield: Software Engineering
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Declaration

I declare that I have prepared my work independently and that I have provided all the literature used.

Prague, 1. January 2019

Abstract

The diploma thesis deals with the topic of crowdsourcing of the accessibility of the sidewalk network with the help of a target group of tourists visiting the city.

In dealing with this issue, We have researched multimodal navigation applications for tourists and crowdsourcing of accessibility data, worked out scenarios and storyboards for a possible solution, described the interface formally using HTA, including plans. Next, We created a sketch, a paper prototype, tested usability, and implemented a mobile application prototype on the Android platform, which We also tested for usability in an urban environment.

The benefits of the work are the results of both testings and recommended solutions for the key findings. Interesting differences are found between paper mockup testing and Android apps. When testing a paper mockup, the design flaws may be overlooked.

Keywords: tourist navigation, crowdsourcing

Abstrakt

Diplomová práce se věnuje tématu davového sběru přístupnosti chodníkové sítě pro osoby se zhoršenou orientací a pohybem za pomoci cílové skupiny turistů navštěvujících město.

Při řešení této problematiky jsme provedli rešerši multimodálních navigačních aplikací pro turisty a rešerši přístupů pro davový sběr dat o přístupnosti, vypracovali jsme scénáře a storyboardy možného řešení, popsali rozhraní formálně pomocí HTA včetně plánů. Dále jsme vytvořili skeče, papírový prototyp, provedli test použitelnosti a implementovali prototyp mobilní aplikace na platformě Android, na kterém jsme taktéž provedli test použitelnosti v městském prostředí.

Přínosem práce jsou hlavně výsledky z obou testování a doporučení na řešení nálezů. Zajímavostí jsou rozdíly mezi nálezy při testování papírového mockupu a aplikace na platformě Android. Při testování papírového mockupu mohou být přehlédnuty zásadní nedostatky návrhu.

Klíčová slova: turistická navigace, davový sběr dat

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Chapter 1

Introduction

The ability to move freely is one of the basic needs of a person. If this option is limited, there may be a significant deterioration in social or working life. Degrading movement can, for example, cause such people to limit activities associated with movement, it can result in a loss of work or hobbies, or exclusion from the collective. In this work, we focus on people with physical or sensory impairments such as: people with impaired ability to walk or people with visual impairments [SM12].

In order to improve the mobility of people with limited orientation and mobility, it is necessary to increase the awareness and improve the provision of information, including information and communication technologies.

This diploma thesis primarily focuses on the problem of extension of the geographical information database for people with limited orientation and mobility skills. Most navigation applications are built on route network database. For example, these databases do not include a pavement network or pedestrian accessibility information. The problem is that filling the database with accessibility data is very challenging because it is necessary to go to the field. Therefore, it is less challenging to create a empty sidewalk site without the accessibility attributes and add those later.

To solve this problem, we decided to take advantage of the many tourists exploring the city with some navigation applications. Tourists are also less likely to be in a hurry compared to the working people and will be more inclined to collaborate in database upgrades.

In this diploma thesis we solve the problem described above using a mobile application. We will focus on creation of a mobile navigation application for tourists, which will serve to collect accessibility attributes for ROUTE4ALL platform. According to user centered design (ISO 9241-210), this diploma thesis consists of partial tasks: research on tourist navigation and crowd-sourcing, creation of scenarios and storyboards, description of the interface formally using HTA (Hierarchical Task Analysis), including plans. Included is a creation of sketches as well as a paper prototype on which a usability

test is carried out, followed by the implementation of the mobile application prototype on the Android platform together with the usability test performed in the urban environment.

Chapter 2

Related work

This section is devoted to a brief summary of 12 articles from navigation applications, crowdsourcing and navigation application requirements. These summaries are often enriched with images for a better understanding of the subject. This part also contains brief research on mobile applications which are now available on Google Play.

2.1 Crowdsoucing

Michaela Riganova, Jan Balata and Zdenek Mikovec [RBM17] focused on crowdsourcing to deal with the problem of navigations which are mainly based on geodatabases for cars not for pedestrians. They made a research focused on collecting data from non-expert crowd (which is cheaper). [SM12] According to Sammer et al.,up to 16 percent of the population is impaired in some way (visual, auditory or movement). Still most navigations do not include sidewalks, crossings with navigation points, and so on. In research they address three major issues: collecting features such as the shape of a sidewalk or curbs, information on temporary restrictions and validation of such data.

Figure 2.1: An image describes how participants performed measurements [RBM17].

During their experiment they split the participants into three groups of different age. To measure the length or distance, participants used stepping or were using their feet. They encountered problems when measuring the

slope of pedestrian segments.

Based on the research, they found that participants do not want to spend too much time with the measurements, so they proposed faster methods of input such as sliders, drop-down menus, or drag&drop instead of text fields. They also used the principle of gamification to attract users to fill in the information.

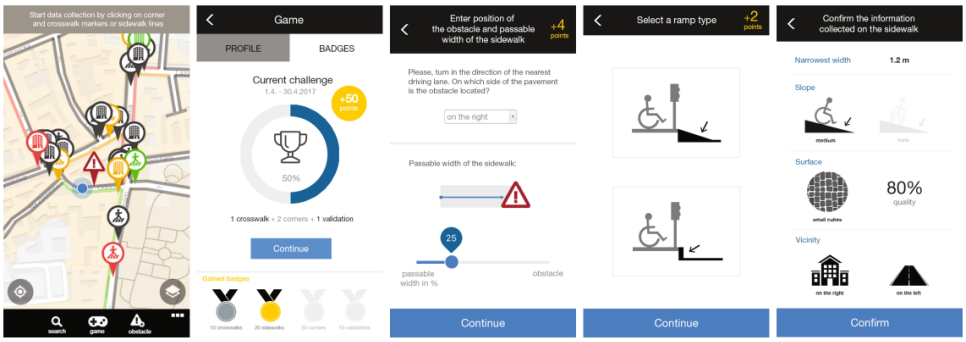


Figure 2.2: From the left: a pedestrian segment visualization with features; gamification elements; obstacle reporting; crosswalk ramps; recapitulation of collected data. [RBM17]

In the bachelor thesis of Michaela Riganova [Rig17], we took over the data structure suitable for data collection by crowdsourcing. This data structure, based on the analysis of the Route4All project and the POV and SONS methods, is needed to successfully navigate impaired people. Such data can be obtained without any special tools by crowdsourcing and are illustrated in the following diagram.

1. **Pedestrian segments**: width, longitudinal slope, cross slope, surface type, surface quality, vicinity
   a. **Street**: pavement location
   b. **Footpath**: sidewalk location, opening hours
   c. **Vertical Transition**:
      (i) **Stairway**: railings location, number of steps, step height, step depth, tactile guidelines, color contrast, spin type and direction
      (ii) **Incline**: length, railing location and height, tactile guidelines, platform size, spin type and direction
   d. **Crossing**: crossing type, control type, number of islets, direction of traffic flow, tactile guidelines, tramlines, length
      (i) **Entry points**: curb height and slope, curb surface quality, platform, passable width, tactile warning, tactile guidelines
2. **Stop place**: type, name, traffic direction, platform location, boarding barrier type, tactile guidelines, tactile warning, audio

3. **Landmarks and Obstacles**: type, description, contrast
   a. **Landmark**: height, material, passable width, duration
   b. **Obstacle**: gap/raise, number, vertical size, horizontal size, slope, duration
   c. **Corner**: shape
4. **Points of Interest**: public toilettes, tram/bus stop, subway entry/exit

Kotaro Hara and Vicki Le and Jon Froehlich [HLF13] wrote paper which describes use of crowdsourcing to find and assess sidewalk accessibility problems in Google Streetview. For their research they used a crowd of untrained workers from Amazon Mechanical Turk. They report on two studies, firstly they labeling by 6 specialized labelers (including 3 wheelchair users) second comparative performance of turkers. Turkers are able to recognize problems with 81% accuracy which can be increased to 93% by simple quality control. The article describes different approaches to labeling problematic locations, such as when users provide labels to objects, indicate objects by drawing bounding boxes or using other tools, for example a tool named LabelMe which allows the user to draw polygonal-outlines around objects. The verification of objects can be done by using pop-ups to confirm a labeled problem.

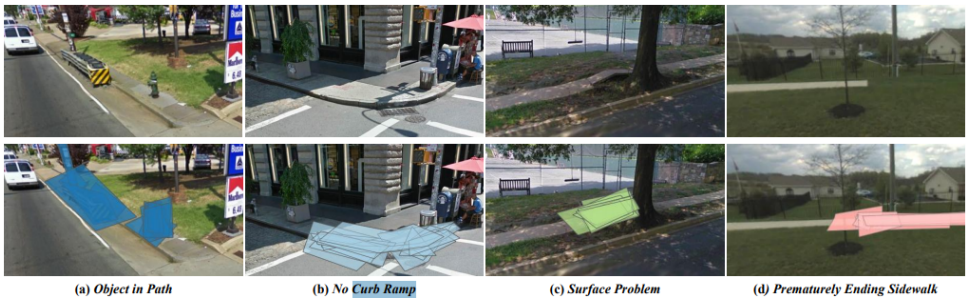


Figure 2.3: Accessibility problems in Google Streetview imagery [HLF13]

Figure 2.4: Labeling GSV images is a three step process consisting of marking the location of the sidewalk problem in the image [HLF13]

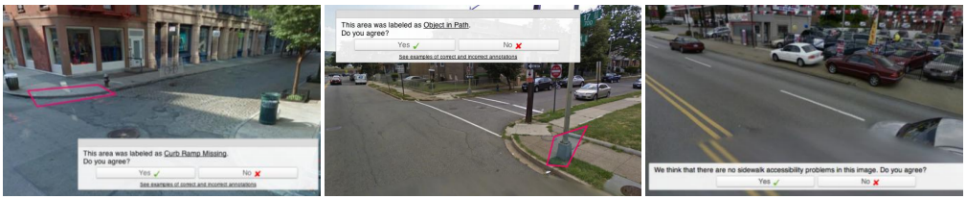


Figure 2.5: Sample of the verification interface used to experiment with crowdsourcing validation of turker labels [HLF13]

From the research on crowdsourcing we mainly used information about the structure of the data about the segments of the sidewalks. We also used the tested prototypes of crowdsourcing. The crowdsourcing must be short enough for users. One article also show that participants are able to recognize probabilities with high probability (81 percent).

The idea of the diploma thesis is the effort to extend the Geographic information system by crowdsourcing, which will be carried out by a target group of tourists using the mobile navigation application. The following chapter is devoted to research on navigation and tourism applications and navigational approaches.

2.2 Tourist navigation

D. McGookin, S. Brewster, and P. Priego [MBP09] introduced the concept of Audio Bubbles. The Audio bubble is a virtual sphere which is located on some place of interest. When the user enters the sphere he is informed about the presence of a point of interest nearby or that the point of interest was reached. Distance information is encoded in audio to lead the user to the point of interest without the need of constantly following the map.

Figure 2.6: A screenshot of the visual display showing the current user location (A) and the location (B) and name of the next landmark) [MBP09].

Alexander Zipf, Amin Mobasheri, Adam Rousell and Stefan Hahmann [ZMRH16] describe problems connected to crowdsourcing data. There are many different geo-data quality elements (positional accuracy, attribute accuracy, completeness, logical consistency and temporal accuracy) that one might need to check before using any kind of datasets in his project. The article describes several tools for checking the level of incompleteness of data. Routing services are also mentioned in the article including the functionality to be extended for to address specialised requirements, such as wheelchair routing.

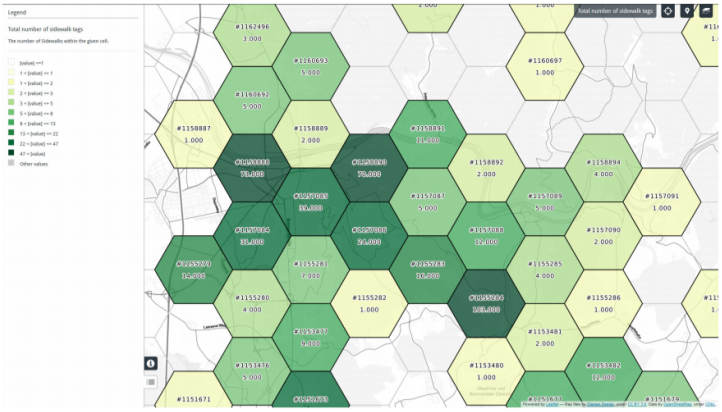
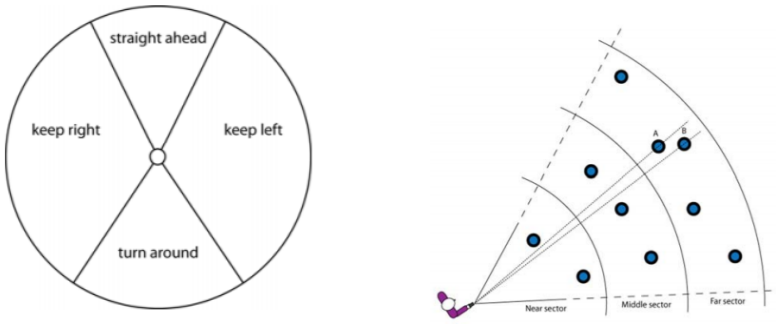


Figure 2.7: Mapping the completeness statistics of total number of sidewalk information using OSMatrix [ZMRH16].

Charlotte Magnusson, Miguel Molina, Kirsten Rassmus-Gröhn, Delphine Szymczak [MMRGS10] describe their approach to navigation for people who have visual impairments. They developed a prototype of navigation which is based on navigating by soundcrumbs. Their application provides speech and vibratory feedback. The main principle is that the user scan the environment by pointing and guiding to selected target. Then the user is navigated by direction (and recommendations like: straight ahead, keep right, keep left, turn around) instead of using more precise instructions.



(a) : Guiding design. The "straight ahead" angle is 46° (to avoid decimals), the "turn around" angle is 60° and the "keep right/left" anlges are 124° [MMRGS10].

(b) : Scanning angle and sector ranges. The points signify POIs, and the POIs A and B in the same sector are close to each other in angle [MMRGS10].

Figure 2.8: User navigation by direction

Meredydd Williams, Kelvin K. K. Yao and Jason R. C. Nurse [WYN17] developed an application for tourists based on usercentered design. They used iterative development approach which consists of Inital Mock-ups, Map Prototypes, Route Planner Prototypes, Browser Prototypes and Final Design. They selected four annotation details for points of interest: name, type, distance and rating. They augmented application by Wikipedia, data and solved users complains. Also dealed with approaches of how to display information about the points of interest.

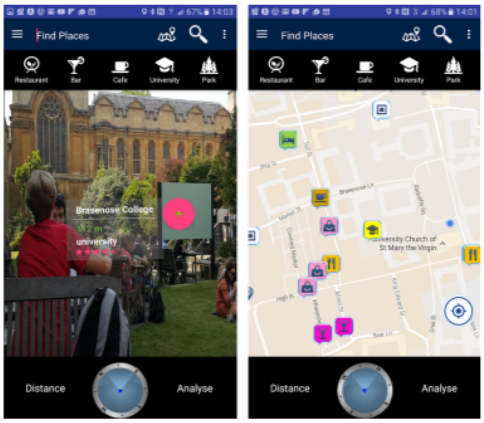


Figure 2.9: Final Augmented Reality Tourism App ToARist [WYN17]

Anahid Basiri, Pouria Amirian and Adam Winstanley [BAW16] wrote paper about how landmarks can improve the performance of pedestrian movements following landmark-based navigational instructions. In light of the fact that almost all users have devices with camera, they can take a photograph of a registered point of interest and then send it for image processing. Additionally, when the navigation contains images of landmarks,

it makes the user more confident about the directions and less prone to disorientation.

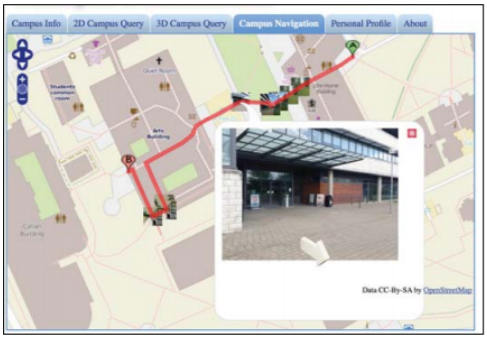


Figure 2.10: Visual navigational instructions in eCampus web application [BAW16]

Eija Kaasinen [Kaa03] wrote about how to improve usability of mobile services and applications. It is better to adapt contents and presentation of the service to each individual user. The paper describes conclusions of key issues related to user needs. There are several methods of locating the user (user locate himself, GPS, telecom operator in the network, service point). Eija carried out a study of future possibilities of personal navigation products with 13 evaluation groups. Topical information is very important for the users. For example, in the case of the search for traffic connections, it is also about the information about the delays as well as suggestions of alternate routes.

Keith Cheverst, Nigel Davies, Keith Mitchell, Adrian Friday, Christos Efstratiou [CDM+00] wrote a paper about developing and evaluating an intelligent electronic tourist guide. They wanted to overcome the limitations of traditional information and navigation tools which are available for tourists. Often schedules are inflexible and catering to the interests of the majority and not the individuals. They aimed to tailor the information to the user dividing information to personal (e.g.visitor's interests) and environmental (the time of day, the opening times of attractions), optimally including support for dynamic information. They conclude with the presentation of their solution as well as user feedback.

Barry BROWN, Eric LAURIER [BL05] wrote a paper about how tourists work together in groups, collaborate around maps and guidebooks. Their motivation was to understand how tourists use a map and make recommendations for the design of a map based systems. They spent a few days studying tourists using small cameras. Tourists usually travel in pairs or groups. They rely on maps heavily. They aim to make the tour around city with minimum time spent by traveling between places. They also try to find attractions which are close by or grouped together. Tourists often cooperate with each other when trying to orientate in the map or find a particular place or a building.

Jeff Wilson, Bruce N. Walker, Jeffrey Lindsay, Craig Cambias, and Frank Dellaert [WWL+07] wrote paper about developing a system which effectively interacts without visual interface. It is developed with regard to persons temporarily or permanently visually impaired. SWAN system combines multiple GPS receivers with either a digital compass (PNI, Inc., model TCM3, 3-axis tilt-compensated) or an Intersense InertiaCube2 inertial orientation sensor to provide a reasonable estimate of location and accurate head orientation. The system uses a technique that navigates the user with audio signals. In effect it means that the user only needs to follow sound cues. The system is also capable of making the user aware of various points of interest, such as park benches, restrooms, bus stops, and restaurants. Other points of interest, obstacles, and surface crosswalks (e.g., change from level sidewalk to a descending stairway) are also represented. Users can also broaden their databases themselves by entering information about the feature and setting the category.

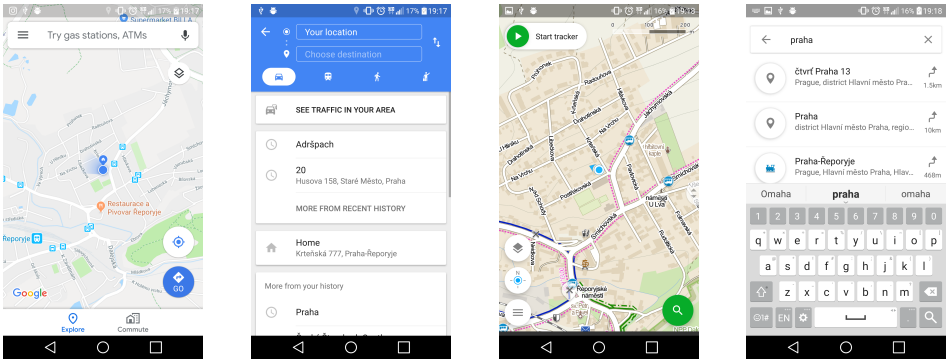
Thanks to the research on navigation applications I made a more comprehensive overview of the possibilities and approaches of navigation solutions for tourists as well as for guiding people with impaired ability to walk or people with visual impairments.

2.3 Existing mobile tourism applications

This section is dedicated to an overview of mobile tourism applications that are already published on the Google Play portal.

Google Maps[1] is not a typical tourist application, but an immense number of tourists use it on their travels. Additionally, the application is used for crowdsourcing widely. The app shows points of interest on the map using small icons. Depending on the type of building / place, different types of icons are displayed. When a user clicks on the icon, they can access details of the place with any photos and additional information. The user can also save their own points of interest.

[1] https://play.google.com/store/apps/details?id=com.google.android.apps.maps



Google Maps - map screen | Google Maps - searching for route | Mapy.cz - map screen | Mapy.cz - searching for place

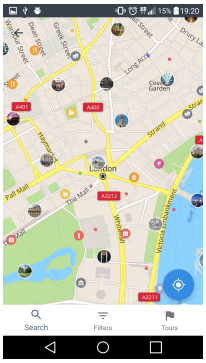
Figure 2.11: Screenshots of Google Maps and Mapy.cz application

Mapy.cz[2] is very common application in the Czech republic. It has a similar functionality to Google maps, with the difference that it has the feature called "Batůžek" (backpack) which allows the user save their created routes.

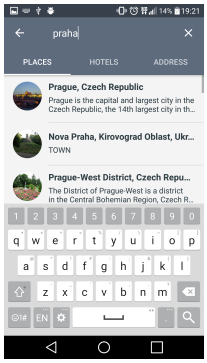
The application Sygic Travel[3] is an application created for tourists. On the one hand, it contains a map with places marked with small icons or thumbnail photos, but it also includes the possibility of creating a custom itinerary, viewing activities of sightseeing activities as well as a listing of interesting places, hotels, car rentals, weather forecast and transfers. The itinerary solution, allows the user to select the places they want to visit in each day, based on this information the application creates a route to follow, including additional information such as the expected duration of the trip.

Another tourist application is the World Travel Guide by Triposo[4]. This application offers a list of interesting places with photos and further information, lists of restaurants, hotels, activities, or entire excursions according to the selected location. These places can be stored by the user in favorites and the user can then create an itinerary for his journey.

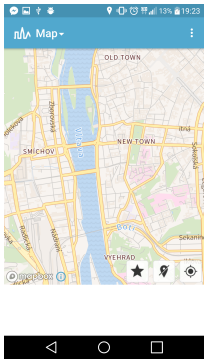
[2]https://play.google.com/store/apps/details?id=cz.seznam.mapy
[3]https://play.google.com/store/apps/details?id=com.tripomatic
[4]https://play.google.com/store/apps/details?id=com.triposo.droidguide.world



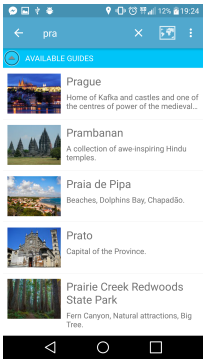
Sygic Travel - map screen



Sygic Travel - searching for place



World Travel Guide by Triposo - map screen

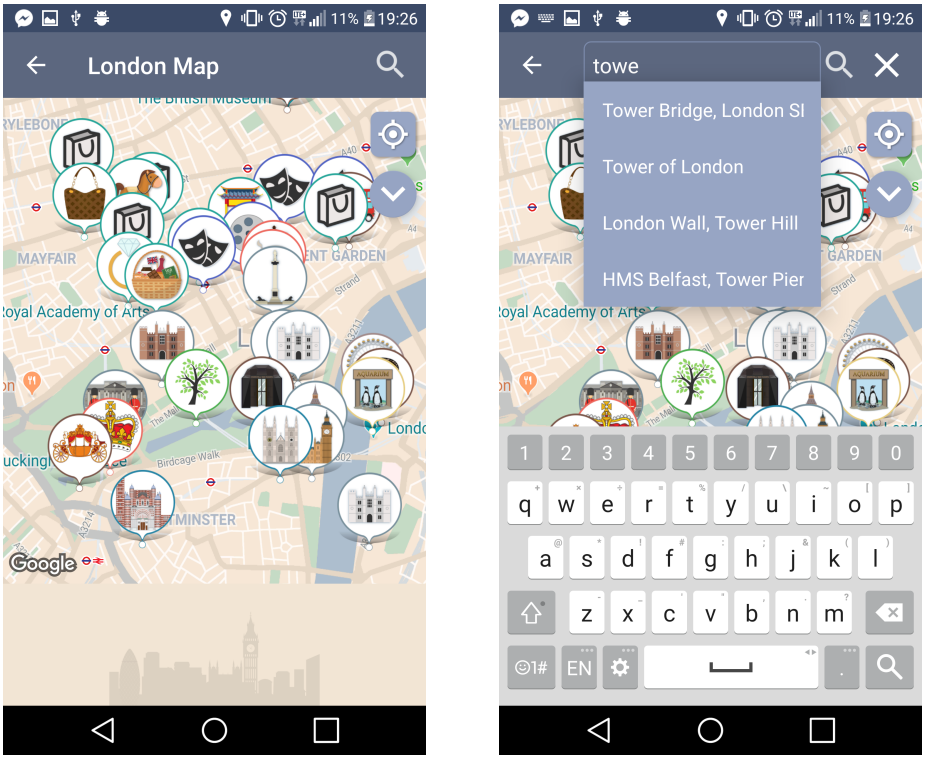


World Travel Guide by Triposo - searching for place

Figure 2.12: Screenshots of Sygic Travel and World Travel Guide by Triposo application

The tourist application London Travel Guide[5] is directly focused on London. It contains four main parts. A map that is not global but contains only a part of England. As with other applications, the locations of points of interest are displayed on the map, marked with icons by place type. Clicking on a point of interest will provide a short description, clicking on the description reveals a detailed view. The application also contains lists of places of interest, recommended routes around the city and recommended itineraries for one or more days.

[5] https://play.google.com/store/apps/details?id=com.cjproductions.londontravelguide



London Travel - map screen

London Travel - searching for place

Figure 2.13: Screenshots of London Travel application

The survey shows that the available navigation applications are quite similar. Applications for tourists have additional functionality for them, such as "Batůžek" (Mapy.cz) or lists of interesting places (Triposo). In my case, I was most inspired by Google Maps, because most users are used to its behavior. I also took into account the possibility of storing places and routes, which could be very good feature for tourists.

2.4 Young adults crowdsourcing experience

For my diploma thesis we used qualitative research of the group students (Lukáš Chvátal, Šimon Kadlec, Michaela Riganová) [LC18] from the course B4M39PUR1 on CTU. The main goals of the research were to find out the reasons why people participate (or don't participate) in crowdsourcing. The secondary aim was to find out how much people would participate in crowdsourcing and what would the form of participation be. Their target group included males and females from 18 to 35 years of age with basic technical skill concerning working with PC or a smartphone. The key findings are mentioned below.

Use of information technology, applications and services: Most

respondents use computer, smartphone for fun or minor work. On both platforms, respondents mostly use it to access social networks and e-mail client applications, following that they used their devices for the navigation system or to monitor weather and traffic connections.

Search for new applications and services: The most common and sometimes the only source of information on technical innovations, new applications and services are respondents friends. In most cases, respondents prefer information from reviews or from friends and acquaintances before their own initiative and application testing.

Lack of awareness of crowdsourcing projects: The main reason for people not responding to crowdsourcing projects is that they do not know about them. Respondents have little awareness of the market with available crowdsourcing applications and services. They mostly do not know about charity crowdsourcing projects, of which they would not have direct benefit. They can not imagine which data collected by them could help a particular group of people. This is partly because they do not think of crowdsourcing as an instrument to help other people.

Reasons not to participate in crowdsourcing: In the event that respondents learn about and participate in a crowdsourcing project, one of the main causes of their absence is that they are not competent enough to provide the given data (in terms of necessary knowledge) or do not like the form of data provision or disagree with the idea of the project. The confusion and user-friendliness of applications used for crowdsourcing is also a negative factor.

Motivation for crowdsourcing: From our interviews with respondents, the motivation to participate in the projects differs from respondents. Nevertheless, there were several motivators common to many respondents. The most frequent motivator for engaging in crowdsourcing is the collection of data / information that the respondent uses and needs. Therefore, it is easier for respondents to engage in projects that are somehow linked to their hobbies and interests.

Useful crowdsourcing projects: Respondents perceive the most useful projects to be those that collect geographic data information, information about current traffic or open database related to their interests and hobbies. Sharing experience and knowledge among people is seen as a great contribution in making and gathering information.

Risks associated with crowdsourcing: Respondents perceive the risks associated with crowdsourcing, namely the possible misuse of data if they are not sufficiently anonymous or inaccurate data that can have more serious consequences, for example, in the case of human health, assessment of the traffic situation, etc. At the same time, respondents are aware that with sufficient control mechanisms it is unlikely that errors will be retained in the data obtained. When using community-captured data, respondents do

not verify their accuracy and trust them. Two respondents have expressed concerns about the possible misuse of personal and sensitive data that services receive automatically, and they provide them involuntarily.

Participation in charitable and charity activities: Respondents have experience with charitable activities, which are mostly in the form of a financial contribution. This method of assistance is also most pleasant for respondents, especially because it does not require more effort. They trust the organization regarding the effective use of the provided funds.

The form of charitable crowdsourcing: It is important for all respondents to know to what cause they collect the data. They would also be interested and would like to know how the data is used to know to know what they spend their free time for.

From the above-mentioned user research, the proactivity of the project is the most important for me. The crowdsourcing project should regularly highlight its presence and require data collection. The speed of crowdsourcing is also important. Due to the scope of my work I did not take into account all the results of the user research but I assume that a large part of the problems identified could be possibly solved by well-formed onboarding screens.

Chapter 3

Analysis and design

This section describes the progress of the application design. The design phase is based on research described in chapter Related work. The design methods were: scenarios, storyboards, HTA, low-fi prototype [RC02].

3.1 Scenarios

Scenarios are informal narrative stories which are directly tied to the person and put emphasis on simplicity. They are not generalizable, which means they are related to a particular person (from the target group) [RC02].

SC1 - Preparation at home

In the comfort of her home Petra decides to travel abroad. She chooses to visit Prague because there are many beautiful sights. Petra is aware of a few places to visit (such as Prague Castle and Charles Bridge) but needs to find other sights and plan her trips. Because of that she is looking for a suitable navigation application. Petra finds a mobile application for tourists on Google Play and installs it (see figure 3.1).

After a while Petra receives notification from the application asking if she does not mind occasionally being asked to help improve the map's information value. Petra is also told why the information is collected and made aware that by crowdsourcing she is helping others). Petra agrees and confirms the request.

Now Petra wants to try some functions of the new application, she opens the application and searches for a specific location on the map. Petra specifies the name of the place where the application is prepared by the site menu according to the string written. Petra confirms her string and the application shows the location marked on the map (see figure 8.7).

Petra also wants to plan a route from one place to another. She chooses the route search and enters the start and destination. Searching for a start and a destination is the same as in the above part of scenario, with the difference that after the confirmation, Petra does not see the location on the map but the start / finish field filled. After entering these two fields, Petra gets the proposed route with additional information such as the length of the journey or estimated time (see figure 8.7).

Petra is not satisfied with the suggested route so she wants to edit the scheduled route by adding the places she wants to visit during the journey. The route in the schedule is automatically recalculated by adding places (see figure 8.7).

In order to not have to retain the information related to her new route, Petra wants to save the searched route for later so she can use it when she's traveling. When saving, Petra specifies the name of the saved route. After saving she wants to see where the route is saved. The application accordingly displays the message for a short while and lets the user navigate to the list of saved routes (see figure 8.8).

Figure 3.1: Sample of storyboard Preparation at home, the rest of the storyboards is available in attachments.

SC2 - Petra in the field

Petra arrives at a place abroad and as she wants to figure out her exact location, she is so she turns on her navigation application. There is a map in the application where Petra can turn on GPS. After that she is prompted to confirm turning on the GPS. Petra acknowledges the message so the map is automatically centered on the place where she is located with the exact location marked on the map.

Petra really wants to see Charles bridge but she does not know where it is. She knows the name of the monument so she enters the name and the map centers on the desired location. This monument is in the database which is why it has its own icon. Petra wants to know detailed information about the

monument, to do that she can display the detail view of the monument with more information including a picture.

Petra wants to visit Charles bridge so she sets this monument as a destination of her route. Then she chooses her current location as the start of her journey and activates the navigation.

She is then navigated along the route she created. Petra continues her trip according to the navigation when she approaches a location where accessibility information is missing. The application is asks her to add information to help. Petra is in a good mood so she fills in the information. After unlinking the location information, Petra sees how much she has advanced in her "game" profile, she can also go directly to the game "part" of the application.

Petra continues her journey until she arrives at the destination. Navigation tells her that she arrived at her chosen destination and the navigation then switches off (see figures 8.9 and 8.10).

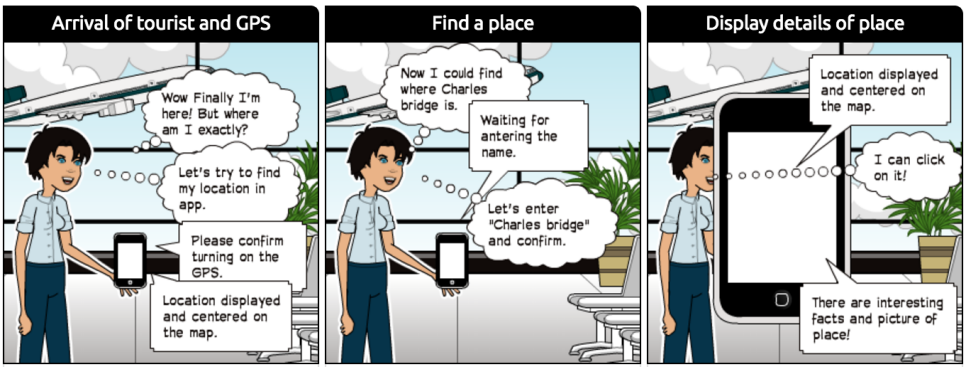


Figure 3.2: Sample of storyboard Petra in the field

AS1 - Asking user if he would help

Petra is asked to engage crowdsourcing. But she is not in a good mood so she rejects the request and continues her journey.

AS2 - Finding location on the map

Petra wants to find interesting buildings in the city but she does not know their names so she searches on the map in the application. There are many icons displayed on the map, representing various monuments. As Petra wants detailed information about one of the monuments, she clicks on the icon and displays the detail view of the monument with more information including a picture.

AS3 - Modify the route

Petra has created a route but she is not satisfied with it. She already added some places to the trip but she changed her mind and wants to remove it. In the application there is a possibility to remove an item from the route planner. When Petra removes the place the schedule is automatically recalculated.

AS4 - Saving path

Petra has created route but she does not want to use it now so she wants to save it. When saving she does not have enough time so she leaves the automatically generated name of route (the name is generated according to start and finish fields).

AS5 - Go to list of saved routes

When Petra saves her route, the application confirms the saving with direct access to the list of all saved routes.

AS6 - Finding place in favorites

Petra remembers that she found a desired location before and she saved it as a favorite location. Petra opens the favorite section in the application and finds the location there. Then she chooses to show the location on the map so location is centered on the map and further marked with an icon.

3.2 HTA

It is necessary to divide the task into subtasks (hierarchically) and to analyze single steps. In my thesis I used HTA (Hierarchical Task Analysis) method. It is a type of hierarchical decomposition which takes the form of a tree. It divides a goal into tasks then subtasks and finally steps. Sequences of steps to be preformed are called plans and they consist only of leaves of the tree. HTA is mainly used for easy understanding and clarity even though it is less compact than a textual form [RC02].

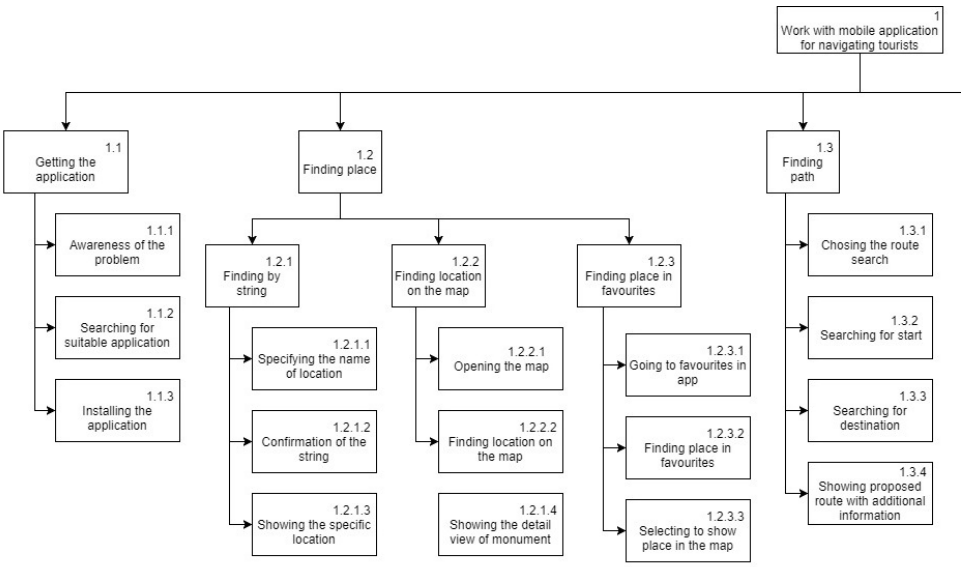


Figure 3.3: This part of HTA shows flows for getting the application, finding a place and path. The other parts of HTA are available in the attachments.

Plans

Below is a list of plans for single parts of HTA (left figure 8.1 middle figure 8.2 and right figure 8.3).

1.1 Getting the application (scenario SC1)

. 1.1.1 - 1.1.2 - 1.1.3

1.2 Finding place (scenario SC1, AS2, AS6)

. 1.2.1.1 - 1.2.1.2 - 1.2.1.3 OR 1.2.2.1 - 1.2.2.2 OR 1.2.3.1 - 1.2.3.2 - 1.2.3.3 OPTIONAL 1.2.1.4

1.3 Finding path (scenario SC1)

. 1.3.1 - 1.3.2 (see HTA 1.2) - 1.3.3 (see HTA 1.2) - 1.3.4

1.4 Editing path (scenario SC1, AS3)

. 1.4.1 - 1.4.2 - 1.4.3

1.5 Saving path (scenario SC1, AS4, AS5)

. 1.5.1 - 1.5.2 - 1.5.3

1.6 Getting users location (scenario SC2)

. 1.6.1 - 1.6.2 - 1.6.3

1.7 Starting navigation (scenario SC2)
. 1.7.1.1 - 1.7.1.2 - 1.7.1.3 OR 1.7.2.1 - 1.7.2.2

1.8 Navigating and crowdsourcing (scenario SC2, AS1)
. 1.8.1 - 1.8.2 - 1.8.3 - 1.8.4 - 1.8.5

1.9 Approaching the destination (scenario SC2)
. 1.9.1 - 1.9.2

3.3 Sketches

Figure 3.4 is a part of hand-painted sketch expressing ideas for graphical elements in a future application. There are ideas for showing different kinds of points of interest (like restaurants, historical monuments, etc.) on the map, different ways to display detail of place, search bar or icons on the map. All the sketches are in attachments (see figures 8.4 and 8.5)

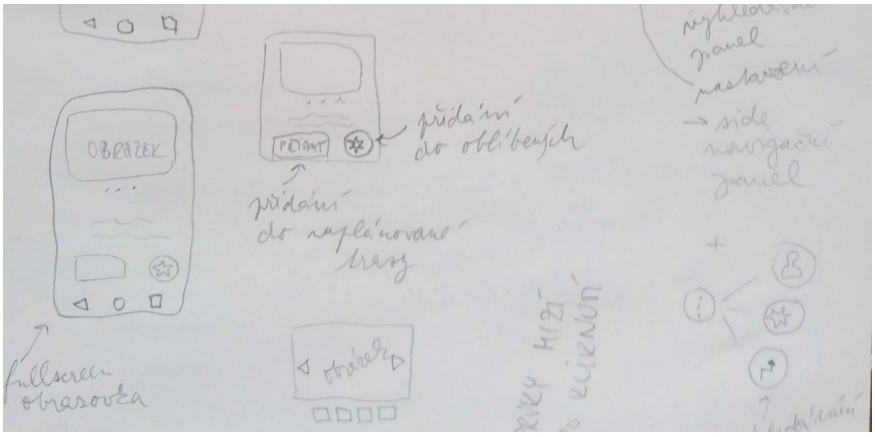


Figure 3.4: First part of the sketches

3.4 Lo-Fi prototype

Based on the research (which included, among other things, user research), scripts, storyboards and HTA with plans, a Lo-Fi prototype was created. The prototype was created from paper and described parts of UI, application states, and was directly designed for testing [RC02]. Lo-Fi prototype testing is further described in Chapter 5.1 .

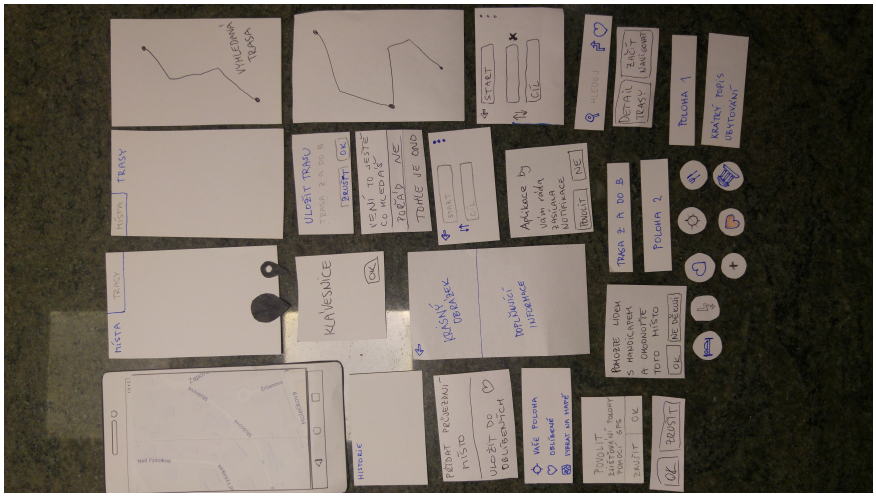


Figure 3.5: Sample of Lo-Fi prototype, full Lo-Fi prototype is available in attachments

Thanks to the testing of the paper prototype, the prototype was modified very quickly based on the findings from chapter 5.1 and then the modified prototype was tested again. This process was repeated. The final prototype and the interaction is described below. There are red numbers which describes important moments of the flow.

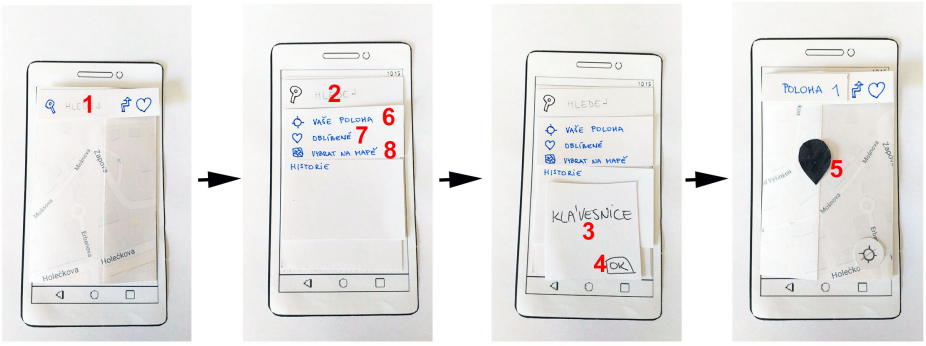


Figure 3.6: Flow of finding a location

Flow of location search 3.6 is one of the most important application flows. When user clicks on the search bar (1), a new screen is displayed with full-text search, current location selection, favorites selection, selection on the map and location history options. If a user taps on a full-text search (2), the keyboard will appear (3,4), if the user selects the current location (6) is redirected to flow 3.8. If the user selects a favorite option (7) is redirected to the favorite screen, selecting the selection on map (8) option is redirected back to the map with the selection functionality. After selecting the location, the map is centered on the location, the marker and the address of the location in the top panel are displayed (5).

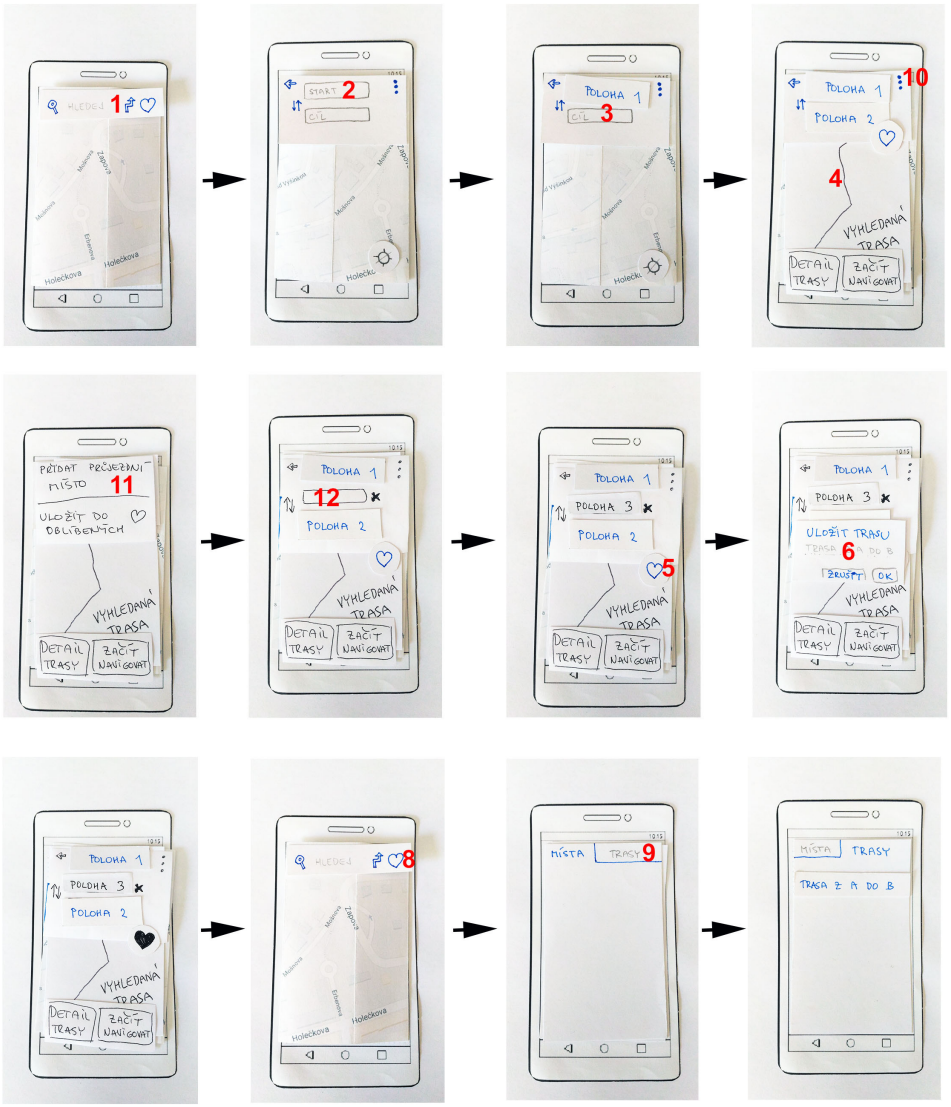


Figure 3.7: Flow of creating a route.

The second most important flow is to create a route 3.7. If the user clicks on the icon of the route creation (1) on the top panel, an overlay panel is displayed to enter the start (2) and the destination. Also the direction change option, and the option to add a waypoint are displayed. If the user searches for a location (3), a flow 3.6 is used. If the user enters both the start and the destination (4), a route is generated and the option to save the route to the favorite is additionally displayed. The option to turn on navigation is also displayed. If the user saves the route (5), the overlay panel is displayed to enter the route name and confirm or cancel the action (6). If the user does not specify a route name, the route is saved according to the start and destination address. The user can then find the route by clicking the favorites icon (8) in the top panel of the screen. Then he is redirected to activity of

favorites where he can display saved routes by taping on "routes" tab (9). When user creates a route they can open settings by tapping on three dots menu (10) and add waypoint of the route (11, 12).

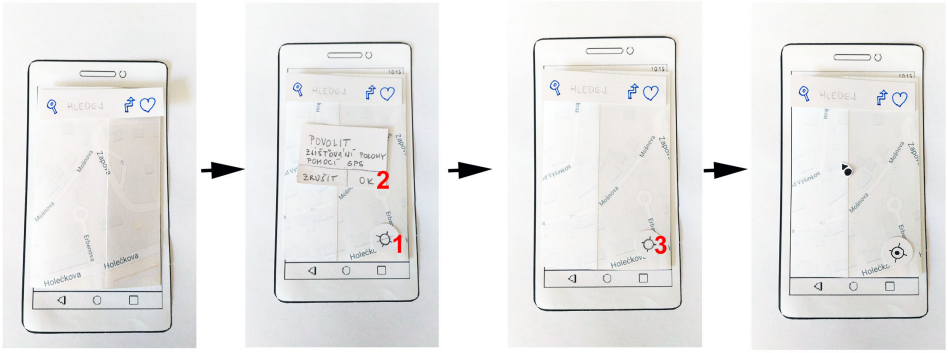


Figure 3.8: Flow of finding a current location

Another important application flow is to turn on GPS 3.8. Clicking on the icon in the lower-right corner (1) of the screen shows user a message for enable permission of GPS (2). The icon is then changed, see the third picture and GPS can be enabled by clicking on that icon (3).

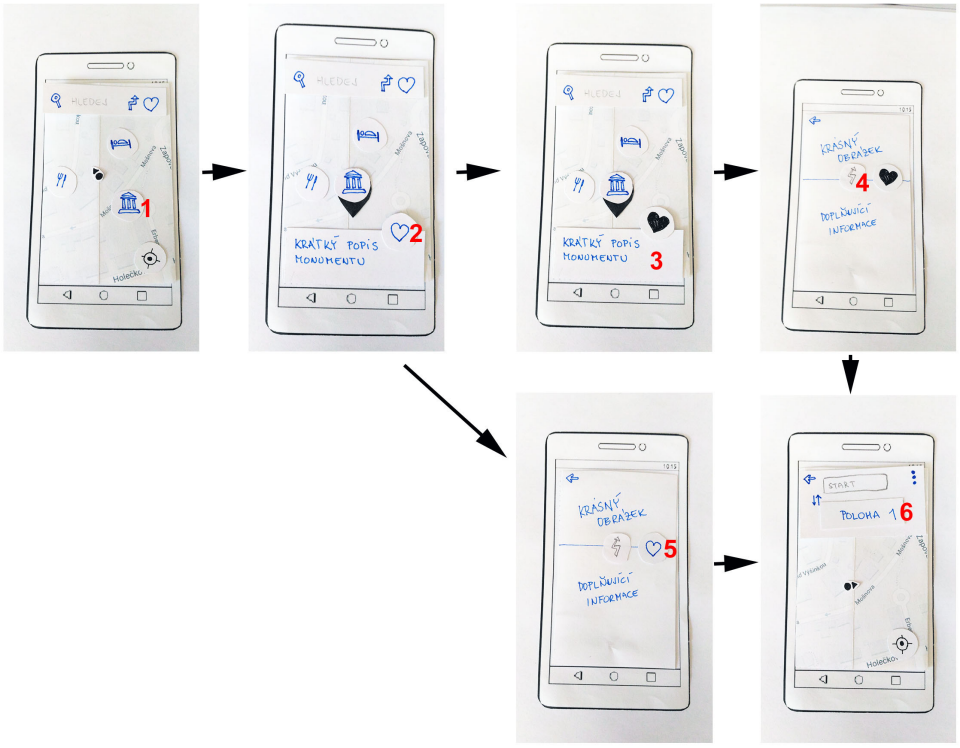


Figure 3.9: Flow of finding information about point of interest

The last important flow of an application is to find a point of interest 3.9, display information, save it, and navigate to the location. If a user clicks the

point of interest on the map (1), a short description of the location with the save icon is displayed, and the map is centered on the location. User can save the location to favorites by tapping on heart icon (2). If the user clicks on a short description (3), he is redirected to the next screen where there is more information about the location and pictures. In addition, user can save (5) or navigate the location. If the user clicks on the navigation option (4), he is redirected to the map with the navigation panel, see flow 3.7. If the user did not search the route, then the location is set as the destination, but if the user has already created the route search and the specified destination, then the location is entered as the waypoint.

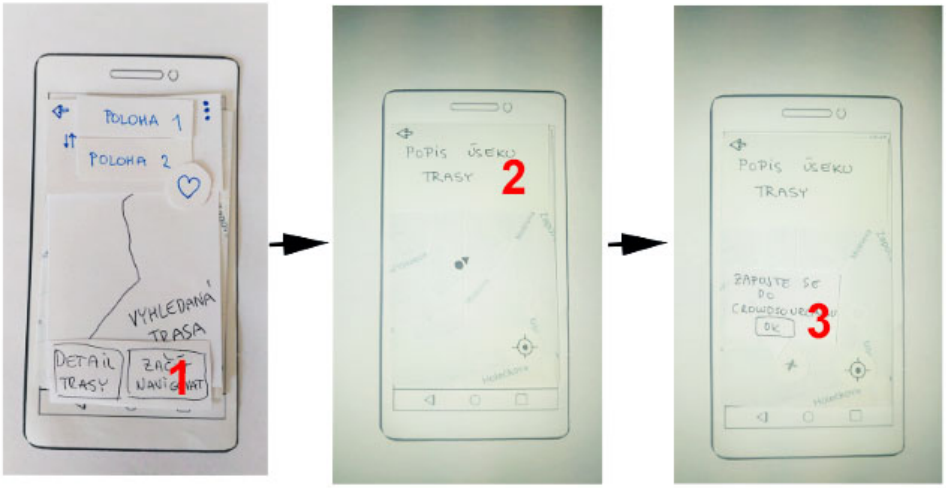


Figure 3.10: Flow of navigation and crowdsourcing

When user starts the navigation 3.10 (1) then a description of the appropriate segment of the route is displayed (2) at the top of the screen. In case the path section changes, the description of the section is updated. If the user moves near a segment that is a crossing while moving, a Marker with an InfoWindow is displayed on the map (3) . This event is also accompanied by vibrations. Such a message remains on the map until the user clicks on it or the user approaches another crosswalk.

Note: For the purpose of testing, crossings were selected as the most important part of data from the data collection structure for crowdsourcing. Crossings were selected mainly for the safety and accessibility of the pavement segments.

Chapter 4

Implementation of the Hi-fi prototype

This section describes the development of the mobile application prototype for Android platform. Functional and non-functional requirements are described below.

Functional requirements

- search for
  - location by full-text
  - current location
  - location saved in favorites
  - location on the map
  - route in favorites
- show
  - route on the map
  - instructions to navigate user
  - crowdsourcing possibilities on the map
  - points of interest on the map
  - description of the point of interest when clicked on the icon
  - detailed screen of the point of interest with possibility of saving to favorites and navigating
- save
  - location to favorites
  - route to favorites
- create a route
- add a waypoint to created route

- change of direction of the route
- crowdsourcing flow
- thank to the user for participating in crowdsourcing

Non-functional requirements

- Android platform
- application will be working with usage of mobile data
- application will be readable in the outdoor environment
- application will be comprehensible to the person who sees it for the first time
- application will show a position with a maximum deviation of 10 meters

Due to testing in an urban environment where participants must be GPS-navigated and interacting with the map, we decided to implement the prototype for the Android platform using the Google Maps API. The prototype was not implemented in a traditional way. The rapid throwaway prototyping approach, otherwise described as a quick and dirty (but also a quick) partial implementation of the system, was used for the creation. Since it is not a final and traditional implementation, quality factors such as efficiency, maintainability, completeness, or documentation are not taken into account here [CV97]. The work is focused on the usability testing which is further described in Chapter 6.2 .

The following articles describe a selection of important or interesting parts of the implementation, including the APIs used.

4.1 Google Maps API

The main part of the application is based on the Google Maps API. In the following subsections, the main elements used in working with Google Maps API are further described.

4.1.1 GPS

Fused Location Provider API is used to find the current location. Using Fused Location API it is possible to take advantage of the signals provided by multiple sensors in the device to determine device location. When creating a request there is a possibility of set several parameters such as interval or priority. In light of the fact that the potential users are pedestrians, the exact

location is quite important, which is why PRIORITY_HIGH_ACCURACY is used. On the other hand, many of these accuracy settings have great disadvantages in battery power.

4.1.2 Autocomplete

One of the most important features is to find a place in the navigation. I have solved this problem by using the Autocomplete widget. The Autocomplete widget creates a list of possible places. As a user enters characters into the field, the widget returns a list of locations to select. If the user make a selection a widget returns the instance of the place. There are several ways how to use the Autocomplete, in Cityplan I used PlaceAutocompleteFragment with setOnPlaceSelectedListener.

4.1.3 Markers

Markers are used to identify a specific location on the map. Markers have a number of customizable properties such as: position, anchor, title, snippet, icon and more. I used markers mainly to mark the places the user is looking for and to highlight the points of interest if the user clicks on them.

The segments of planned route for pedestrians (and especially the junctions), that is why they are often relatively short. In addition GPS is not accurate in the city, crowdsourcing needs to be displayed that way so the user is confident about which segments is crowdsourcing related to. For these reasons, I used markers with a message to show crowdsourcing. Markers with messages are marked on the map and will not disappear until the user clicks on them (and participates in crowdsourcing). I also used Vibrator to make the user notice that new crowdsourcing appeared along his route..

4.1.4 Drawing on the map

To draw a shape of the planned route on the map I used Polyline object. This object consists of a set of LatLng objects that determine the exact location. The shape can then be modified, changed in color or thickness.

4.1.5 GeoDataClient

To display information and photos of specific locations, I used Geo Data API. This API has a variety of public functions from which I used the method getPlaceById which returns Place objects for each of the given location IDs. I used this method mainly because of sending information between activities for example to show a detail of a location to the user. To show further detail of the location I also used method getPlacePhotos() which also takes place

ID as a parameter. This method returns the metadata for up to 10 photos associated with a place.

When finished with the result of these methods it is important to call release() function to release resources used by the buffer.

4.1.6 Businesses and other points of interest

Users often search for specific locations on the map. By default, the map shows points of interest (POIs) with varied icons. These are parks, schools, government buildings and also businesses POIs such as shops, restaurants, hotels, and more.

Since no info window is displayed by default (when the user clicks on an icon), I've implemented GoogleMap.OnPoiClickListener to view more information about the point of interest. To bring up more information about a place I used GeoDataClient because POI corresponds to a place, as defined in the Google Places API.

4.2 Saving data

Android allows several data storage approaches. The first option is to use internal storage. By default, files are stored to internal storage so the data are private and other apps don't have access to them. The second option is to store files on the shared external file system which is usually for shared user files. In Cityplan I used Shared preferences and Databases approaches which I'll describe below.

4.2.1 Shared preferences

The SharedPreferences API allows to store and read key-value pairs of primitive data types: booleans, floats, ints, longs, and strings. If there is a need to store a small amount of data which does not have a more complex structure, then this approach can be utilised. That is why I used this approach to store IDs of locations which the user marked as favorites in the application.

4.2.2 Database

For storing structured data, it is practical to use a private database. Android has full support for the SQLite database, so it is possible to create databases that are only accessible by the application. Instead of working with the SQLite API directly, it is recommended to use the Room persistence library which provides an abstraction layer over SQLite to allow fluent database

access while harnessing the full power of SQLite. The room consists of three main components: the database (contains the database holder), the entity (represents the table within the database) and the DAO (contains the methods used for accessing the database) see figure 4.1. In Cityplan, I used SQLite to store information about crossings and for storing favorite routes planned by the user.

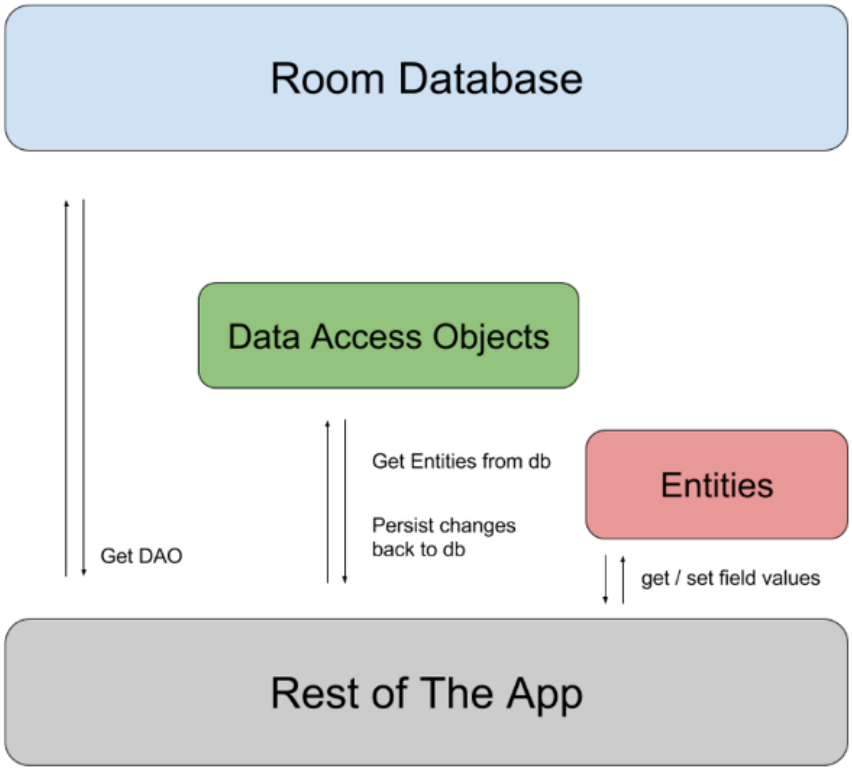


Figure 4.1: Diagram which describes room architecture and it's major components (database, entity and DAO).

4.3 Route planner

I used the HTTP library to generate the route. One of the benefits of this library is, for example, dealing with multiple concurrent network connections, which I used to generate a cross-route path. For the request itself, I used the JsonObjectRequest class to return the JSON Object from that URL with a JSONObject passed in as part of the request body. The request was directed to the Naviterier REST API. To restore the path, I created a POST request with start and destination parameters specified by coordinates and a parameter containing path descriptions. In the request I included header parameters to obtain a response in the Czech language (being the native language of the participants of the usability testing).

4.4 Butter Knife

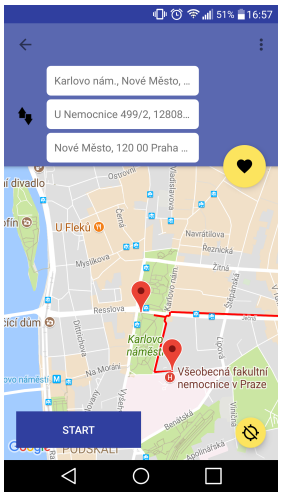
To make work with the layout easier, I used the Butter Knife library in the project. Annotating fields with @BindView and a view ID for Butter Knife allows you to find and automatically cast the corresponding view in your layout. It solves the problem of slow reflection and the code using this library is then easier and more readable. The library allows resource binding (@BindBool, @BindColor, @BindDimen, @BindDrawable ...), non-activity binding (binding on arbitrary objects by supplying its own view root), reset of bindings and other features.

4.5 Navigation

Navigating a person is based primarily on their current GPS position. At intervals, it is monitored whether the user is approaching another section of the route that they were following. As GPS positioning is not accurate and the user does not always follow the recommended route to the letter, the user is informed about the changes with a 10-meter deviation.

4.6 Samples of the final Hi-Fi prototype design

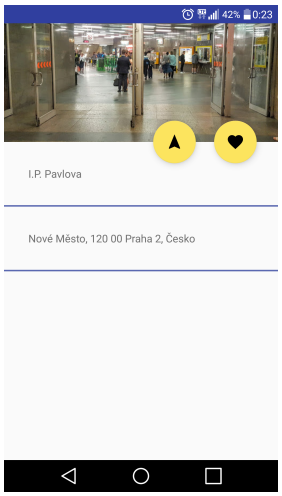
Sample screenshots of the Hi-Fi prototype are shown in figure 4.2. The rest of screenshots is available in attachments.



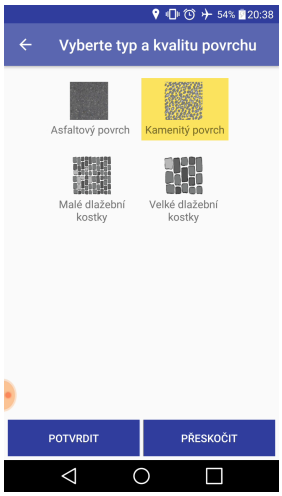
Searching for the path with the waypoint

Showing the crowdsourcing

Searching for the place



Showing detail screen of the place



Sample of the crowdsourcing screen

Screen of the favorite places and paths

Figure 4.2: Saples of the final Hi-fi prototype design

Chapter 5

Evaluation

This chapter is dedicated to describing the testing of Low-fidelity and High-fidelity prototypes.

5.1 Usability testing of Low-fidelity prototype

On the basis of the research, a paper Low-fidelity prototype was created. After the creation of the low fidelity prototype (paper prototyping), testing was carried out in order to detect possible deficiencies in the usability of the prototype. The findings were corrected between tests and the changes were tested by other participants. This process has been repeated.

5.1.1 Participants

It is assumed that the application will be used by the general population without special requirements apart from owning and using Android smart phone. Participants were selected non-randomly using the Self-selection method. For the experiment 7 participants (5 male and 2 female) were selected in range from 15 to 80 years of age with average age 44. Each participant received a pre-test questionnaire, so the test group was excluded from those who never used any map or tourist applications [DL08].

5.1.2 Procedure

Before testing a pre-test questionnaire was submitted to the participants. Participants were familiar with what they will test and that the testing is anonymous. Also they were assured that we were not testing them but the application. They were instructed to follow the prepared scenario and try to think aloud during testing. Each participant testing took approximately 30-40 minutes. After testing the participants received a post-test questionnaire to

supplement the test information [DL08].

Testing scenario

1. Locate the application in place of "Na výšinkách 1223"
2. Find the path from the address "Mošnova 20" to "Zapova 5"
3. Add "Holečkova 5" to the route and save the route
4. Find your saved route in the application
5. Find your current location.
6. Find a point of interest on the map and find out more about it
7. Create a route from your current location to the searchable sights
8. Turn on navigation
9. Respond to requests for adding information
10. Get to the finish

Task number 9 has not been tested. This part was taken from the bachelor thesis by Michaela Riganová, the outcome of her work were lo-fi prototypes tested by usability tests, hi-fi prototypes (also tested), design descriptions, and functional requirements for contributing common population to geographic data for navigating people with specific needs using a mobile application [Rig17].

5.1.3 Apparatus

The prototype was made of paper. Small or much used components were cut out of hard paper for better testing. The prototype is mainly painted with a pen or permanent marker, or supplemented with printed components such as mobile device or a map. Texts in the prototype are in the Czech language for easier understanding of the participants.

5.1.4 Results and discussion

During the testing, the following findings were compiled. Based on the findings, the prototype was modified and subsequently tested for change. As the testing continued, the volume of reported findings decreased.

Below are all findings resulting from testing with corresponding solution written bold.

Findings related to place search

1. The participant could not find how to confirm location search by name
   the magnifying glass icon is inappropriate when entering a String, rather use the text button for confirmation
2. The participant did not see a keyboard when it wanted to enter an address
   show software keyboard whenever needed
3. The participant entered the starting point that had its current location
   do not show the exact address but a String like "Current location"
4. The user was missing a popup menu when searching for addresses
   use the help popup when entering a string

Findings related to path creation

1. There was a missing confirmation button to start searching in navigation
   add a confirmation button
2. The participant could not find how to save the route
   add a route save option to the options menu (three dots menu)
3. There is no offer to add a waypoint from the map
   add the menu for adding the waypoint after long press on the map
4. There was no button to confirm a location on the map when planning a route
   add the confirmation button
5. The participant did not know how to leave the searched route
   use back press button and back navigation button in action bar
6. The participant did not know how to close the context menu by adding a transit point and adding it to your favorites
   show the menu below the dots not over them
7. The participant did not know how to leave the path find
   use back press button and back navigation button in action bar
8. The participant wanted to add a waypoint by clicking on the map or by clicking on the start and finish field
   improve adding the waypoints by adding the "plus" icon between start and finish fields

Findings related to the detail screen

1. There is no navigation button on the detail screen
   add navigation button on the detail screen

2. There is no add to favourites button on the detail screen
   add the button to the detail screen

5.2 Usability testing of Hi-fi prototype

5.2.1 Participants

I used the self-selection method to select participants. The assurance that a participant is a suitable candidate for testing was conducted using a pretest.

There are 7 participants (4 male and 3 female) int the testing group. All group members have some (mostly good) experience with navigation applications and are using Android platform. Some of them are participating in crowdsourcing but most of them do not engage in crowdsourcing. Some, however, are considering engaging in the idea that it will be a meaningful thing. None of participants know where the Hotel Beseda is and do not have much knowledge of navigation of people with limited orientation and mobility skills. The list of participants is shown in the table 5.1.

Also worth mentioning is that some of those participants participated in both testings. Although these participants were on both experiments, important bugs weren't found until the second test and their behavior was clearly different for the Hi-Fi prototype.

5.2.2 Procedure

The process of testing is divided into following parts, which are described below.

Ice-breaking

Prior to testing, the participant was welcomed by the moderator and was familiar with the testing process. Basic instructions were communicated to the participant and familiar with the application being tested, not the participant. Specifically, the participant was informed of the possibility of adding data and was asked to use it if he noticed such options.

No.	Sex	Age	Experience with navigation applications	Experiences with crowdsourcing	Consent to recording
1	M	80	Exceptional user	does not participate	YES
2	M	47	Everyday user	does not participate	YES
3	M	18	Weekly user	does not participate but inclined to participate	YES
4	F	45	Weekly user	does not participate but inclined to participate	YES
5	M	23	Weekly user	participates	YES
6	F	25	Weekly user	participates	NO
7	F	21	Weekly user	participates	YES

Table 5.1: A table describing the group of the participant

Pre-test questionnaire

The pre-test is used to get additional information about the participant or to verify the information. Pre-test questionnaire information also helps to better analyze the behavior of the participant in the test. The most important question in this case was whether the participant knows where the target route is, so the participant can navigate the route by navigation rather than by the memory. The questionnaire consists of the following questions.

1. Do you use device with Android platform?
2. How often do you use navigation?
3. Have you ever been involved in data collection by mobile applications?
4. Do you know where the hotel Beseda is located?
5. Do you know something about navigating or moving people with limited orientation and mobility skills?
6. Do you have a problem with recording the testing (anonymously) ?

Fulfillment of tasks

The main activity of the participants is the fulfillment of the prepared list of tasks. The testing is practically divided into three parts. The first introductory part is performed independently of the location, mostly in the home environment. Participants tested basic application flows (locating, saving locations, creating a route, enriching a pass through, saving it, and re-searching).

During the second part of the session, the participant creates a route from his location (restaurant U medvídků) to hotel Beseda (unfortunately it means that due to GPS inaccuracy, the participants start the trip a little differently and some miss the first test crossing). Then the participant starts the navigation and if they are called to crowdsourcing and notice it, they join in.

This part is followed by a move to Mama Coffee Cafe, which is located on Vodičkova Street. From there, the participant completes the third part of testing, planning a shorter route leading to Karlovo náměstí, where testing ends.

During the second and third part of the testing, the moderator keeps close to the pariticipant to monitor his behavior, but leaves the lead on him and therefore stays slightly behind him.

Testing takes about 45 to 60 minutes.

Testing scenarios

Testing scenario - Home

1. Locate the application in place of "Karlovo náměstí".
2. Find Všeobecná fakultní nemocnice near Karlovo náměstí and find out more about it.
3. Save this place to favourites.
4. Find the path from the address "Karlovo náměstí" to "IP Pavlova" with transit point Všeobecná fakultní nemocnice near Karlovo náměstí.
5. Save the route.
6. Leave route planning.
7. Find your saved route in the application.

Testing scenario - City

1. Create a route from your current location to Hotel Beseda which is located near Národní třída.
2. Turn on navigation.
3. Respond to requests for adding information.
4. Get to the finish.

Testing would be too long, so testing is being interrupted at this point and the moderator accompanying the participant to the third test part. In addition, it will be tested more because the participant has to plan another route.

1. Create a route from Mama Coffee in Vodičkova to Karlovo náměstí.
2. Turn on navigation.
3. Respond to requests for adding information.
4. Get to the finish.

Route description

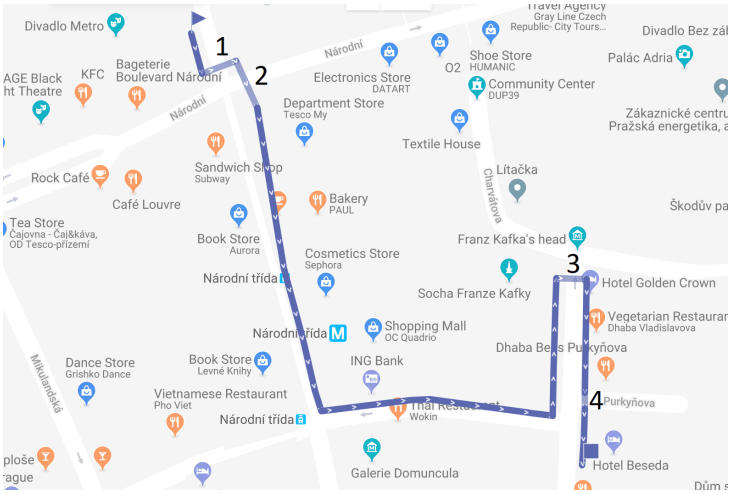


Figure 5.1: Second part of testing

This route has been selected for several reasons. The first ones are crossings 1 (5.3a) and 2 (5.3b) that are in close proximity to each other, and they are at a large crossroads with 4 crosswalks, so I assume that the user may not orient properly. Additionally, there is an important crosswalk 3 (5.4a), which has as one of the few leading lines for the blind. All crossings on this route do not have either audio signal or traffic lights.

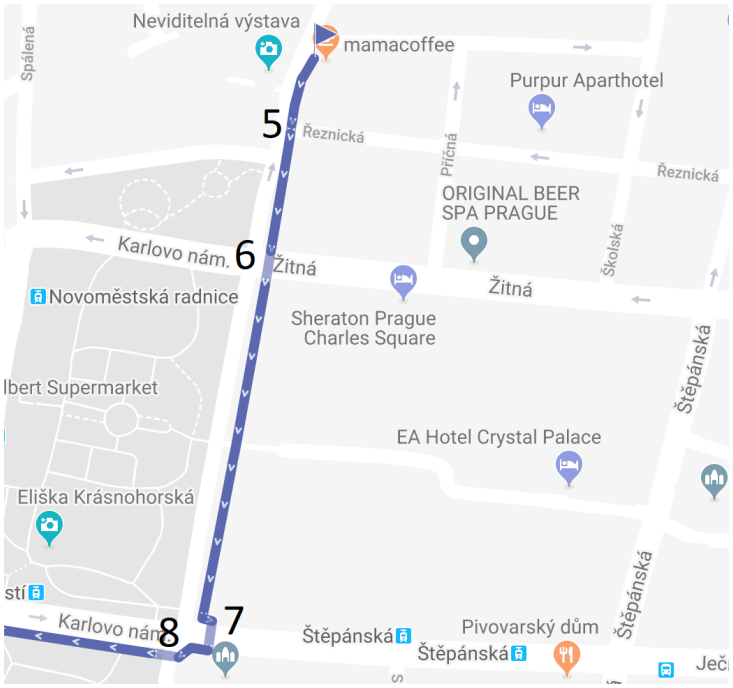


Figure 5.2: Third part of testing

The second route, on the other hand, contains most of the crossings with audio and light signalization. For example, crosswalks 6 (8.11b), 7 (8.12a) and 8 (8.12b). Crossings 7 and 8 are again interesting because they are relatively close together.

An overview of the crosswalks that were part of testing and their correct evaluation is in table 5.2.

No.	Curb	Leading line	Traffic lights	Audio signal	Signal button	Surface
1	NO	NO	NO	NO	NO	big cobblestones
2	NO	NO	NO	NO	NO	asphalt
3	NO	YES	NO	NO	NO	asphalt
4	NO	NO	NO	NO	NO	big cobblestones
5	NO	NO	NO	NO	NO	asphalt
6	NO	NO	YES	YES	NO	asphalt
7	NO	NO	YES	YES	NO	asphalt
8	NO	NO	YES	YES	NO	big cobblestones

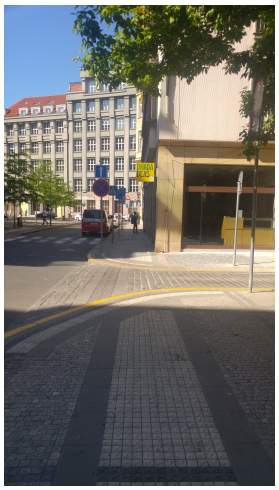
Table 5.2: A table describing properties of the pedestrian crossings.

(a) : Crossing 1

(b) : Crossing 2

Figure 5.3: Photos of the crossings from the second part of the test

(a) : Crossing 3



(b) : Crossing 4

Figure 5.4: Photos of the crossings from the second part of the test

Post-test questionnaire

After completion of all tasks (or after the elapsed time), the participant is asked to complete the final questionnaire. In this questionnaire, the participant shares their impressions from the application. This questionnaire is intended to find out what the participant was or was not satisfied with. The questionnaire consists of the following questions.

1. What did you like about testing?
2. What did you dislike about testing?
3. How did you notice crowdsourcing?

4. How do you evaluate adding information about crossings?
5. How do you evaluate pavement navigation?

5.2.3 Apparatus

Testing was carried out using the implemented Hi-fi prototype, which is devoted to Chapter 4. Since all participants were Czech, the created application supports only Czech language.

5.2.4 Results and discussion

Following are the enumerations of the findings obtained during testing. The severity of the findings is categorized according to the following table 5.3.

Relevance	Description
3	A serious finding that negatively affects the use of the application or directly prevents its use. It should be repaired as soon as possible.
2	A discovery that exacerbates the use of the app. The application can still be used.
1	A minor finding that has little effect on the usability of the application. It can be removed later.

Table 5.3: A table describing relevance of findings

Key findings and discussion

The findings are divided into thematic units according to the type of activity during the testing. Each finding has a bold recommended solution.

Findings related to the creation of the route

1. The participant lacks the ability to navigate to a location after finding a place in the search panel. [Severity-3, participant: 1,2,4,7]
   Add the same panel as it appears when user clicks the point of interest icon on the map and add the navigation floating action button to this panel. In addition, if the user searches for a location and then clicks on the menu navigation icon, the finish field is automatically filled in by the given location.

2. Select location on map does not work validly. [Severity-2, participant: 1,3,4]
   Implementation improvement

3. The participant canceled the route by clicking back, the field values were not saved. [Severity-2, participant: 2]
   Keep the values in the navigation fields even when leaving the navigation panel.

4. The keyboard did not automatically appear when the participant clicked on the search, the participant is waiting for it. [Severity-1, participant: 1,2,3,4,5,6,7]
   Show the keyboard but do not overlap the other choices (e.g current location, favorites) until the user starts typing.

5. The participant has inadvertently planned the route in reverse. [Severity-1, participant: 1]
   Mark the start and finish with different markers.

6. The participant is not able to save the route in the three dots menu. [Severity-1, participant: 2]
   Add this option to the menu.

7. The participant was looking to save their favorite places on the favorites screen. [Severity-1, participant: 5]
   Add the option to add a favorite location from the Favorites screen. This would follow to the screen for searching for the location which is already used in the app.

8. The participant tried to swipe to open the detail of the place and there was no action. [Severity-1, participant: 3,7]
   Implement swipe action to open detail. This option is intuitive for many users.

9. The participant tried a long tap and it did not work. [Severity-1, participant: 6,7]
   Add a long tap to select a place on the map. This action should display: a marker, a coordinate panel, and save and navigate icons.

Findings related to the navigation in self

1. The participant noticed illogically created routes. [Severity-3, participant: 1,2,3,4,5,6,7]
   It would be preferable for users (who have no limitations) to use classic car navigation. And the crowdsourcing would be displayed based on the Naviterier database.

   Note: Testing has shown that the database does not contain all the crosswalks and that it generates illogical routes. In addition, in some cases only the side of the road can extend the route by approximately one half of the way. Some of these participants laughed during the testing and some of them commented on them seriously, in the long run they would definitely reduce the credibility of the generated route.

2. The participant is missing the rotation of the map and is therefore worse oriented. [Severity-2, participant: 1,3,4,6,7]
   Add screen rotation when navigation is turned on.

3. The participant gets lost. [Severity-2, participant: 4,7]
   It would be useful to improve the user's orientation in the map, see key result 2. It would also be advisable to redraw the route according to how the user is navigating. In addition, cases where the user has to turn and the cases that the user deviates from the route should be accompanied by vibrations.

4. The participant was confused due to inaccuracies of GPS. [Severity-2, participant: 2,4,6]
   This problem is not very solvable, GPS in the city is not accurate even with the highest accuracy of Fused Location API. When using a classic car navigation, it is much more likely that the navigation will show the correct instructions given

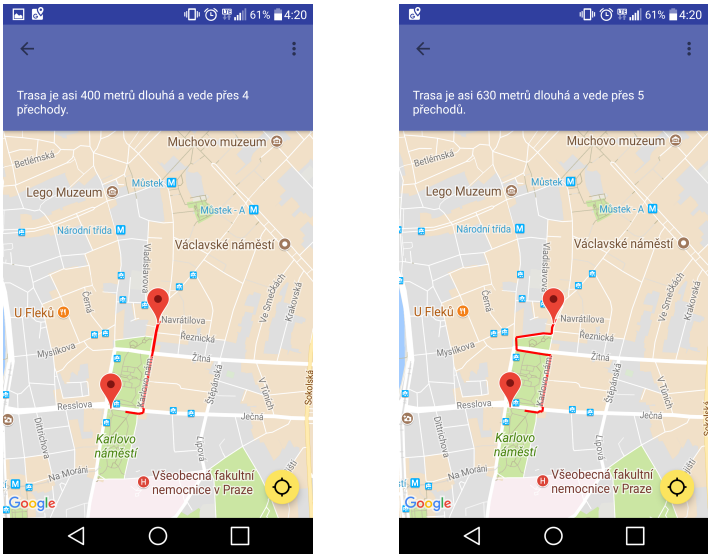


Figure 5.5: Screenshots of paths generated from left and right side of the route

that the whole crossing or turning circle is much larger than turning circle of the sidewalk.

Note: Some participants noticed that the text description of the sections did not correspond to reality, and some commented on the bad displaying of the current location (for example, in the middle of the building).

5. The participant could not find the route icon for a while. [Severity-1, participant: 1]
Choose a better icon for route creation.

6. The zoom did not suit the participant. [Severity-1, participant: 2]
Set the default zoom, but edit it if the user manually zooms in or out of the map.

Findings related to the crowdsourcing

1. The participant was not sure for which crosswalk they were crowdsourcing. [Severity-3, participant: 2,3,7]
A miniature of crosswalk location should be added to the crowdsourcing screens.

2. For the user is an incomprehensible message for engaging in crowdsourcing. [Severity-3, participant: 1,2]
There should be a message that will be comprehensible to people who do not have crowdsourcing experience. If possible, it should also saying that this is an aid to needy people because even those who are not inclined to get involved in crowdsourcing tend to get involved if it has a meaningful reason.

3. The participant was not sure whether crowdsourcing was for the crosswalk as such or for the pavement near the crosswalk. [Severity-3, participant: 3,5,7]
   The solution could be to change the surface images or add an image with highlighting the crosswalk as such.

   Note: At least one of the participants expressly confused the screen about the crosswalk properties on the other side.

4. The participant did not notice the crowdsourcing. [Severity-3, participant: 1]
   The solution could be to repeat vibration, for example three times. The vibration was relatively long, but some of the participants did not notice them, and one participant himself said he would expect vibration here.

5. The participant could not return to the filled-in crowdsourcing. [Severity-1, participant: 2]
   If the user tries to leave the first crowdsourcing screen, a message will be displayed to confirm if the user is sure he wants to leave the crowdsourcing.

6. The summary screen did not make sense to the participant. [Severity-1, participant: 3]
   Remove this screen and focus more on the clarity of the previous screens.

   Note: This screen did not show much that was useful when tested. For the whole test, it was used once to correct the surface at the crosswalk, while the participant filled the crosswalk that was not a part of the route and the surface selected according to the sidewalk and not the crosswalk (ie incorrectly).

7. The participant wanted to do the change in the summary of crowdsourcing by clicking on the item. [Severity-1, participant: 7]
   Option to change a specific item from a summary. By clicking on item the appropriate crowdsourcing screen should be reopened.

Results of data collected during testing and discussion

During testing, participants did not engage in crowdsourcing multiple times for the following reasons. The most common reason was the GPS inaccuracy, which is why the message was not displayed at all and the user could not get involved in the crowdsourcing. The second most common reason was that the user did not notice the crowdsourcing, which unfortunately was almost as common as filling in the data for different crosswalk. This was the case when the participant filled out the information about the crossing at small junctions. The exact percentage values are visible in the following graph.

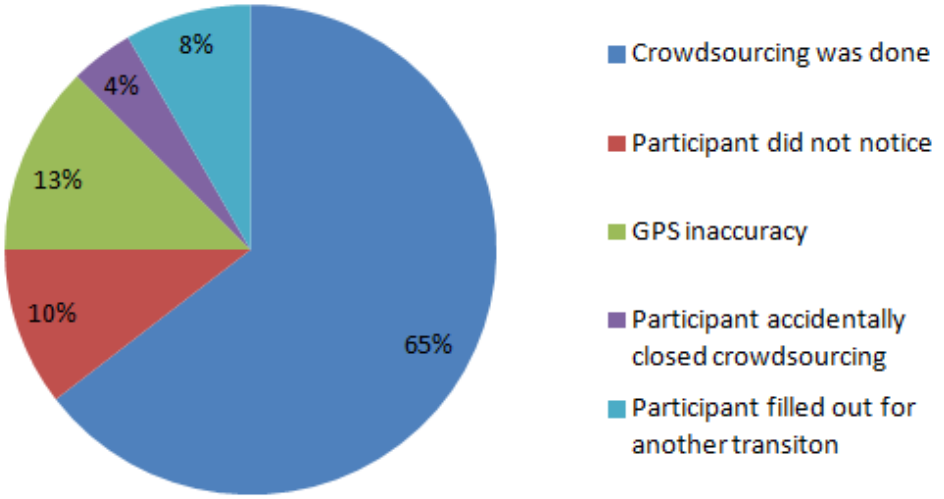


Figure 5.6: Graph showing participation in crowdsourcing

Probability that the participant will notice the crowdsourcing could be increased by vibrating longer or repeating the vibration. The likelihood that a participant fills the information for the correct crosswalk can be increased by adding a map thumbnail with a crosswalk section directly to crowdsourcing screens, or by highlighting a different color crosswalk section on the map.

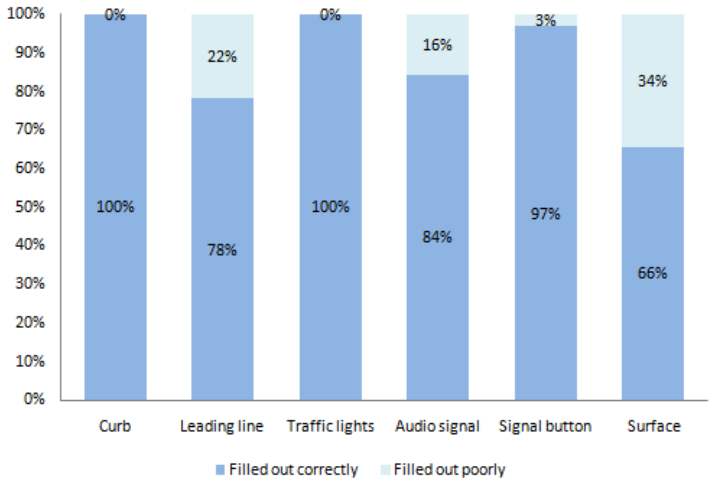


Figure 5.7: A graph illustrating the success of filling in information about crosswalks

Curb. Fill in this information whether crosswalk has the ramp or curb has a 100% success rate. Sometimes, particpants were not completely sure, but they filled in the information correctly.

Leading line. Entering the leading line and choosing a surface was most problematic for participants. Here, it turned out that no participant was unsure of what the leading line is. Some participants thought the leading line was any crosswalk mark, therefore there was information filling out where the leading line was not at all. On the other hand, where the leading line was really, the participants always filled in correctly. The success rate is shown in the graph.

I would propose here a different icon for choosing the leading line. See firuges 5.8

Figure 5.8: The current leading line icon (left) and possible icon solution (right).

Traffic lights. Filling this information whether the crosswalk has traffic lights was also 100% successful. Here particpants showed no signs of uncertainty.

Audio signal. Here, many users did not realize what the audio signal means, and some were not sure whether they could pick multiple items on the properties screen and did not try or try it by the end of testing. The success rate is shown in the graph.

Signal button. The signal button was filled in once during testing and was chosen only by mistake. The participant stated that he had chosen the button automatically because he was expecting signal button on crosswalk with traffic lights and audio signal. The success rate is shown in the graph.

Surface. The crosswalk surface was very problematic for a number of participants because the participant was not sure whether it was the surface of the crosswalk or the surface of the pavement before and after the crosswalk. The success rate is shown in the graph.

I would propose adjust the icons to see that it is the crosswalk surface and not the sidewalk surface.

I would definitely add a so-called onboarding screen to the application to get the user familiar with the reason why the data is being collected. In addition, users would at least partially learn about how information is being utilised.

Post-test questionnaire results

What did you like about testing? Nearly all participants liked that it is something new and alternative. Everyone already had some experience with other navigations. They like that the app provides very detailed information about the environment. Some participants appreciated the idea of adding status information, for example, to help people with disabilities or even babies with a stroller. One participant amused the way the route was rendered.

What did you dislike about testing? Participants were generally dissatisfied with route planning. Due to the missing crossings in the database, the route was generated illogically, which was noticed by all participants and was confusing for them. All participants also had less or more problems with navigating in the map as such, most of the participants were missing the map rotation by direction, and one of the pariticants did not fit the default zoom on the map. As far as crowdsourcing is concerned, one participant complained that he could not see for which crossing he was providing information. Then one of the participants did not want to join the crowdsourcing at the beginning of testing because she did not know how to enter the information. The last whistle of the participants was related to storing to favorites, the participant sought to save the place over the favorite screen and not over the map.

How did you notice crowdsourcing? Some participants claimed that they noticed crowdsourcing by accident, but most of the participants noticed crowdsourcing with vibrations or visually by jumping out of information message. One of the participants, on the contrary, did not notice the vibration at all and suggested this possibility as an improvement. He recommended to make vibration longer or vibrate repeatedly. It was also obvious from the testing, and some participants mentioned that they were getting used to entering information at the crossings, and were surprised when this option did not appear.

How do you evaluate adding information about crossings? All participants except one were satisfied by the speed and briefness of the crowdsourcing. One participant had remarks that it would be appropriate to optimize the passage to make it even faster, to propose the information given just on one screen and then to save it. In addition, the participants commented on the addition of information as such, mostly they were not sure what the leading line is, and some were not sure whether they should add information about the of the edge of a crosswalk (pavement) or whether it was a crosswalk as such (here we are mainly talking about choosing surface).

How do you evaluate pavement navigation? Most participants had reservations about the generated path, specifically that it led them to a detour.

During testing, they were more confused than angry. In addition, the participants commented on the GPS accuracy, for example, that GPS showed them a position in the middle of the house. Otherwise, in general, they gave positive feedback on the sidewalk navigation. Only one participant preferred a car navigation rather than sidewalk navigation because of needlessly long generated route for it. Otherwise, the participants were satisfied with detailed information about walkways and routes in general and liked the idea of providing information as a help.

Chapter 6

Conclusion

In this diploma thesis, we have conducted research on crowdsourcing and tourism applications, including a survey of tourism applications which are currently on the market. On the basis of the information we gathered, we created scenarios with storyboards, HTA including plans, sketches and paper prototype. An usability study was performed on a paper Lo-Fi prototype, and then a prototype was created on the Android platform, which was then tested for usability in the city.

The main benefits of our work are the Lo-Fi and Hi-Fi prototype testing, both including recommendations for finding solutions. Some findings contain additional explanatory notes from experiment. Testing of the created Lo-Fi prototype was very effective, and due to paper material of the prototype it was possible to quickly modify the prototype and test it again. However, the disadvantage has been that users apparently behave differently (partially unnatural) to Lo-Fi prototype than to real-life applications, so some relatively important bugs were not found.

As far as the Hi-Fi prototype experiment is concerned, crowdsourcing was a success without any bigger problems, the participants especially preferred the speed of crowdsourcing (how quickly participants were able to go through the crowdsourcing flow). Problems from experiment were related mostly to the application itself, the lack of GPS accuracy, and the ROUTE4ALL generated route (which was too detailed for most common tourists and made it difficult for participants to travel, for example they were not used to wondering which side of the sidewalk they were going). From the information that the participants had to fill out, the most problematic was the filling out the surface (participants didn't know if they should fill the information for the surface of the street or sidewalk near the crossing), the leading line (participants didn't know what is it) and the audio signal (participants didn't realized what is it).

Based on the tested prototype Hi-Fi and recommended changes, a beta version of the Android application will be created in the future. Also I would recommend to use ROUTE4ALL only for crowdsourcing flow (triggering the

places for it), and for navigation as such, use a road network that users are used to generating more logical routes.

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List of abbreviations

API	Application Programming Interface
App	Application
AS	Alternative scenario
CTU	Czech Technical University
DAO	Data access object
db	Database
GPS	Global Positioning System
Hi-Fi	High-Fidelity
HTA	Hierarchical Task Analysis
HTTP	Hypertext Transfer Protocol
ID	Identifier
JSON	JavaScript Object Notation
Lo-Fi	Low-Fidelity
PC	Personal computer
POI	Point of interest
REST	Representational State Transfer
SC	Scenario
SQLite	Structured Query Language Lite
UI	User interface
URL	Uniform resource locator

Chapter 7

Content of included CD

`|-- design`	Images of Lo-Fi and Hi-Fi prototype flows
`|-- hifi`	Screenshots taken from Hi-Fi prototype
`|-- hta`	HTA
`|-- route`	Photos and map of the route that was used to test the Hi-Fi prototype
`|-- hifi-develop`	Source code of Hi-Fi prototype
`|-- screenshots-apps`	Screenshots from the existing mobile tourism apps
`|-- sketches`	Sketches
`|-- storyboards`	Storyboards
`|-- videos`	Videos taken while testing Hi-Fi prototype
`|-- kreckjoh_thesis_2019.pdf`	This thesis in PDF
`|-- kreckjoh_thesis_2019.zip`	Source code of this thesis

Chapter 8

Attachments

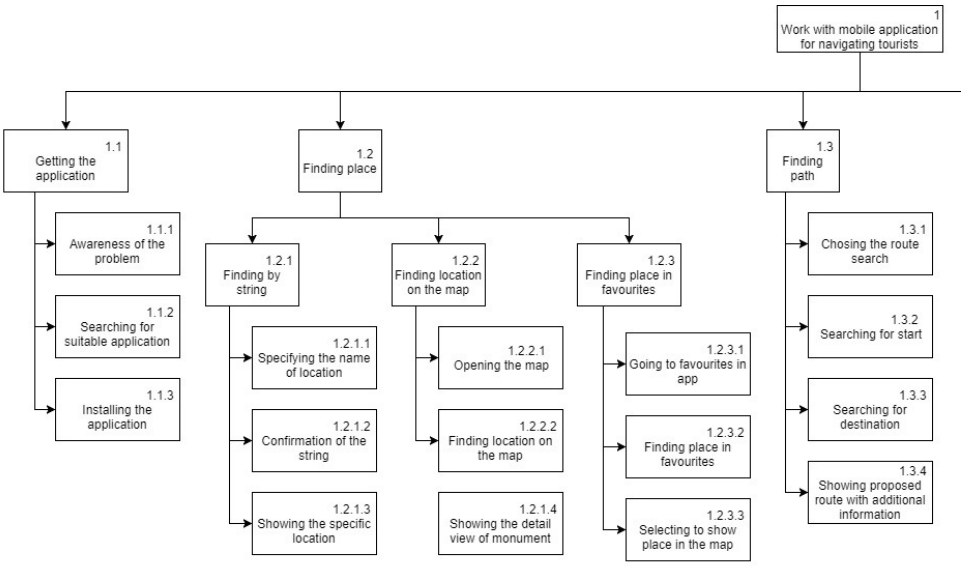

Figure 8.1: Left part of HTA shows flows for getting the application, finding a place and path. The other parts of HTA are available in the attachments.

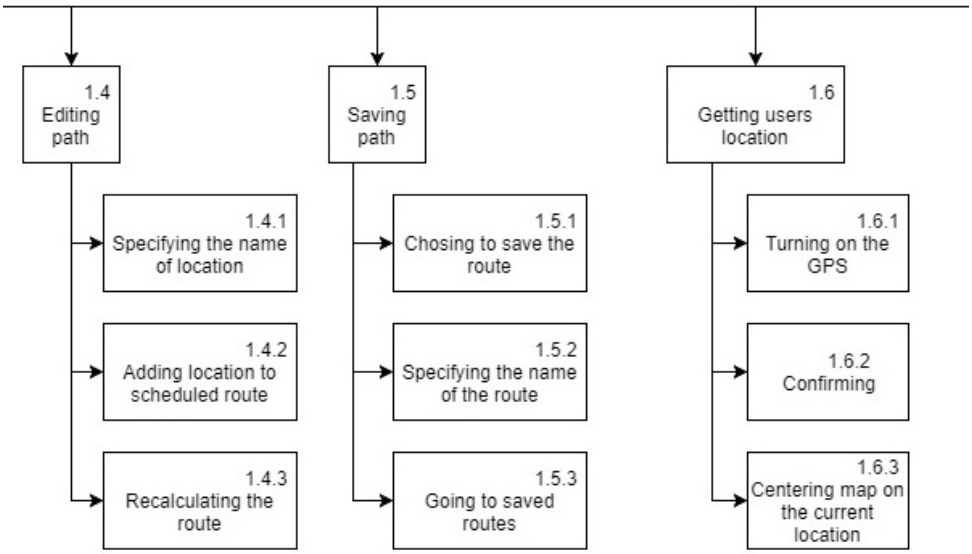

Figure 8.2: Middle part of HTA shows flows for editing and saving path and for getting users location.

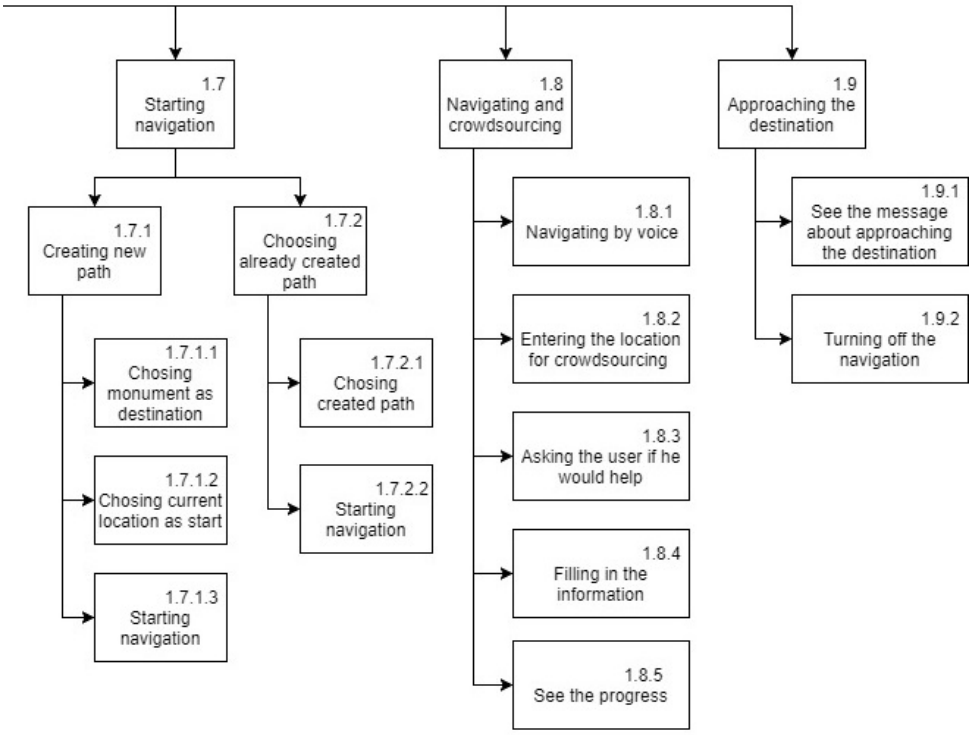

Figure 8.3: Right part of HTA shows flows for starting navigation, navigating and crowdsourcing and approaching the destination.

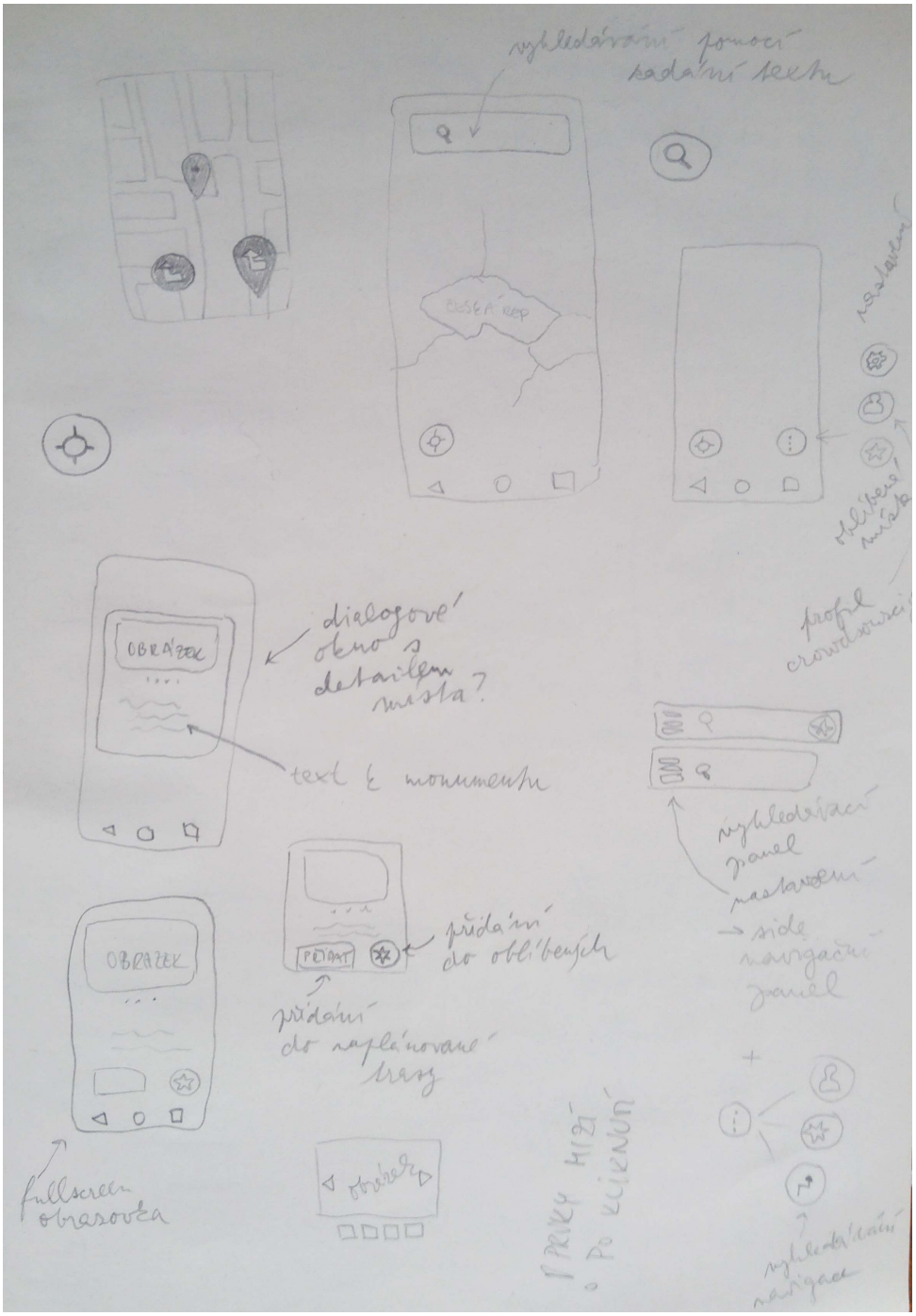

Figure 8.4: Sketches - First part of sketches is showing different ways how to display detail of a place. Also there are several ideas related to navigation buttons in the app and search panel.

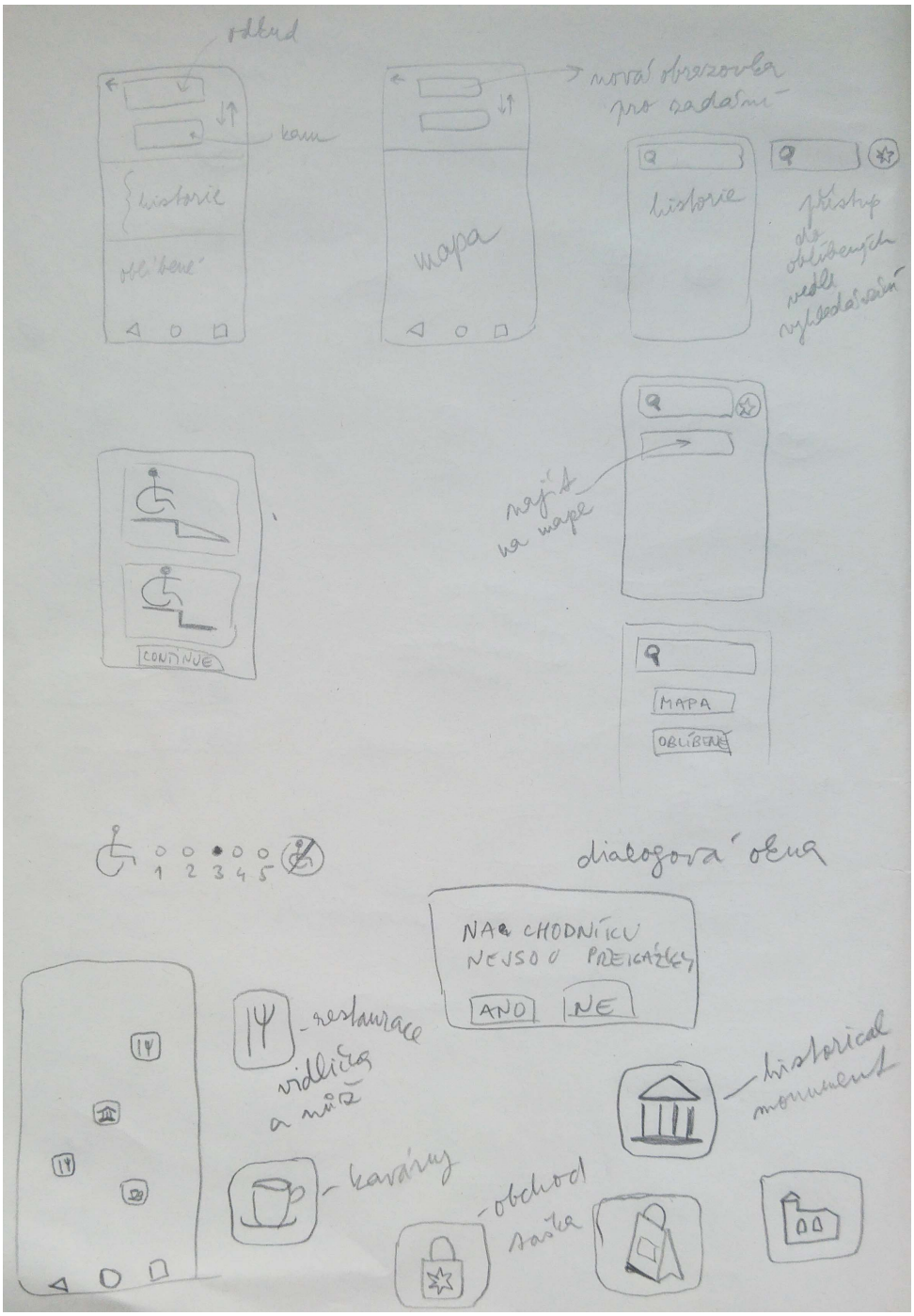

Figure 8.5: Sketches - Second part of sketches is showing different ways how to display types of points of interest and also different approaches how to display screen with creating the route.

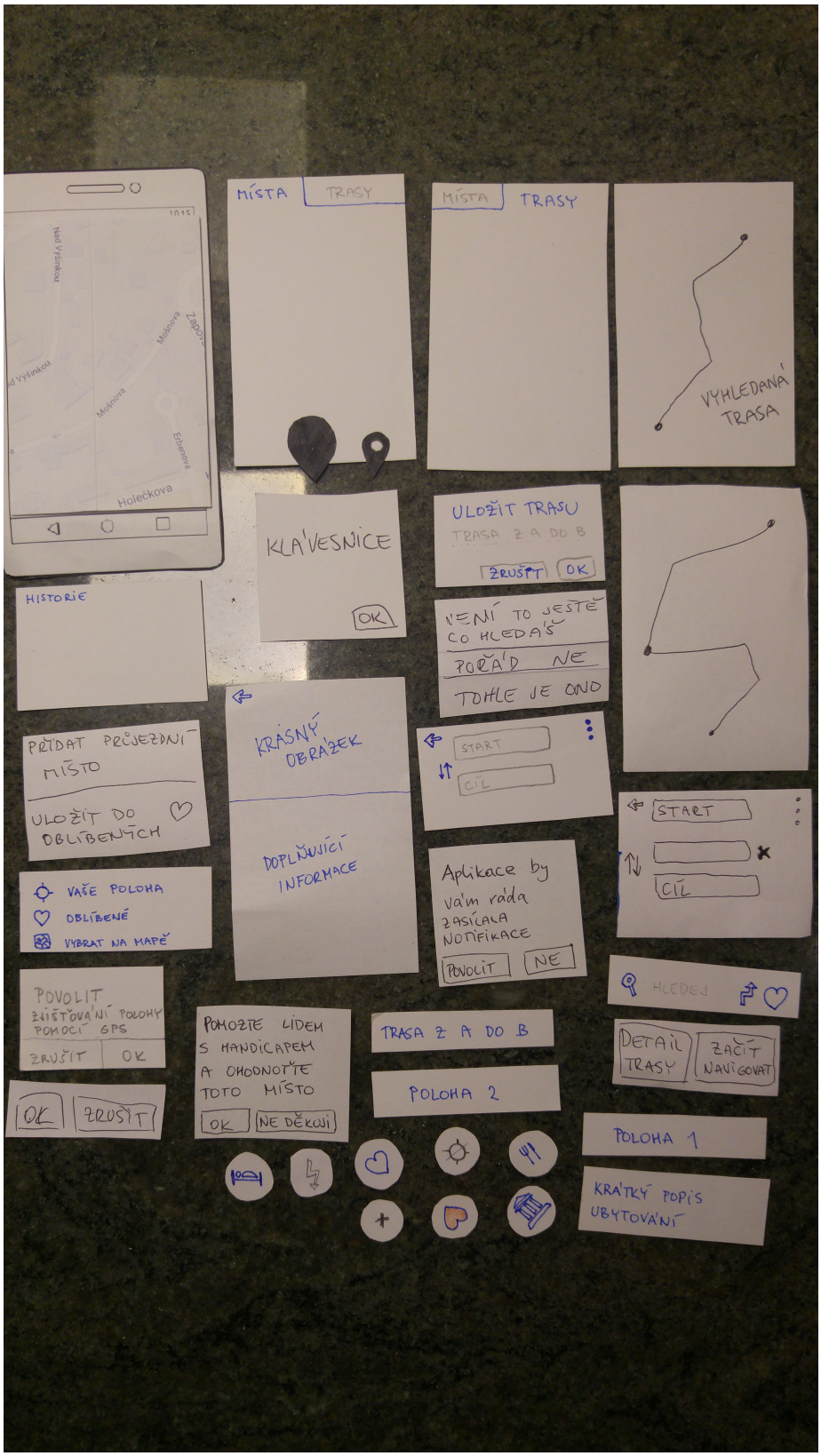

Figure 8.6: Lo-fi prototype

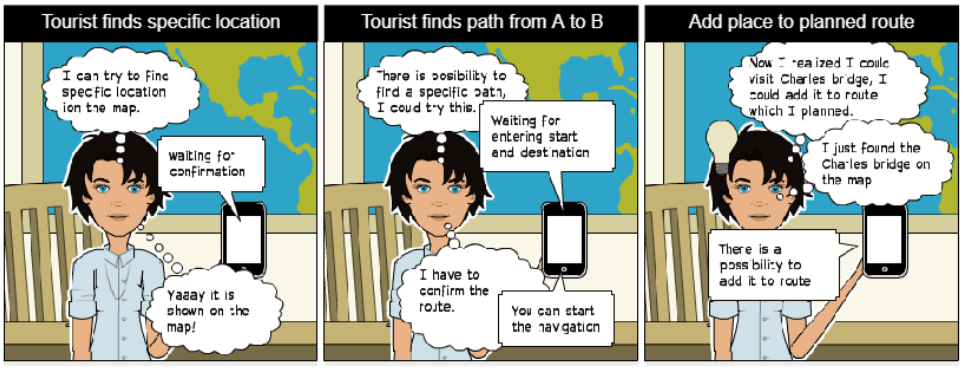

Figure 8.7: Storyboard - Finding specific location and route planning

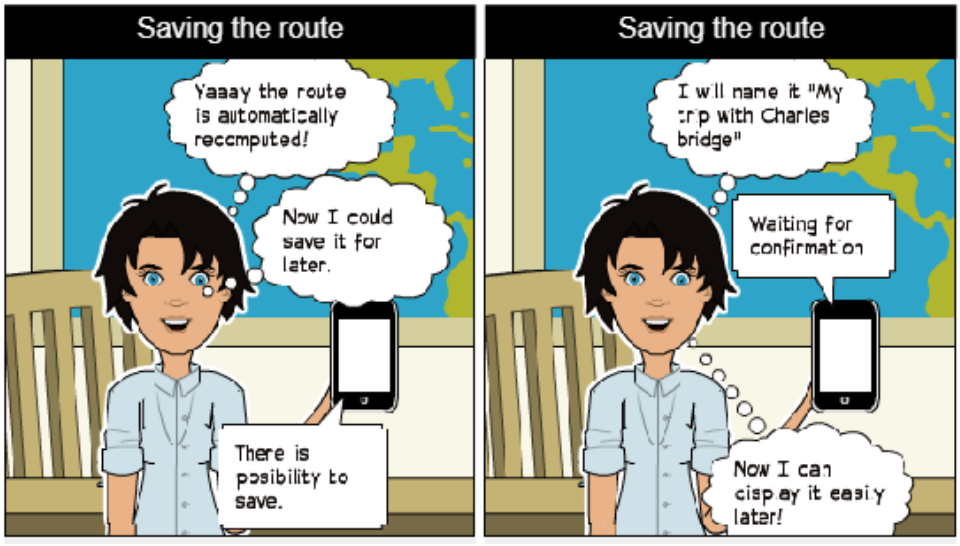

Figure 8.8: Storyboard - Saving the route

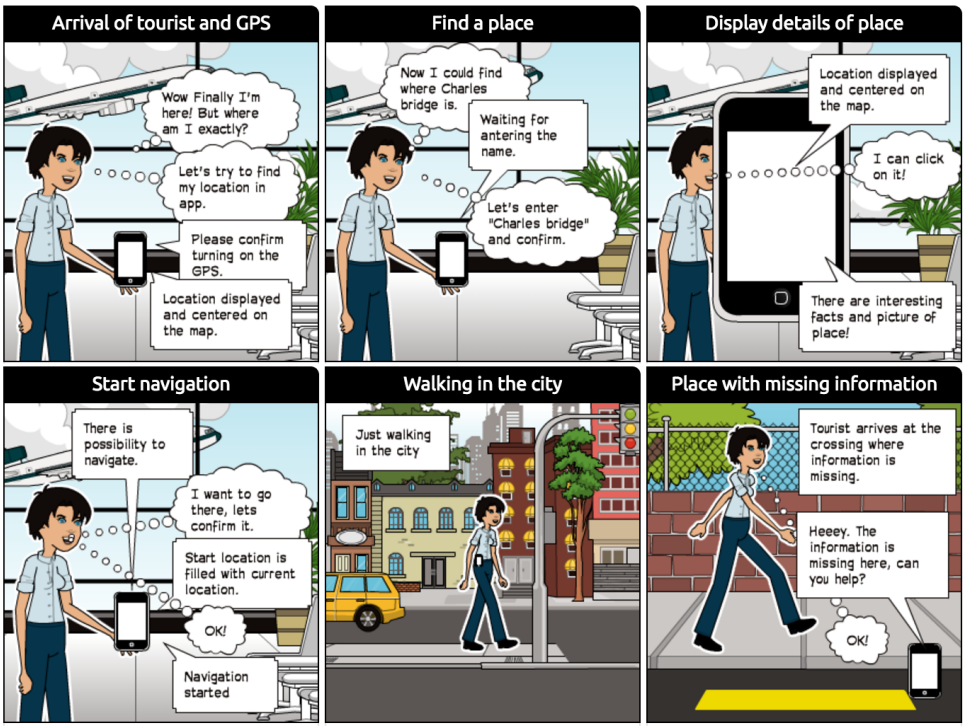

Figure 8.9: Storyboard - Using the application in field

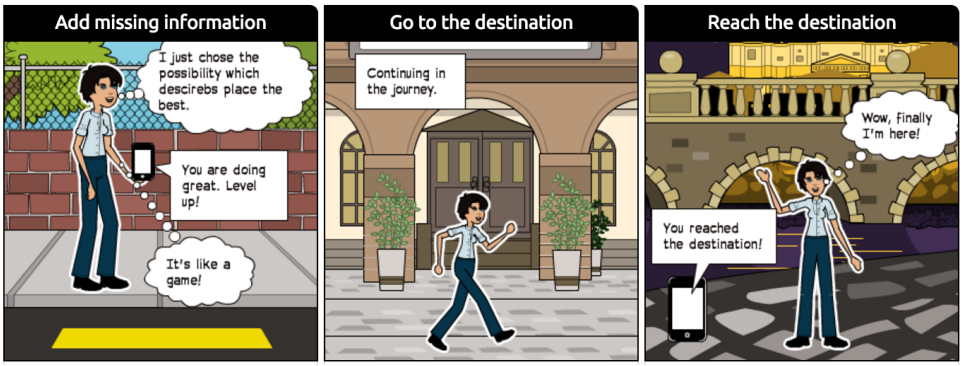

Figure 8.10: Storyboard - Crowdsourcing and reaching the destination

(a) : Crossing 5

(b) : Crossing 6

Figure 8.11: Photos of the crossings from the third part of the test

(a) : Crossing 7

(b) : Crossing 8

Figure 8.12: Photos of the crossings from the third part of the test