Masters Program in Geospatial Technologies

Feature Info – Improving the visualization and usability of GIS background information in the context of a mobile tourist application

Yevgeniya Litvinova

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NOVA IMS Information Management School

UNIVERSITAT JAUME·I

WESTFÄLISCHE WILHELMS-UNIVERSITÄT MÜNSTER

FEATURE INFO – IMPROVING THE VISUALIZATION AND USABILITY OF GIS BACKGROUND INFORMATION IN THE CONTEXT OF A MOBILE TOURIST APPLICATION

Dissertation supervised by

Prof. Dr. Christian Kray

Prof. Dr. Pedro Cabral

Dr. Morin Ostkamp

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FEATURE INFO – IMPROVING THE VISUALIZATION AND USABILITY OF GIS BACKGROUND INFORMATION IN THE CONTEXT OF A MOBILE TOURIST APPLICATION

ABSTRACT

Feature info is an interactive map tool that allows viewing background information about a map feature in response to a user action. Mobile devices come with a number of limitations, e.g. small screen real estate and the variety of screen sizes, that can affect map and feature info usability. Existing recommendations for feature info design [1], [2], [3] focus mostly on content, i.e. effective communication of data, leaving the "interaction design" aspect overlooked. This Master's Thesis attempts at improving the visualization and usability of feature info interfaces in the context of mobile tourist applications and presents nine feature info design guidelines that address specific usability problems. The problems were identified through heuristic evaluation of five tourist applications and a user interview. Literature survey and two usability experts provided ideas regarding how several of these problems can be resolved. Three guidelines were evaluated in a lab-based usability test with twenty participants. On average, assessed guidelines demonstrated a significant positive effect on feature info usability by decreasing task completion time by 33% and increasing task completion rate and System Usability Scale (SUS) score by 26% and 28% respectively. Proposed guidelines are not restricted by any specific use case and can be applied to other application domains. Researchers and business practitioners can use the guidelines as a reference in their daily work.

KEYWORDS

Mobile Human-Computer Interaction

Usability

Usability evaluation

Interactive maps

UX/UI design

User interfaces

User-Centered Design

ACRONYMS

GIS – Geographic Information Systems

GI – Geographic Information

HCI – Human-Computer Interaction

POI – Point of Interest

PWA – Progressive Web Application

SUS – System Usability Scale

UCD – User-Centered Design

UI – User Interface

UX – User Experience

WebGIS – Web-based Geographic Information Systems

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1. INTRODUCTION

This section describes the problem that motivated the author to carry out this research. The first subsection presents the definition of “feature info” and its role in map applications. It also describes the challenges of mobile development and how they may affect feature info design. As this thesis is use case driven, the second subsection introduces the main application under study and highlights usability defects in its feature info. The third subsection outlines the goal of this thesis and proposes research questions that are aimed at achieving it.

1.1. What is Feature Info?

Ubiquitous accessibility to the Internet, personal computers, and smartphones have impacted the development of geographic information systems (GIS) in the last 30 years. In addition, broadband Internet and cloud technologies have made possible the shift from desktop to web, leading to the advent of Web-based Geographic Information Systems (WebGIS). Initially designed for experts, today online map services and applications have become a mainstay in our daily life. Today the average person relies on map-based technologies to determine where they are, how to get where they are going, how to track their personal health, and so much more. They link people and devices all over the globe allowing them to share spatial data, information, and knowledge instantaneously and cost-effectively [4].

With the beginning of “map revolution”, where interactive maps are taking over their static ancestors, cartographic research has started focusing on interaction design in pursuit of finding best solutions for map interaction. Making map services and applications more user-friendly and accessible has shifted the focus of industry and academia to usability. The term “usability” refers to a quality of a product describing to what degree it can be used by a specific user group in order to achieve its specific goals in a specific context with effectiveness, efficiency, and satisfaction (adapted from ISO 9241-210:2010 [5]). If a system is developed following the principles of usability and user-centered design[1] (UCD), it benefits not only users, but also its creators through reduction in production and maintenance costs as well as increase in productivity, popularity, and sales [6].

This thesis sets out to explore the usability of feature info interfaces. Feature info (Figure 1) is an interactive map tool that retrieves background information about a single geographic entity and presents it in a dialogue window that overlays the map. The dialogue window appears as a result of an action: click, hover over, or tap applied to select a feature of interest shown on the map. The tool has different names across different GIS software and services: “pop-up balloon”, “pop-up”, “info window”, however, to stay consistent the term “feature info” will be used further on in this thesis. Feature info is a core map interaction element of many proprietary and open source Web mapping technologies [7].

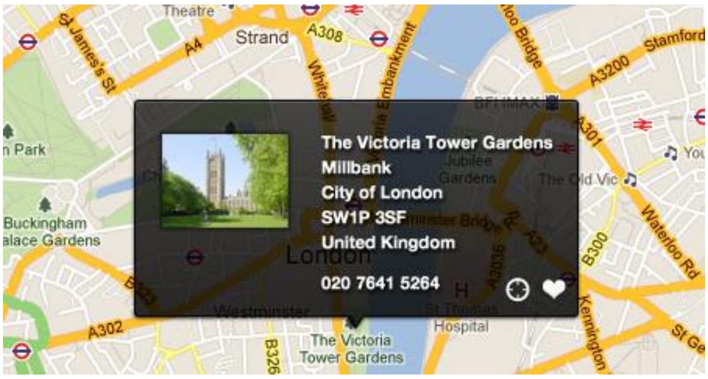


Figure 1. An example of a feature info *[8]*.

Feature info notion has remained unchallenged during the last several years. For instance, Figure 2 demonstrates a feature info interface from Google Maps back in 2005. Below in Figure 3 displayed are feature infos of six currently popular Web mapping technologies. As GIS applications have evolved, feature info has maintained its “classic” look - a pop-up balloon with background information anchored to a map feature.

[1] User-centered design – “approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques” [5].

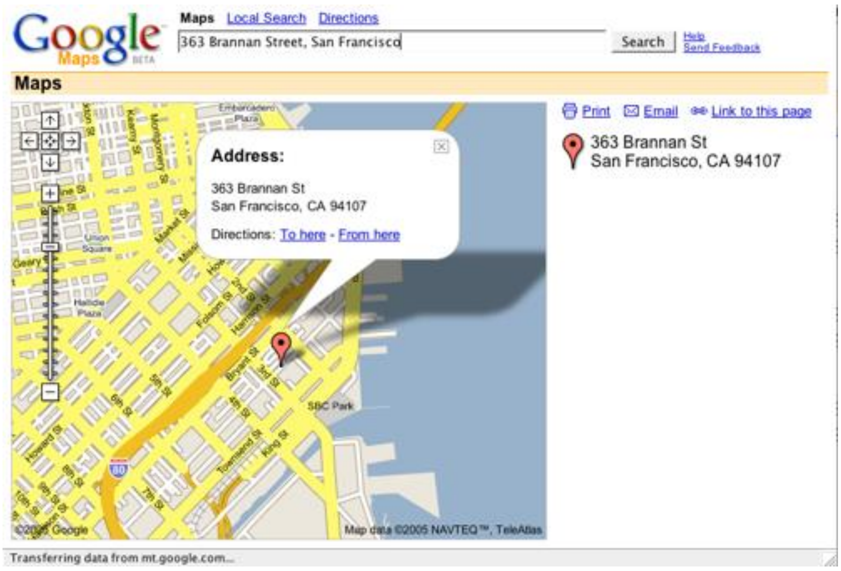
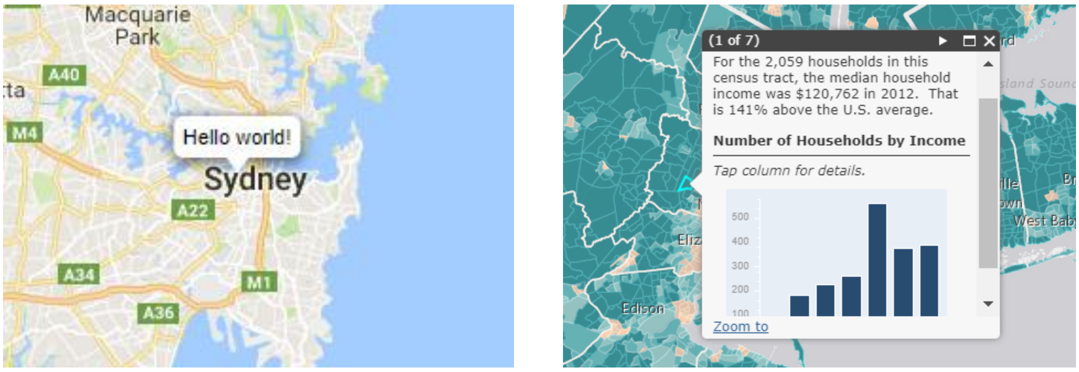


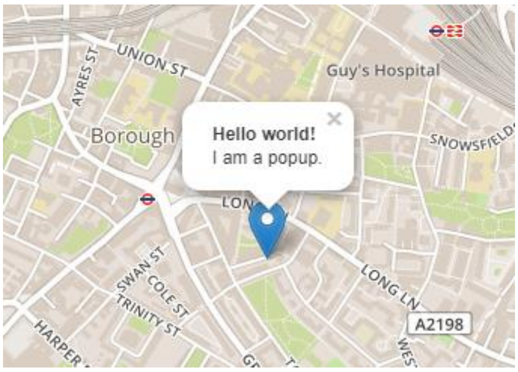
Figure 2. Feature info interface of Google Maps in 2005 *[9]*.

Because technologies mentioned in Figure 3 are frequently used as platforms for dissemination of geographical information and knowledge, map applications based on them oftentimes inherit the default "classic" feature info look, unless map creators invest their time and effort into customizing not only the content, but also the visual appearance.

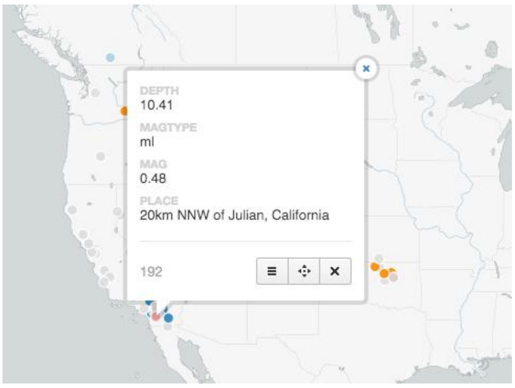


(A) Map by Google Maps JavaScript API [10].

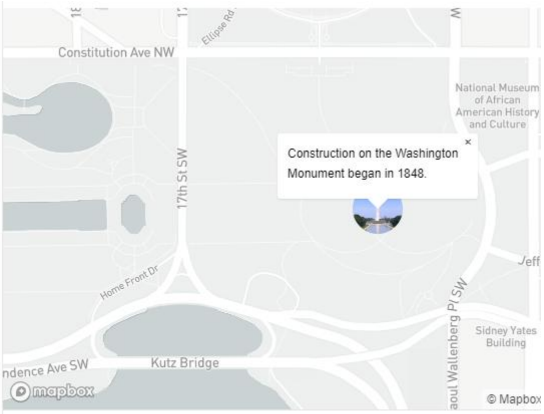
(B) Map by ArcGIS Online [11].



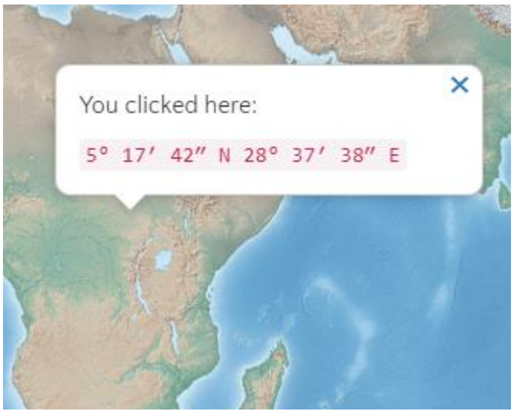
(C) Map by Leaflet [12].



(D) Map by CARTO [13].



(E) Map by Mapbox [14].



(F) Map by OpenLayers [15].

Figure 3. Feature Info windows in various mapping technologies.

The aforementioned companies encourage map creators to customize feature info (e.g. [13], [16]) by styling it to match the map’s user interface (UI) design and by displaying content to users according to their needs. For example, general users may prefer to see multimedia files (photos/videos) about a feature to get to know it better, while experts may be satisfied with the ability to view just a few numbers describing feature’s attributes. In some applications, apart from only displaying background information about a feature of interest, feature info also incorporates additional functionality. For example, certain action buttons, a form that can be filled out to submit additional information about the probed feature, or sophisticated tools that show temporal dynamics of attributes of the probed feature. It is, then, necessary to distinguish between working with the map and working with the feature info. Based on that, feature info dialogue windows will be an auxiliary or main interface element respectively. Finally, feature info functionality and visual appearance should not be overlooked. Rather, approached by applying design thinking[2] and integrating users into the design process [17].

Nowadays mobile map applications are just as popular, if not more, as desktop web map services [4]. They came to existence with the wide spread of mobile technologies starting from 1990’s and have grown beyond mapping to offering location-based services that are used by the majority of smartphone owners [18] . Such services include local recommenders, navigation, fitness-tracker apps etc.

The usability of mobile applications depends on a number of factors:

- limitations of mobile devices, such as small screen real estate, various screen sizes, single-window interfaces, connectivity, fragmented sessions, and touchscreen input;
- a wide variety of available devices and their operating systems;
- different ways of deployment (Web vs. native apps) [19].

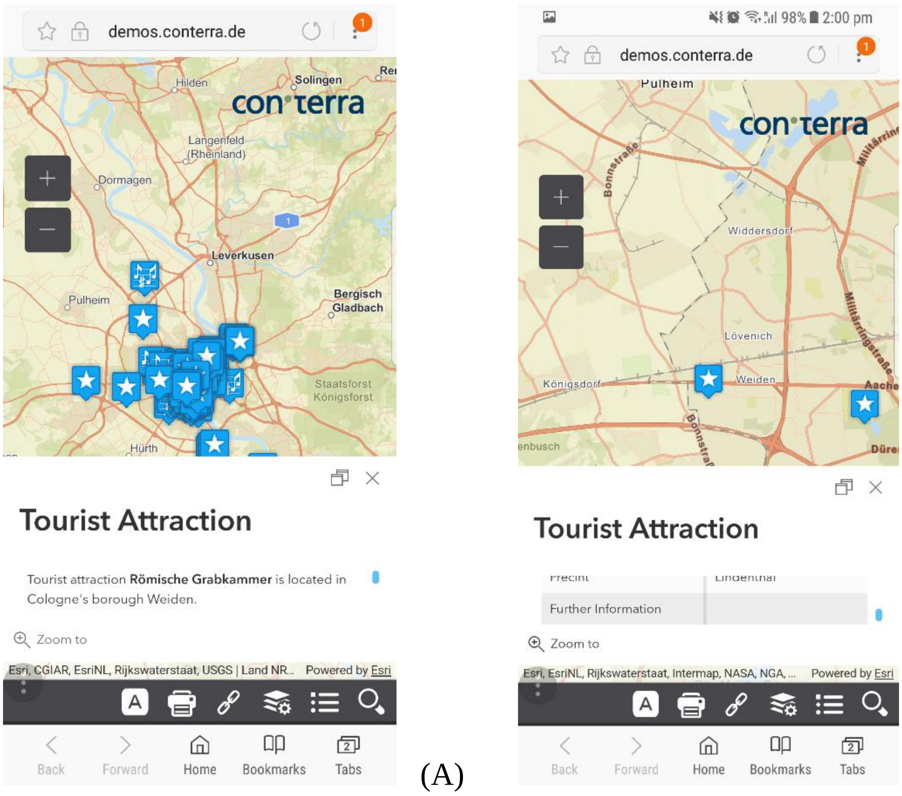
As a result, mobile map applications need a separate design approach when it comes to their development. Let us have a look at a specific example: open feature info window blocks a certain part of the map. Having obstructed map view may cost users losing understanding of the environment. Compromising between two windows on a mobile screen will not be possible without trade-offs, although map view should be the first priority [20]. Conclusively, further usability studies of feature info interfaces in mobile map applications are required.

1.2. Use Case: con terra App

The main application under study is a Web map service[3] developed by con terra GmbH (“the con terra app”) as this thesis is a collaboration between the University of Münster and the aforementioned company. The application is a technology demonstrator and offers geographic data about Cologne, namely city districts, boroughs, and precincts grouped into Basic Data layer[4]; libraries, museums, and schools – grouped into Education and Culture layer; and tourist attractions,

[2] Design-thinking - “design-specific cognitive activities that designers apply during the process of designing” [60].
[3] https://www.conterra.de/en/produkte/con-terra-solutionplatform/mapapps/produktdetails
[4] Layer – “A collection of entities of the same geometric type (dimensionality)” [4].

playgrounds- and sports areas, and places of event – grouped into Recreation layer. The con terra app can be accessed through any browser on any device and once loaded the Recreation layer is shown by default what makes it looks like a typical tourist application. Examples of feature info windows are shown in Figure 4. They present only simple attribute data and have easily noticeable usability problems. For instance: the heading with its large margins leaves 20 pixels-wide space for scrolling and viewing background information; only one row of the table can be viewed at a time, and there is missing information.



(A) (B)

Figure 4. Web application developed by con terra GmbH accessed via Samsung Galaxy S8 (A, feature info opened. B, feature info scrolled).

Feature info interface in the con terra application has a lot of room for improvement. Further formal usability inspection is required to detect additional problems. It will be useful to look at other mobile applications of similar nature to see the broader spectrum of usability defects in feature infos.

1.3. Motivation and Research Questions

The goal of this thesis is to improve the visualization and usability of feature info interfaces in the context of mobile tourist applications. It is motivated by the lack of scientifically-derived recommendations on feature info interaction design; and the need of considering the limitations of mobile devices and producing high-usability feature info interfaces. To achieve this goal, the following research questions are proposed:

1. **What usability problems occur when users interact with feature info in mobile tourist applications?**
2. **How solutions addressing these problems can be generalized into usability guidelines for feature info design?**

These research questions will be answered by applying the UCD approach, i.e. understanding problems that occur in feature infos, specifying design guidelines to address these problems, producing design solutions based on the guidelines, and evaluating them. The results obtained in thesis are supposed to help usability researchers better understand feature info interfaces and how users interact with it.

The remainder of this thesis is structured as follows: section two discusses the usability of WebGIS and mobile maps as well as existing literature focusing on feature info design; section three discusses research methods applied in this thesis; section four provides detailed description of how feature info usability data was analyzed and answers the first research question; section five introduces feature info design guidelines and answers the second research question; section six describes in detail the usability test conducted to evaluate the proposed guidelines; section seven discusses the results of the evaluation and this thesis, the limitations, and future work; and section eight concludes this thesis.

2. RELATED WORK

Originally, research in WebGIS usability was focused on desktop scenario, whereas today it has been increasingly revolving around mobile technology. This section follows this pattern and discusses, first, the usability principles of WebGIS services and, second, mobile map applications. The third subsection provides an overview of existing literature that supports feature info design. In addition, it also establishes feature info design dimensions and describes what research methods can be applied to evaluate the usability of feature info interfaces.

2.1. Usability of WebGIS

Usability of WebGIS is an emerging research field and recent publications discuss establishing methodologies to measure it, conducting lab and field experiments to benchmark systems and improve them.

In order to evaluate the performance of WebGIS, their specific particularities must be taken into account [21]. Schobesberger, for instance, developed a framework for UCD and evaluation of Web map-based systems [17]. The framework suggests various usability research strategies that depend on resources available to researchers at any given stage of system design (Figure 5). As UCD advocates for prioritizing user in order to design better products, in the context of this thesis it was important to learn more about potential users of tourist GIS applications. Chang and Caneday [22] found that the behavior and perception of users who seek tourist information via WebGIS depends on sex, age, and education. These user characteristics, therefore, must be taken into consideration when initiating any usability research for such applications. Another study by the same authors [23] showed that two factors – usefulness and playfulness – drive users to interact with WebGIS when executing tourism-related tasks. Of particular interest is playfulness because it is associated with the presence of interactive tools, such as feature info, that allow to manipulate spatial and attribute data.

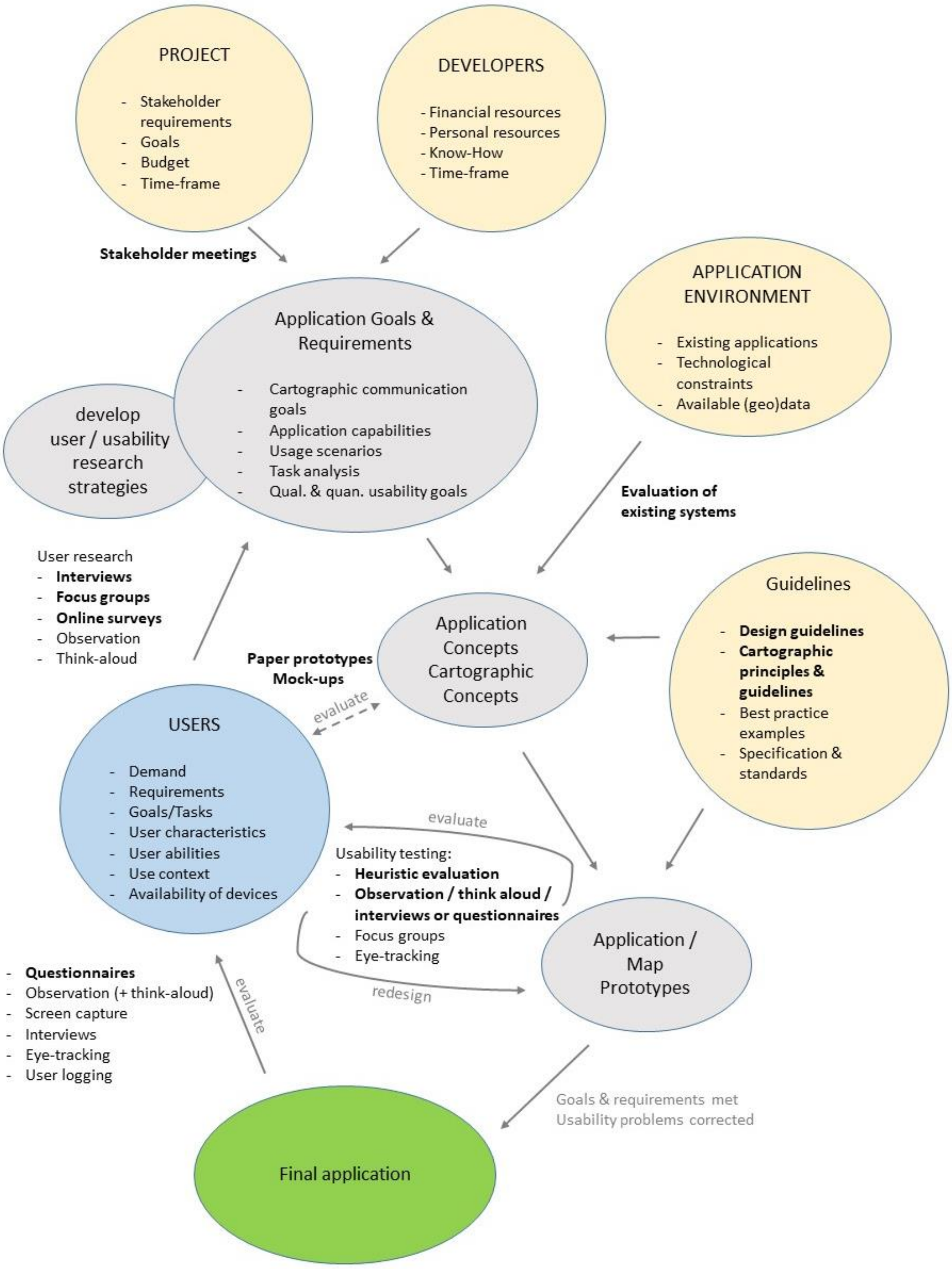


Figure 5. User-centered design framework for WebGIS applications. Methods in bold type correspond to a minimal required strategy. Adapted by permission from Springer Customer Service Centre GmbH: Springer Nature, Modern Trends in Cartography, Integrating User and Usability Research in Web-Mapping Application Design, Schobesberger D., [COPYRIGHT] (2014).

Although WebGIS has its own domain-specific usability principles proposed by Komarkova et al. [24], it is very common that researchers apply Nielsen's heuristics [25] to design and evaluate user interfaces. Common usability problems identified in desktop WebGIS relate to violation of cartographic principles, accessibility, input and search problems [26]; map visualization and map tools [27]; violations of usability principles such as learnability, flexibility, robustness, and aesthetics [28]. Usability problems associated with map tools in the above mentioned studies include issues with map legend, calculate distance tool, scale bars, missing control to turn on/off map layers, panning and zooming. Problems related to feature info were not described, however authors suggested it as new tool that could provide benefits to users. Roth and MacEachren [29] described interaction strategies users apply to interact with map primitives (zoom, pan, retrieve [feature info] etc.) of a web-based geoapplication. Rapid usage of feature info was indicative of the user being lost, confused, and unaware of the filter tool. On the other hand, a single purposeful instance of using feature info supported users in executing their tasks, although slightly increasing efficiency.

2.2. Usability of Mobile Maps

Similar as with WebGIS, usefulness, ease of use, and satisfaction drive users to interact with mobile map applications [30], [31]. Usefulness can be described as how the content of an app is relevant to users, ease of use – how easily that content can be extracted, and satisfaction – how they feel about using the app. UCD stresses that users must decide and prioritize what content they want to see in a mobile app. However, it is developers who are in charge of ease of use and usability of mobile applications that both are determined by the choice of a development platform.

The recent evolution of progressive web[5] apps (PWA) made it possible for PWAs to expand their capabilities and offer almost the same functionalities as native apps do, e.g. using device's hardware: GPS, proximity sensors, accelerometer, camera, storage, and other exclusive features. Web applications can only be accessed via a mobile browser that has its own controls and functionalities. An example

[5] https://whatwebcando.today/

provided further in this thesis demonstrated that users' behavior was influenced by continuous usage of native apps. Performing these habitual actions in a web app resulted in a usability error.

Usability principles for mobile map-based applications have been established and validated recently by Kuparinen [20]. These heuristics, however, lack a comparative study against general heuristics that would allow judging their effectiveness. Little if any research is available on usability of mobile map-based applications and especially interactive map tools. Some studies have explored how users' background influenced their ways of zooming and panning [32]; how multiple modalities (speech and touch) make it easier to interact with a mobile GIS [33], and how searching is carried out in a context-aware location-based service with an adaptive interface [34].

2.3. Feature Info Status Quo

Steady growth of map-based applications produced commercially and voluntarily has led to sophisticated innovations in feature info design that appear sporadically in a small number of map products. These innovations have a potential of wider application if scientific evidence of their efficiency is obtained and properly documented in academic publications.

GIS companies publish videos and documentation on feature info design within the capabilities of their desktop software, however there exist very little recommendations for mobile platform. Skarlatidou [1] presented trust guidelines for WebGIS interface design in five dimensions: graphic design, content design, structure design, and functionality design. However, only some of these guidelines are also applicable to mobile feature info interfaces. Muehlenhaus outlined general design guidelines specifically for the feature info in interactive and mobile devices [2]. He stated: "On maps that make heavy use of info windows [feature info], as much thought should be put into their design as is put into the design of the mapped area itself".

This thesis proposes four design dimensions that constitute the feature info interface: interaction technique (how to open/close and interact with it), placement (where on the screen it will appear), content (what user will see when it opens), and layout (or styling, i.e. how the user interface will look like). Below are presented literature findings that provide design recommendations for each corresponding dimension.

Interaction technique

Tapping (a "mobile" alternative to mouse clicking) as a gesture corresponds to "select" user action [35] and map users always need to select a map feature for its feature info to open. As a result, tapping is the most common gesture to open a feature info window. A general rule of thumb is that only one feature info can be open at a time [36]. Once open, user should be able to close it easily. Not only mobile screens limit the size of the map displayed, they also require objects on the map to be larger to match the touch target size. When the feature info window is active, it may occupy only a small portion of the map or the entire screen. Depending on the content, it is also possible to perform interactive actions within the feature info, for example swiping, tilting, or scrolling.

Placement

By supplying information on top of what is shown on the map, the system increases user's cognitive workload – an important aspect of usability [37]. Placing feature info window next to the map feature will stress the connection between them. Placing it at the top or bottom of the screen may yield different results depending on the context of use. There are several open-source plugins, e.g. Snazzy Info Window[6] or Leaflet Responsive Popup[7], that support responsive placement. These and other empirically implemented ideas should also be supported by theoretical frameworks.

Content

Providing relevant, accurate, and reliable content is important in order to support users in executing their tasks. Unless textual content is easily understood by user, it must be supplied with explanations and definitions for any kind of terminology and abbreviations, and other notations [25]. For instance, users participated in the study [38] commented that "ID" of the object presented in the feature info was not

[6] https://github.com/atmist/snazzy-info-window
[7] https://github.com/yafred/leaflet-responsive-popup

informative, and knowing object type would be more beneficial. If this system-related information is not meaningful to users, there is no need in including it in the feature info. Frequent content updates must be carried out to ensure that users are supplied with up-to-date information, and to avoid having missing data or broken links. Non-technical explanations should be provided also for error messages, along with the information about alternative ways for user to achieve the desirable goal/result [1].

Hennig and Vogler outlined content recommendations to guide feature info design in web apps for teenage users [3]. The total of 5 recommendations were derived through participatory design and focused on content requirements (e.g. youth-specific language, multimedia) and its visual representation (labeling and highlighting hyperlinks, high contrast between letters and background, different text size to differentiate between title, headings, and text). Another research [39] also supports simple language and avoiding technical jargon when presenting natural hazard information to non-expert users. These two examples suggest that context of use is crucial to feature info, and to evaluate mobile tourism systems it is necessary to understand user's travel behavior [40].

In the proliferating era of interactive technologies and big data, researchers raise the question of useful integration of rich content into mobile maps [41]. It is no longer what to tell, but rather how and why, and whether what is told relates to users and adds value into their interaction with mobile map technologies.

Layout

One way to design feature info layout is according to structure design guidelines from Skarlatidou [1]:

1. "Group content in a logical manner (information should be easy to find)
2. Textual information on different pages [feature info may be scrollable/have tabs] should be grouped effectively and should be relevant to the context.
3. Titles, headings and subheadings should be meaningful and should help with skipping paragraphs".

Among many examples of feature info available on the Internet, it is possible to delineate three common layout types: cards, table, and narrative (Figure 6). ESRI has similarly proposed three feature info “display options” [16] that appear similar to those proposed. Cards is an example of a completely custom layout where information and action buttons are all shown separately as cards on a surface. Table is the simplest form to display content since it only includes attribute names and values. Narrative could be either information from a single attribute field or just text that surrounds the attribute value, e.g. “Current water temperature [VALUE]”. The choice between these types of layout should be made according to user needs and preferences. As mentioned earlier, custom styling of feature info is often regarded as a mandatory. It must go hand in hand with responsive sizing, which is essential in mobile context because users access maps from a wide variety of devices.

(A) Cards (B) Table (C) Narrative

Figure 6. Common feature info layout types.

Current usability state of a feature info interface can be evaluated for each dimension individually or together using human-computer interaction (HCI) research methods [42]: interviews, camera studies, customer feedback, surveys, questionnaires, usability testing, heuristic evaluation etc. Specific methods applied in this thesis will be discussed in the next section. Collecting qualitative and quantitative data through lab and field testing allows understanding user’s workflow with it, finding usability defects and measuring precisely the impact these defects produce, e.g. lowering efficiency or effectiveness. It is very common that researchers mix methods in order to achieve their research goals [43]. Although mobile web applications differ from native ones in a number of aspects, in terms of feature info visual design and content presentation both can be easily compared.

This overview of related work summarized usability principles of WebGIS and mobile map applications, methods of evaluating the degree of compliance to these principles, common usability problems associated with map applications and feature info in particular. Content, as one of the feature info usability dimensions, is the most extensively studied and described in academic literature, whereas interaction technique, placement, and layout are generally subjects to experimenting and finding optimal solutions for specific use cases. The rest of this thesis will be dedicated to exploring these three dimensions and establishing specific design guidelines related to them.

3. METHODOLOGY

Research methodology of this thesis was based on the framework for user-centered design and evaluation of Web map-based applications (Figure 5) [17]. The summary of research methods applied to answer each of the research questions is presented in Table 1. Measurements and analyses carried out as part of the applied methods are shown in Table 2. How these methods work together and why they were a good choice is described below.

Table 1. Research methods used in this thesis

	Research question # 1 (analyzing usability problems)	Research question #2 (creating design guidelines)
Heuristic evaluation	X	
User interview	X	
Literature review		X
Questionnaire for experts		X
Usability test		X

Table 2. Summary of measurement and analysis types used in this thesis

	Qualitative	Quantitative
Measurements	Questionnaires for users and experts, comments and feedback obtained in the course of the user interview	The number of usability problems found during heuristic evaluation, usability testing of prototypes: task completion time and rate, and SUS scores
Analysis	Interpretations of questionnaire responses, comparative analysis of apps reviewed in heuristic evaluation	Comparative analysis of heuristic evaluation results, Statistical analysis of the usability test results

The *first research question*, finding and analyzing feature info usability problems, was to be answered by testing existing systems. A heuristic evaluation of five mobile tourist applications was conducted by the author of this thesis along with a semi-structured user interview where users evaluated one of the five applications - the con terra app. The decision to mix two methods was made because heuristic evaluation done by one evaluator allows finding only 20 to 51% of the usability problems in an interface under study [44]. Thus, an interview with users was conducted in order to find additional problems that could have been missed during the heuristic evaluation and to explore how users perceive feature info.

Heuristic Evaluation

A heuristic usability evaluation is a fast way to understand the current usability state of an interface by comparing it against a set of predefined usability principles or "heuristics". It is called "fast" because it does not necessarily require user participation. The evaluation can be carried out by both usability specialists and non-specialists, although the former tend to produce better results [45]. Some of the heuristics for map-based services (Kuparinen [20], Komarkova et al. [24]) mentioned in Related Work section were not applicable for feature info evaluation since they were developed to assess an entire system and not just an individual interface. Hence, generic Nielsen's heuristic for user interface design [25] were chosen.

User Interview

Interviews is popular qualitative research method that is also used to evaluate the usability of existing information systems [46]. In contrast to heuristic evaluation, users take part in the interview and share their experience while interacting with the system either by thinking aloud or filling out a post-interview questionnaire. During the interview conducted in this research, users only interacted with the con terra app. The main reason for this was that the app was not ready for deployment and could still benefit from participatory design, i.e. user feedback would provide more details about how feature info could be improved. Another goal of the interview was to understand how people with cartographic/GIS background perceive feature info as opposed to people without one.

The *second research question*, creating feature info design guidelines, was to be answered by proposing recommendations that would help eliminate usability problems identified while answering the first research question. While some problems already had solutions available in academic literature, others lacked theoretical backing. Then, it was decided to seek answers from best-practice examples by sending a questionnaire to industry experts to get qualitative insights into how they approach feature info design and development. Altogether, literature review and responses from the questionnaire contributed to deriving feature info guideline concepts. Lastly, a lab-based usability test was chosen to make conclusions regarding how guidelines influence user's efficiency, effectiveness, and satisfaction.

Literature Review

Literature review is an essential step in carrying out any research project [47]. The review of related work presented in the previous section showed that feature info interaction design was an area where further research was needed. Once usability problems were analyzed, another round of literature review was carried out this time looking for specific solutions to specific problems. Supporting literature was also found to back up expert opinions.

Questionnaire for Experts

Same as interviews, questionnaires are widely used for qualitative research of information systems [46]. This method is moderately complex in its execution: first, it requires creating a list of unique questions, second, recruiting participants, and finally, analyzing obtained qualitative data that may come in different levels of detail. Gable also reported that questionnaires may not provide deep insights into the studied phenomena [48]. One particular challenge in the course of this thesis was designing the questionnaire. It required a lot of modifications to ensure it was formatted properly and questions were easy to understand.

Usability Testing

Engaging target users into usability testing is encouraged by UCD. By letting them interact with prototypes, developers can identify early on if concepts work as expected and user requirements are met. If concepts contain usability problems, then prototypes require another iteration of design and testing. The goal of the usability test in this thesis was to compare feature info interface prototypes before and after applying the guidelines. To achieve this goal, methods of observation and a System Usability Scale (SUS) questionnaire [49] were employed. Observations consisted of tracking task completion time (i.e. efficiency) and rate (i.e. effectiveness). SUS score was a measure of perceived ease of use. SUS is a post-study standardized questionnaire that offers a number of advantages: objectivity, replicability, quantification using mathematics and statistics, economical to use, the results are easy to communicate, and, of course, scientific generalization [50]. In addition, the questionnaire produces reliable results even with small sample sizes, does not require any license fee, and the scores can be easily calculated by downloading a spreadsheet [51].

Summing up, methods used in this thesis were selected based on the amount of resources available, i.e. personal, human, financial, and temporal. Further detailed explanations of how each method was applied are provided in the next sections.

4. ANALYZING FEATURE INFO USABILITY

This section is dedicated to answering the first research question posed in this thesis - *what usability problems occur when users interact with feature info in mobile tourist applications?* Research methods applied to answer this question are described in depth together with the obtained results. The first subsection covers heuristic evaluation. The second – user interview. Additionally, the section touches upon the second research question and explains how some of the problems can be resolved. This knowledge and how it can be acquired is described in subsection three dedicated to questionnaire for experts.

4.1. Heuristic Evaluation

Participants. The evaluation was performed by one evaluator, the author of this thesis, who was not a usability expert, however had several years of active experience with mobile map applications.

Apparatus and Material. Heuristic evaluation of feature info interfaces was carried out for five mobile map applications: con terra app, TripAdvisor, Foursquare, Google Maps app, and mobile version of Google Maps website. The applications were selected based on their: category – tourist app, popularity – with more than 10 million downloads (it is hard to imagine that apps with bad usability would be popular), and platform – native and Web-based. Three of the apps analyzed were native (Google Maps, TripAdvisor, Foursquare) and two were web-based (mobile version of Google Maps website and con terra app).

After selecting the applications, a list of tasks was defined to help the evaluator get familiar with their feature info interfaces:

1. Find Cologne on the map and zoom in to view the city.
2. Select any point of interest (POI) on the map, open its feature info and scrutinize background information and actions presented.
3. Repeat the previous step 20 times with other POIs randomly selected from the map.

Nielsen's heuristics for user interface design [25] were used to detect usability problems and categorize them. The severity of problems was rated according to the following scale [52]:

0 = I don't agree that this is a usability problem at all

1 = Cosmetic problem only: need not be fixed unless extra time is available on project

2 = Minor usability problem: fixing this should be given low priority

3 = Major usability problem: important to fix, so should be given high priority

4 = Usability catastrophe: imperative to fix this before product can be released.

In addition to heuristic evaluation, feature info interfaces of the applications were analyzed to obtain additional details:

- interaction technique (e.g. tap or double-tap),
- placement (top, bottom, or next to the feature),
- percentage of the screen occupied when minimized,
- available modes (minimized or maximized),
- layout (table, cards, narrative),
- content amount (level of detail, actions in maximized feature info),
- context (temporal – e.g. "Open Now", spatial – "0.5 km from current location") and help, as well as,
- means of handling missing information (blank field, hidden field, or a suggestion to contribute).

The first five items from this list above related to feature info design dimensions introduced in Section 2.3.

Procedure. For each application, the evaluation took around two to three hours. While carrying out the predefined tasks, the evaluator recorded feature info usability problems and assigned each problem a severity score. After the evaluation was completed, additional details were collected including required estimations, i.e. percentage of screen occupied, amount of content offered. To identify the proportion of the screen that was covered by feature info, the area in pixels occupied by feature info was divided by the total area in pixels of the screen. Measurements were carried out in GIMP 2.8.22 image manipulating program. To measure the amount of content presented in feature info, level of detail and actions available were counted. This was done only for maximized feature infos because minimized usually offered just feature name, address, and rating.

Results. The summary of problems identified during heuristic evaluations is shown in Table 3 (the numbers in each cell represent the amount of discovered issues with regards to that specific heuristic).

Table 3. Problems found during heuristic evaluation of the apps

	Con terra app	**Mobile Google Maps website**	**TripAdvisor**	**Google Maps App**	**Foursquare**
1. Visibility of system status.	1				
2. Match between system and the real world.	1		1		
3. User control and freedom.	4		1	1	
4. Consistency and standards.	4		1		
5. Error prevention.					1
6. Recognition rather than recall.	1				
7. Flexibility and efficiency of use.	2		2		
8. Aesthetic and minimalist design.	3		2	2	
9. Help users recognize, diagnose, and recover from errors	1	1	1		
10. Help and documentation					
Total number of errors	**17**	**1**	**8**	**3**	**1**
Major or catastrophic problems	**16**	**1**	**4**	**1**	**1**

The full description of problems can be found in Appendix A. The greatest number of usability defects, especially major and catastrophic, was found in the con terra app. This result was expected since the application is only a demo product. Among the released apps, TripAdvisor had more errors than Foursquare or Google Maps (both the app and mobile website). Such outcome can be partially described by the fact, that TripAdvisor offered the widest variety of content (Figure 7, Appendix B) in comparison to the rest of the evaluated apps, and it might have been cumbersome for developers to keep everything in order.

Because heuristic evaluation was conducted only by one non-expert evaluator, some usability problems detected might have been misclassified. It was not seen as a problem, because the goal of the evaluation was only to identify the problems and Nielsen's heuristics were used just for reference. There is also a possibility that some problems detected were false positive.

A general trend among the analyzed apps shows that it takes one tap on the map feature to open its feature info window in minimized mode, i.e. located at the bottom of the map and covering a certain part of the map. Percentage of the screen occupied by feature infos in minimized mode ranged from 10 (Foursquare) to 30% (con terra app).

In four out of five apps, maximized feature info is presented in fullscreen mode as a separate window that slides by swiping from left to right (TripAdvisor, Foursquare) or from bottom up (Google Maps app, mobile version of Google Maps website). In Google Maps app, it is also possible to view feature info in full-screen mode by double-tapping on a map feature. In the con terra app, by tapping the "maximize" icon in the upper right corner of the feature info, it does not maximize into a fullscreen window, but moves from the bottom of the map closer to the selected feature. As a result, it covers up a significant amount of the map and prevents from viewing other POIs unless closed. It is worth noting, that in Google Maps certain features with limited temporal extent (e.g. road construction) only have a minimized feature info that presents the most relevant information about a feature (less than five lines of text). In applications with feature info available in fullscreen mode

(TripAdvisor, Foursquare, Google Maps app, and mobile version of Google Maps website) all information about a feature can be viewed by scrolling down the dialogue window. Google Maps app and Foursquare also offer shortcut tabs that help users access faster certain sections of the scrollable feature info window. Depending on the operational layer that is viewed on the map (e.g. attractions, hotels, restaurants), the layout of a feature info interface may change. Thus, the apps can be commended for customizing the layout according to the content displayed.

Content and actions offered in the feature info interfaces deserve a separate paragraph. If one chose to sort the apps analyzed based on the amount of content offered (Appendix B) from the largest to the smallest, then he or she would get the following result (Figure 7).

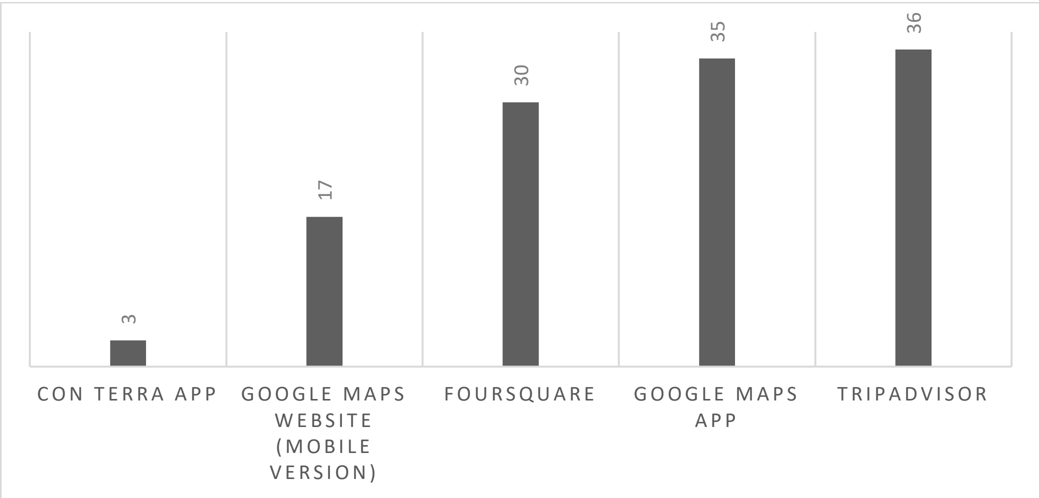


Figure 7. The number of attributes and actions shown in a single feature info by apps studied in this thesis.

Con terra app currently provides only basic attribute information about POIs in the form of text. On the other hand, Google Maps app and website, Foursquare, and TripAdvisor altogether let users to:

- view infographics, browse videos and photo gallery of the feature;
- read, translate, filter, and write reviews;
- email, call, share, save to favorites, and navigate to the feature;
- check availability, make reservations and place orders;
- open other websites to access real-time information;

- know average time spent at the feature and its popular times;
- view upcoming events at the POI, other places located within the POI, and also suggested similar POIs;
- submit any missing information, suggest edits, and ask questions.

Each feature info provides minimum background information about the feature, but enough so to allow users make decisions without accessing any second-party sources, for example the feature's official website. In crowd-sourced apps (Google Maps, TripAdvisor, Foursquare) features located around the city center tend to have more background information supplied by users (reviews, scores etc.), than those on the periphery. This may be explained by tourists visiting only the most popular places (usually around the city center) and sharing their experiences afterwards.

When installed for the first time, none of the apps provide any tutorials or tips on how to work with the map and the feature info. Developers, perhaps, assume that by now tapping on a feature to retrieve more information is a conventional rule and potential users of the app are expected to possess that knowledge.

4.2. User Interview

Participants. According to [44], having more than 5 evaluators allows finding at least 75% of usability problems. The total of 6 users (age group: 20-30) took part in the study (user demographics is presented in Table 4). None of the participants had worked with the con terra app before. The study was approved by the Ethics Committee of the Institute for Geoinformatics, University of Münster. Recruiting participants and carrying out the study took one week.

Table 4. Demographic profile of user interview participants

	Male	Female
With GIS background	2	1
Without GIS background	1	2
Total	3	3

Apparatus and Material. Three tasks similar to those used during heuristic evaluation were created to let users get acquainted with the con terra app:

1. Find Cologne on the map and zoom in to view the entire city.

Note: When the application is started, you will see markers on the map that represent attractions and venues.

These markers altogether have been grouped into "Recreation" category. In addition to this category, there are two others - Basic Data that shows city districts, boroughs, and precincts; and Education and Culture that shows libraries, museums, schools.

Choose the category you want to view by clicking on the icon  at the bottom panel of the app.

2. Select any point of interest on the map (POI) and try to get the following background information about it:
   a) Name
   b) Type
   c) Address
3. Repeat the previous step 10 times with other POIs randomly selected on the map.

While completing the tasks, users were requested to share their experience by thinking out loud. Upon finishing, they were also requested to fill out a questionnaire (Appendix C) that consisted of twelve open-ended questions designed by the author of this thesis. Questions aimed at achieving the goals of this interview: recording usability problems in the feature info of the con terra app, finding how users perceived the feature info, and finding what users were missing in the feature info. Pilot interview was conducted with one person, after which some questions were modified for the sake of clarity.

Procedure. The interviews were held in a lab-based setting. At the start, participants (or users) were requested to sign the informed consent. Then, they were invited to get acquainted with the con terra app by performing the tasks. While users were performing the tasks they were requested to think aloud and their comments were recorded by the facilitator. After finishing the tasks, the participants were invited to fill out the questionnaire. The responses have been anonymized and processed in aggregate. Finally, usability problems detected during heuristic evaluation and user interview were matched to eliminate duplicates.

Results. Users felt like feature info could benefit them by providing more information about a single geographic entity, allowing to manipulate that information through actions, and serving as an access point to new screens and interfaces that would show even a deeper level of detail about specific aspects of interest. All users indicated that they would like to view background information in an interactive way because it could give better first impression of place and let them execute certain actions right in the feature info (e.g. without having to copy the phone number and paste in the dial screen). One user stated that he or she would like to customize feature info to see only preferred content. Users were indifferent towards the layout of the feature info and could not tell how recent the provided information was. They needed the map often and five users shared that having minimized feature info still kept their focus on the map, whereas fullscreen feature info would let them focus only on the background information.

Four users liked the design of the feature info interface and especially that external links were provided. However, there were more comments about particular things they disliked, for instance the feature info was uncomfortable to use (icons were difficult to select, scrolling area was too small, text font was too small); it did not provide enough information (note: the app is only a demo); some did not understand attribute names, and also they could not see the connection between the map feature and its feature info. Participants also expressed what background information they were missing: opening hours, pictures, distance from current location, prices, popularity, contextual information (e.g. distance from current location or current events at the venue).

The main result was recording six additional usability problems missed during heuristic evaluation:

1. font size was too small;
2. the UI was difficult to understand;

3. “maximize” and “close” controls were small and located too closely to each other – participants had problems using them;
4. system failed to respond when a feature was tapped on, however after zooming in, it responded with opening a feature info;
5. missing information made table look incomplete; and, finally,
6. there was no visual cue to hint users that the feature info was scrollable.

4.3. Questionnaire for Experts

Participants. To find experts, LinkedIn[8] was queried for specialists in UX, front-end development, and usability, currently working in companies of mapping / GIS industry, such as ESRI, Mapbox, CARTO, HERE, TripAdvisor, and Trivago, and involved in the development of mobile apps. Out of eight prospect participants that agreed to participate, only two submitted their responses. Recruiting participants and collecting responses took three weeks. The study was approved by the Ethics Committee of the Institute for Geoinformatics, University of Münster.

Apparatus and Material. The questionnaire (Appendix D) consisted of sixteen open-ended questions that covered specific aspects related to feature info, such as visual design, content, customization, and conducted usability studies. Questions were designed in the way to obtain best-practice examples from mobile map application and feature info development.

Procedure. After experts expressed their interest in participating, they were provided with a consent form together with a questionnaire document, with a submission deadline of two weeks. Once the responses were collected, they were anonymized and processed in aggregate.

Results. Both respondents indicated that they approach feature info development following user-centered design. One interviewee stated that “*If the map isn’t going to be critical for the user to get to the end goal, I make it a smaller feature in the application, however if it is, I make it larger*”. Visual design of feature infos in different products usually remains the same and agrees with design guidelines

[8] https://www.linkedin.com/

established by their respective companies. Feature info layout is chosen according to the target audience, e.g. presenting background information as a table makes content easy to scan and understand. However, a table may look too mechanical when it shows "Walking duration: 1 minute 47 seconds" instead of "2-minute walk".

With regards to feature info placement, if it is a feature users are expected to use frequently, it is critical to make sure it is placed in a location that not only the user can find, but can access quickly if need be. While one respondent suggested experimenting in identifying optimal feature info shape, its dimensions and position through user testing, another suggested trying to maximize available screen real estate, prioritizing map view over feature info view, and taking into account reachability.

Any type of content can be presented in feature info as long as it is relevant to the map feature, recent, and benefits the user. Providing dynamic context is important because the feature info should be assisting users in real-time decision making. Also, developers may want their app to be a "one-stop shop" providing the maximum necessary information for users in order to support them in executing their tasks. Both respondents also indicated that when designing feature info windows for mobile map products, they only customize content presented in the feature info. One respondent stated: "*I haven't come across a use case for personalizing the look of the feature info, but of course there may be scenarios where this is needed*". Another argued that "*Giving users the ability to customize the look/content causes the user to potentially lose focus of why they were there in the first place, which could cause a higher bounce rate*". Suggested use cases where feature info customization might be relevant were saving/bookmarking places and adding personal notes or comments, customizing layout to access the most frequent actions/information, adding missing information, i.e. flagging or suggesting an update.

Both experts indicated feature info discoverability as a main usability problem many novice users face. Therefore, they suggested that having a feature info tutorial or a walk-through during onboarding would benefit users.

Only two out of eight experts contacted, submitted their responses to the questionnaire. This might have inhibited the author of this thesis from getting a deeper understanding of how industry experts approach feature info design. In addition, having more best-practice examples would allow producing even more specific guidelines.

The results of the heuristic evaluation and user interview answered the first research question and presented thirty-four unique usability problems in feature info interfaces. The majority of those problems were the result of poor interaction design. For some usability problems described in this section it was challenging to find complete solutions in academic literature. Contacted usability experts shared their opinions regarding how these and other problems they experienced could be resolved.

5. GUIDELINES FOR FEATURE INFO DESIGN

This section provides an answer to the second research question, i.e. *how solutions addressing these problems can be generalized into usability guidelines for feature info design?* It introduces the guidelines and explains them on a conceptual level.

Feature info design guidelines that target specific usability defects are presented in Table 5. Seven out of nine guidelines cover the "Design" aspect that is related to usability dimensions (interaction technique, placement, and layout) established in Section 2.3. The other two guidelines focus on "Content" and "Awareness" (one for each category respectively). Guidelines:

- # 2, #3, #5 were derived based on expert feedback;
- #1 and #6 were derived based on existing solutions presented in studied applications – Google Maps app, TripAdvisor, Foursquare;
- #4, #7, #8, #9 were derived based on a combination of sources: expert feedback or existing solutions further supported by research literature.

How each guideline was derived and what usability problem it addressed is further elaborated below.

Table 5. Feature info design guidelines

	Content
1.	Provide context, e.g. measurement units for numerical values or relative rank of the feature based on an attribute (e.g. area size or popularity), to help user understand the relationship between the currently viewed feature and the rest of those presented on the map.
	Design
2.	Choose feature info layout according to target audience. Users must decide and prioritize what type of content they want to have in the feature info and how it should be presented.

Table 5. Feature info design guidelines *Continued*

3.	Avoid cramming more content by making minimized feature info window scrollable and switch to maximized/full-screen window instead. The size of feature info should be primarily guided by the amount of content it offers. Shape and dimensions of the minimized feature info window must be chosen in a way that prioritizes map view.
4.	When designing feature info interface, the control to return back to the map should be clearly visible and touch-friendly.
5.	Choose maximized feature info window to present interactive content because interactive gestures - swipe, pan, or tap, may contradict those of the map.
6.	To avoid selecting multiple features accidentally, cluster point features at small scales and show them individually when zooming in; for polygon and line features, make only labels selectable.
7.	To ensure natural interaction, place minimized feature info window at the bottom of screen.
8.	Find a way to show the connection between the map and the feature info window by bringing into focus the feature that was selected (e.g. change marker color / size).
	Awareness
9.	Feature info as a map tool struggles with the problem of discoverability. Provide a tutorial or a walk-through during onboarding to let users know about it.

Guideline # 1: Providing measurement units and relative ranks. On a mobile device, due to limited screen real estate it may be cumbersome to fit in the map legend that displays maximum and minimum values and a measurement unit of a layer currently displayed. When feature info is open, user will see the value of an attribute at current feature without knowing the measurement unit or relative rank of the attribute at this feature in comparison to other features (e.g. colder/bigger/more populous than others). In tourist apps that were reviewed, e.g. features were always ranked based on the ratings they receive from the people who visited them. It could be a good practice to provide measurement units and a relative scale position of a value characterizing a certain attribute in feature infos.

Guideline # 2: Choosing feature info layout. Six out of eight user interview participants agreed that presenting background information formatted as a table makes content easy to scan and understand. Especially when it comes to comparing background information between several features. Knowing the target audience and the type of content that will be displayed can definitely benefit the design process of the feature info layout. When users need information urgently, having to process narrative or long text may cause frustration, make user lose track and turn to other sources for desired information. For advanced users of an app/system, table or cards will be the fastest and easiest way to obtain information, often because they memorize the names, measurement units, and order of the attributes in the feature info thanks to their daily exposure to the map product they utilize. In other scenarios users might prefer information presented in a natural conversational flow as if "*offered by Wikipedia*" (quoted from one of the interview responses).

Ensuring that an attribute's value can be fetched easily on demand, hence, becomes the main task for the UX researcher. One way to make table look "friendlier" is by experimenting with its visual design. Eliminating borders or making them subtler may help drive more focus to the content. Certain terms used to describe attributes may seem ambiguous or confusing, and providing context (text that surrounds the attribute value, e.g. "You can fly your drone at [WIND SPEED VALUE] m/s") will make the interaction between users and the map app seem more natural. Another option would be to use icons instead of words for certain commonly understandable attributes (see Figure 8 below). By doing so, designers manage to achieve two goals at the same time: keeping the design clean and intuitive and also saving screen real estate. Icons created for any other attributes are suggested to undergo user testing to ensure that they communicate the right information.

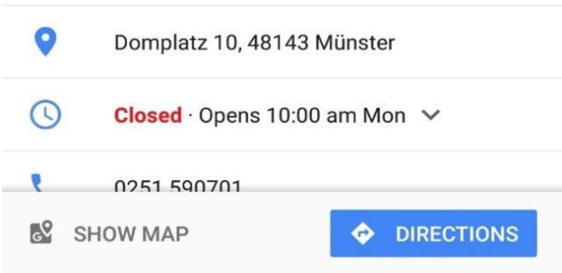


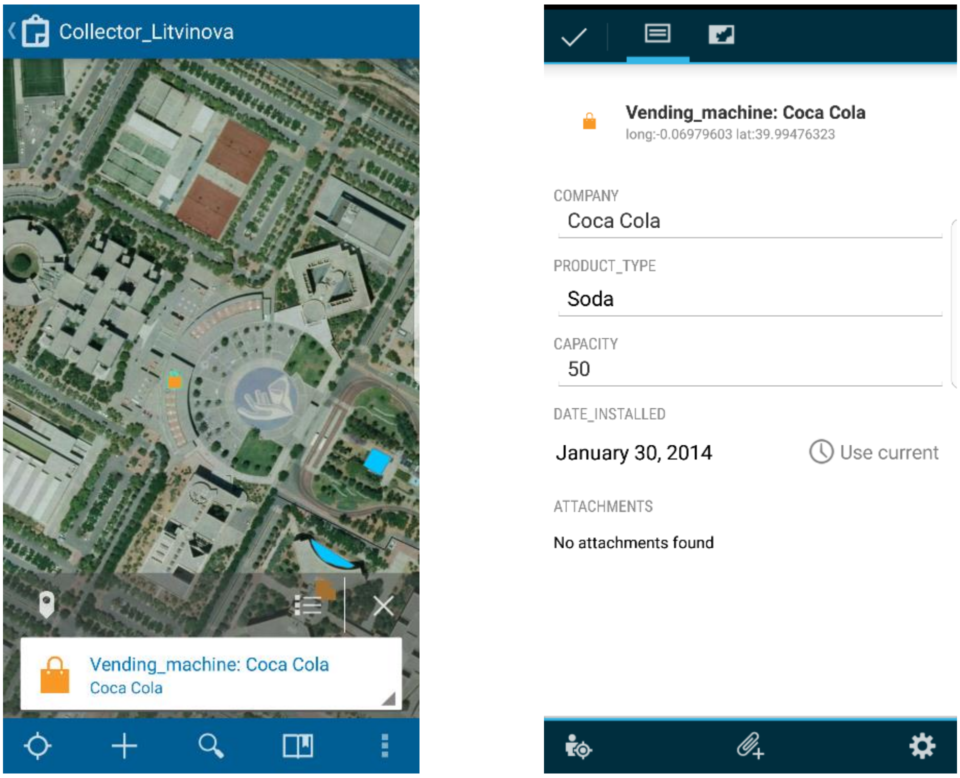
Figure 8. Google Maps uses icons to represent "Address" and "Open time".

Guideline # 3: Choosing feature info window size. Another important aspect is identifying the amount of content that will be presented and the need for a full-screen feature info window. As one expert stated: "*having a miniature feature info window allows presenting the most relevant background information about a geographic feature while still keeping the user's focus on the map*".

According to Material Design, feature info definition is somewhat similar to the "card"– "a sheet of material that serves as an entry point to more detailed information" [53]. Material Design does not encourage making the card scrollable. During user interview this rule was empirically proven by all users who participated in the study and found it extremely difficult to scroll in a narrow space of the feature info of the con terra app (users with "fat fingers" were frustrated the most). Moreover, heuristic evaluation of the apps showed that none of the apps except the con terra app allowed scrolling through minimized feature info window. If the amount of content that needs to be presented in the minimized feature info window does not fully fit into the window's boundaries, instead of making it scrollable, expand it into a full-screen window that can be scrolled internally. Vice versa, there is no need for full-screen feature info window if no extra information is provided. To help users understand that the feature info can be expanded into a full-screen window, a number of visual cues can be implemented, such as animation (sliding in from the bottom would suggest that the window is swipe-able); cropping content, or simply showing a "more info" button. Alternatively, shortcut tabs can be offered to help users access certain sections of the scrollable dialogue window faster, like in Google Maps or Foursquare.

Guideline # 4: Providing visible controls to close feature info. While observing participants interacting with the con terra app during the user interview, several of them had a problem closing the feature info. The reason for this could be the fact that users of Android native apps were accustomed to using the system's "Back" button to exit an unwanted state. Applying the same action in a browser while using a Web app, instead, returned users to a previously visited website. Thus, another usability catastrophe was witnessed. When designing feature info windows, the control to close them should be clearly visible and touch-friendly [2].

Guideline # 5: Choosing maximized feature info for interactive content. All participants of the user interview wanted to see interactive content in the feature info. When offering such content, designers should consider making it fullscreen, because otherwise interactive gestures such as swipe/pan/tap may conflict with those of the map. This practice is widely followed by apps evaluated during the heuristic evaluation and also other mobile map apps (see Collector for ArcGIS example with a form in Figure 9 below):



(A) (B)

Figure 9. Map (A) and Collect screen (B) interfaces of Collector for ArcGIS.

Guideline # 6: Making map features easy to select. Zoom level plays an important role when users interact with the map and feature info. When multiple features were located nearby (Figure 10), the app did not cluster feature markers, making the map look cluttered.

Since the tap target size is usually considered to be 48 x 48 pixels, multiple map features can fit into this square. Tapping on a feature marker at a small scale sometimes opened feature info for another than selected map feature. Moreover, four out of six users had problems with opening the feature info, i.e. system failed to respond upon tap until they zoomed in to a larger scale. One way to tackle all these issues would be to reduce marker overload by clustering and showing one cluster marker with a number of features that belong to it. Tapping on a cluster marker should bring map to a certain scale where each individual marker can be selected to view its feature info separately.

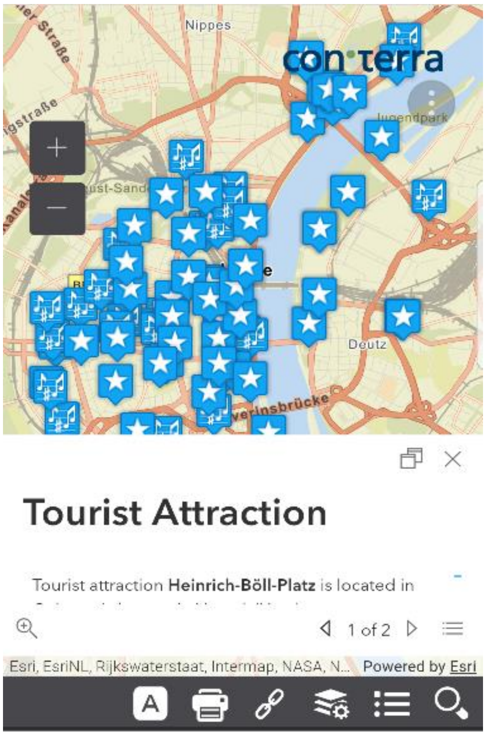


Figure 10. Feature info window for two features. Currently displayed feature is indicated by enumerator in the bottom right corner.

Finally, if two layers were displayed on the map at the same time (Figure 11), e.g. a polygon and a point layer, and it happened so that a point was located within a polygon, two users faced a situation when upon tapping the point, a feature info for the polygon was shown instead and users were confused and unable to execute the assigned task. This particular problem can be solved by placing a name label within each polygon and making only the label clickable. Labels, of course, should be visible only at a certain zoom level. In such way, even if there are point features within the polygon, they can be selected individually to open their feature infos.

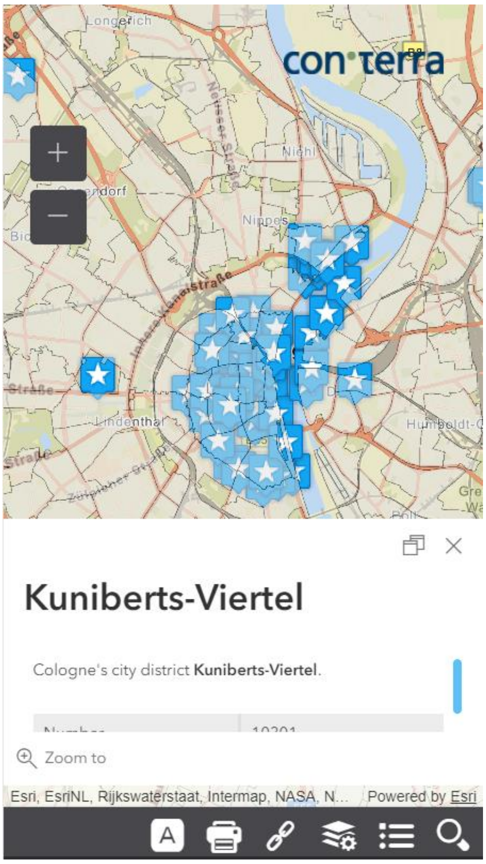


Figure 11. City districts and tourist attractions shown in con terra app.

Guideline # 7: Placing feature info to ensure natural interaction. Placing feature info next to the selected feature can block a substantial area in the middle of the map. User interview participants responded negatively to this while they were using the con terra app. In general, users of mobile devices prefer to hold them in one hand [54] and use that hand's thumb for interaction. Thumbs can only reach so far and limited thumb reachability narrows down the functional area of the screen (shown in green in Figure 12). Keeping in mind these two ideas and also expert feedback, place minimized feature info window at the bottom of screen to prevent it from blocking the map and allow it to be reached easily.

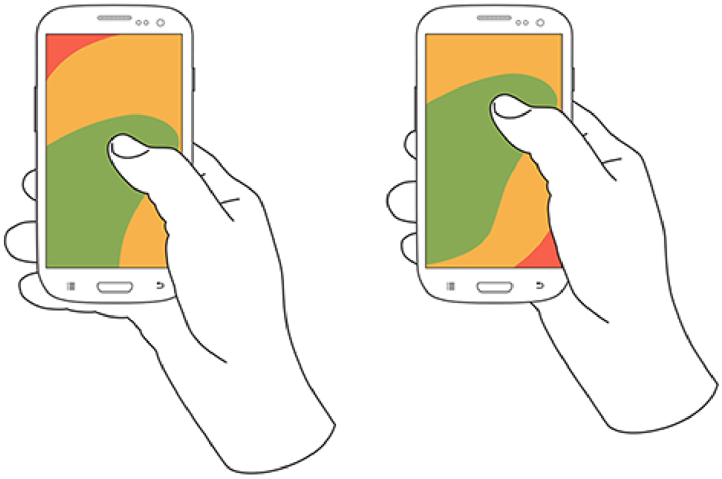


Figure 12. Thumb reachability areas during one-handed interaction with a mobile device [42].

Guideline # 8: Establishing mental connection between the map feature and its feature info. If feature info is shown at the bottom of the screen, it is important to provide visual distinction of the selected feature from the rest of those displayed on the map, as done by TripAdvisor, Foursquare, and Google Maps. While listing the aspects users liked the least in the con terra app, two users indicated that features were difficult to distinguish between, and after certain amount of time they lost the track which feature the currently displayed feature info window belongs to. Therefore, it is highly important to show the link between the feature and its feature info window by e.g. changing the color of the marker selected, dropping the shade, or increasing its size (as suggested by users participated in the interview and [2]).

Guideline # 9: Supporting feature info discoverability. Both experts indicated feature info discoverability as a main usability problem many novice users face when working with mobile map apps. This claim was further supported by Andrienko et al. [55] and by the fact that none of the tourist apps analyzed during the heuristic evaluation provided any tips or hints on how to use feature info. Experts commented that having a tutorial or a walk-through during onboarding might be beneficial to users. While onboarding is quite common for native apps, product developers must think carefully of how to implement it into Web apps. If every time the link is clicked, a map opens up with an onboarding popup, users may get frustrated with having to get rid of it. One solution could be having a "help" button on the map that could provide tips for working with that map and its interactive tools.

6. EVALUATING GUIDELINES

How the proposed guidelines can affect a feature info interface was decided to assess through a lab-based usability test. Due to the time constraint placed by the deadlines of this thesis, only three out of nine guidelines were chosen for testing. In addition, recruiting large sample of participants in short time appeared challenging, therefore the test was designed to be within-group. The choice of guidelines was based on the severity of problems that they were supposed to solve, and also on the fact that the majority of users clearly expressed their frustration when they faced these problems. The following hypotheses were proposed:

Hypothesis 1 - based on Guideline # 3**:** Maximized feature info design will perform better than minimized window when serving user rich content:

Sub-hypothesis a: Long text

Sub-hypothesis b: Forms

Hypothesis 2 - based on Guideline #4**:** Visible control to close feature info window will perform better than invisible.

Hypothesis 3 - based on Guideline # 8**:** The presence of visual feedback will allow establishing and maintaining the mental connection between the selected feature and its feature info window.

The effect that guidelines produce was assessed through performance and perception measures: task completion time and rate, and SUS score.

Participants. Twenty participants (aged 20-30, 10 males and 10 females, 10 with GIS background) were recruited to take part in the usability test. Participants had to have knowledge and experience of using mobile tourist applications. The study was approved by the Ethics Committee of the Institute for Geoinformatics, University of Münster. Recruiting participants and carrying out the test took two weeks.

Apparatus and Material. Selected guidelines were applied to redesign feature infos of two applications: the con terra app and Google Maps. The former was chosen because it was the source of usability problems that provided the basis for the guidelines under study. Whereas the latter was chosen because of its popularity [56], [57]. Having used it on a daily basis, users acquired a certain behavior where they became accustomed to certain controls and layouts. It was of interest to observe how users' behavior would change after induced interface changes. The total of twelve prototypes (Table 6) were created to test the hypotheses.

Table 6. The overview of conditions placed to produce prototypes

Prototype #	App	Stimuli
		Hypothesis 1a
1.	con terra app	Small feature info
2.	con terra app	Fullscreen feature info
		Hypothesis 1b
3.	Google Maps app	Small feature info
4.	Google Maps app	Fullscreen feature info
		Hypothesis 2
5.	con terra app	Visible control to close small feature info ("X" button)
6.	con terra app	Invisible control to close small feature info (tapping outside feature info)
7.	Google Maps app	Visible control to close fullscreen feature info ("Back to the map" button)
8.	Google Maps app	Invisible control to close fullscreen feature info (use Android's Back button)
		Hypothesis 3
9.	con terra app	Presence of visual feedback for small feature info
10.	con terra app	Absence of visual feedback for small feature info
11.	Google Maps app	Presence of visual feedback for fullscreen feature info
12.	Google Maps app	Absence of visual feedback for fullscreen feature info

The prototypes were designed in Balsamiq Mockups[9] v.3.5.15. Static prototypes exported in PNG-format were transferred to a Samsung Galaxy S8 mobile device and uploaded into POP 2.0 - Prototyping on Paper[10] app to create interactive prototypes by linking images with one another. Examples of prototypes are shown in Figure 13.

Twelve tasks typical for tourist map applications (e.g. finding phone number, ordering cinema tickets, browsing restaurants) were created for the test (Appendix E). All tasks were designed to be independent from one another.

Observed data were recorded by the facilitator (the author of this thesis). Task completion time was tracked using a simple stopwatch from the moment user started interacting with the prototype until reaching a predefined goal. Completion was recorded using binary digits: 1 - for success and 0 - for failure. Although SUS is a post-study questionnaire, in this usability test, it was used to measure perceived usability after each task. The reason for this, was that technically each prototype represented a different [feature info] system. Original SUS questions were modified by substituting “system” for “feature info” (Table 7). According to Lewis and Sauro [58], such substitution does not affect the resulting scores.

Google Forms[11] were used to collect and organize SUS data. Later, the scores were calculated using the spreadsheet [51]. A pilot test was conducted with one participant, after which some tasks were modified for clarity.

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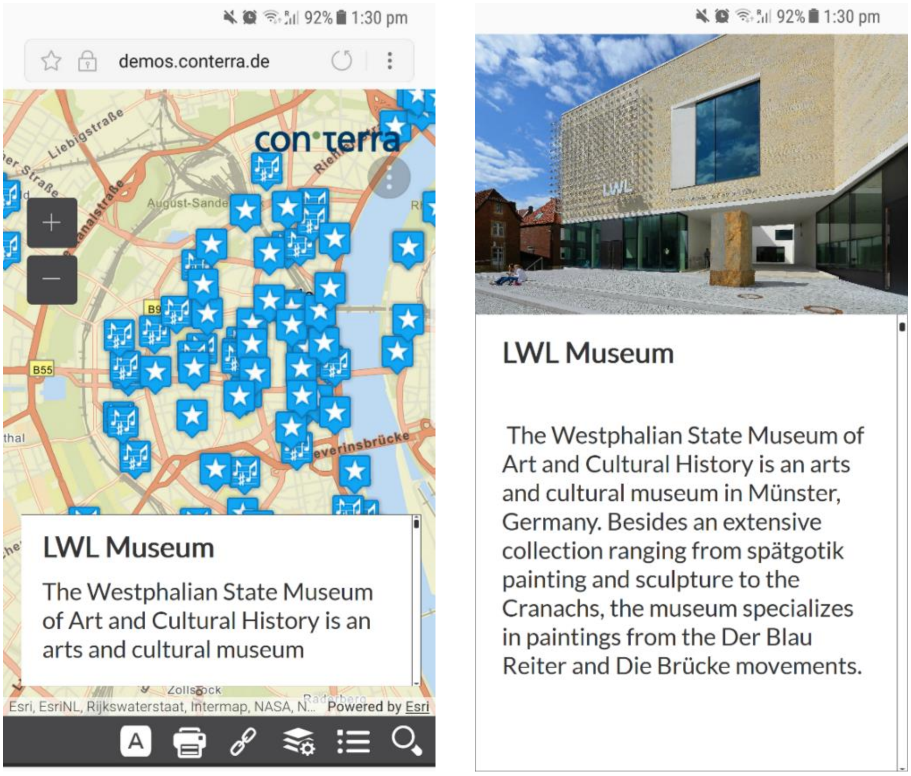
[9] https://balsamiq.com/
[10] https://marvelapp.com/pop/
[11] https://www.google.com/forms/about/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LWL Museum
The Westphalian State Museum of Art and Cultural History is an arts and cultural museum
Esri, EsriNL, Rijkswaterstaat, Intermap, NASA, N...
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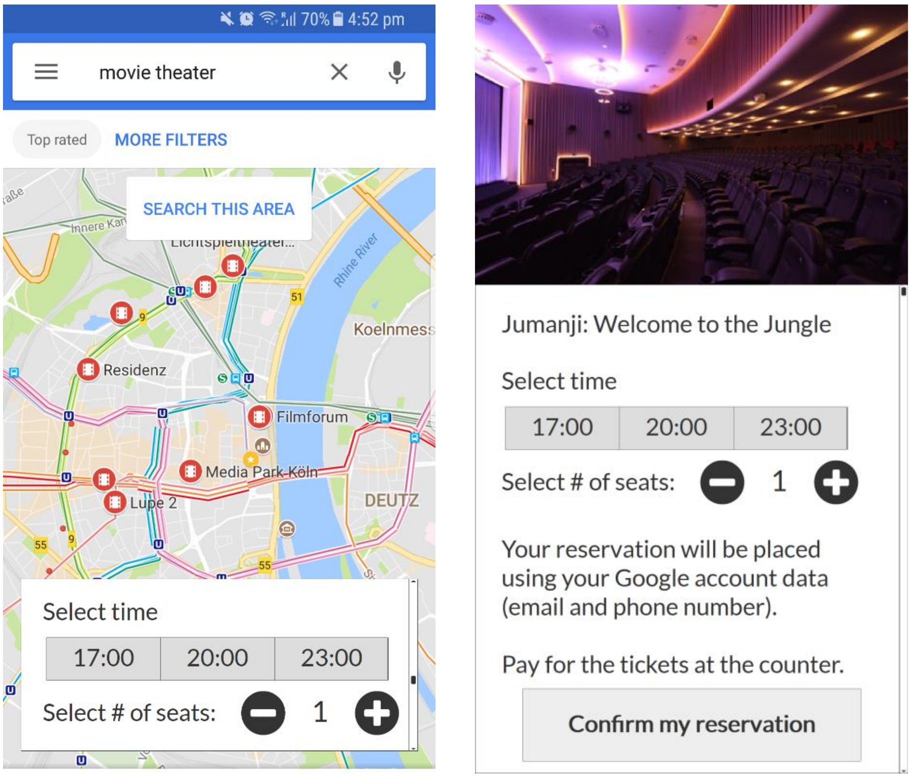
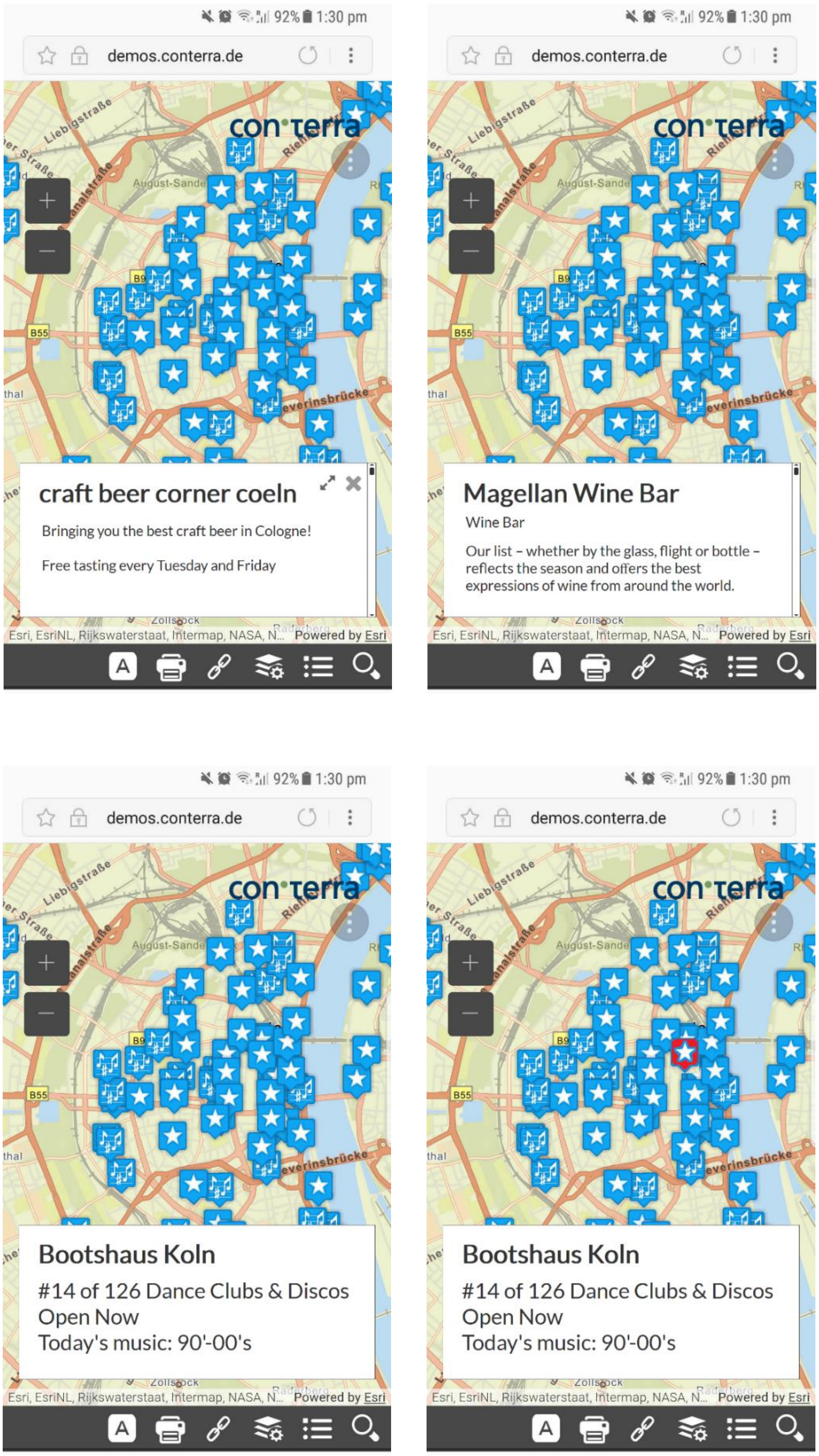
LWL Museum
The Westphalian State Museum of Art and Cultural History is an arts and cultural museum in Münster, Germany. Besides an extensive collection ranging from spätgotik painting and sculpture to the Cranachs, the museum specializes in paintings from the Der Blau Reiter and Die Brücke movements.

(A)


70% 4:52 pm
movie theater
Top rated
MORE FILTERS
SEARCH THIS AREA
Residenz
Filmforum
Media Park Köln
Lupe 2
Koelnmess
DEUTZ
Rhine River
Select time
17:00
20:00
23:00
Select # of seats:
1
Jumanji: Welcome to the Jungle
Select time
17:00
20:00
23:00
Select # of seats:
1
Your reservation will be placed using your Google account data (email and phone number).
Pay for the tickets at the counter.
Confirm my reservation

(B)



(C)

(D)

Figure 13. Examples of prototyped feature info interfaces (A, Prototypes # 1 and 2. B, Prototypes # 3 and 4. C, Prototypes # 5 and 6, D. Prototypes # 9 and 10).

Table 7. The SUS version used in the usability test

		Strongly disagree 1	2	3	4	Strongly agree 5
1.	I think that I would like to use this feature info.					
2.	I found the feature info unnecessarily complex.					
3.	I thought the feature info was easy to use.					
4.	I think that I would need the support of a technical person to be able to use this feature info.					
5.	I found the various functions in the feature info were well integrated.					
6.	I thought there was too much inconsistency in this feature info.					
7.	I would imagine that most people would learn to use this feature info very quickly.					
8.	I found the feature info very cumbersome to use.					
9.	I felt very confident using the feature info.					
10.	I needed to learn a lot of things before I could get going with this feature info.					

Procedure. Participants were invited to participate in the test individually. The test was conducted in a lab-based setting with one facilitator. Prior to starting the test, an informed consent was collected from each participant. Following the explanation of the test procedure, users were presented a practice prototype to get acquainted with the test. Once they were ready to start, printed tasks were randomly mixed and users drew one task at a time. After completing the task, users shared their experience by filling out the SUS questionnaire. The executed task was then removed from the pool to avoid having some tasks not performed. Before each experiment, all tasks were put back together and shuffled to randomize their order and avoid learning effect. Average test duration was 35 minutes.

Data analysis. Raw performance and perception data were reported using box plots. Shapiro-Wilk Normality Test was performed to verify if collected data was normally distributed ($p < 0.05$). Non-parametric Wilcoxon Signed-rank test was performed to identify the effects of guidelines on task completion time and SUS scores. This test was chosen because the general assumptions for parametric tests were not met: some populations were not distributed normally and some were measured through ordinal variables (SUS scores were based on Likert-type scale). Since task completion data was categorical (1 or 0), McNemar's test, a paired version of Chi-square test, was applied to determine how guidelines affect completion rate. Spearman correlation test was performed to identify the effect of GIS background on participant's performance and perception. Data analysis was performed in R Studio Version 1.0.143. For Wilcoxon test, an additional package 'coin' [59] was installed to address the problem of calculating the exact p-values because of ties.

7. RESULTS AND DISCUSSION

Prototypes 1 and 2. Fullscreen feature info demonstrated higher usability when users had to work with long text. On average, applying the guideline reduced task completion time by 15% and increased SUS score by 20% (Figure 14). Task completion rate also decreased by 5% only because 1 out of 20 participants failed to complete Task 2. The reason for failing was that the participant misunderstood the task. The guideline # 3 was found to have insignificant effect on task completion time ($W = 143$, $Z = 1.42$, $p > 0.1$, $r = 0.22$), but significant effect on task completion rate ($\chi^2(1, N = 40) = 17.05$, $p < 0.001$) and SUS score ($W = 14.5$, $Z = -2.82$, $p < 0.005$, $r = 0.45$). Obtained results supported Hypothesis 1a.

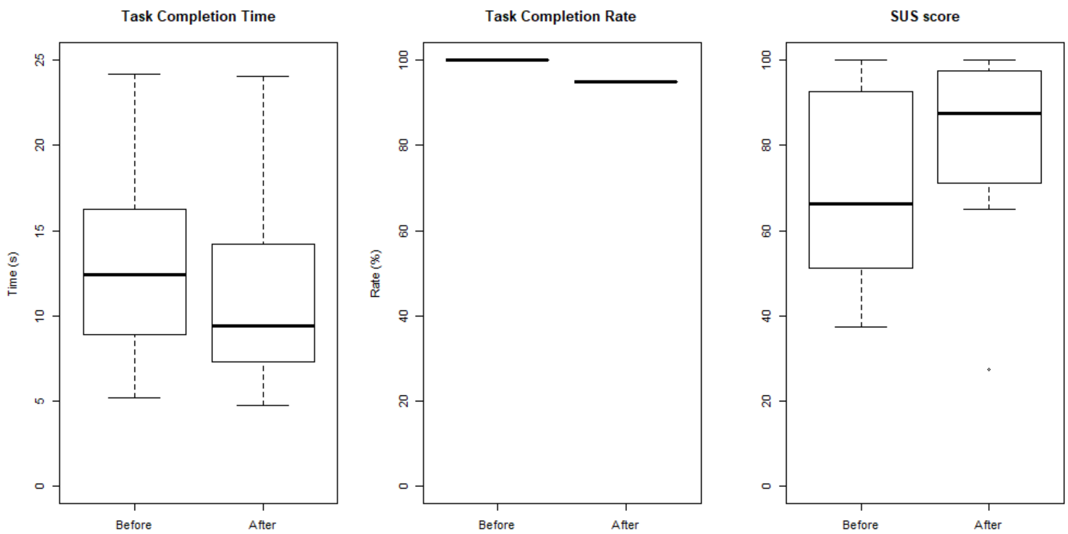


Figure 14. Task completion time and rate, and SUS scores for Prototype 1 (before) and Prototype 2 (after) applying the guideline # 3.

Prototypes 3 and 4. Fullscreen feature info demonstrated higher usability also when users had to work with a form. On average, applying the guideline reduced task completion time by 32%, and increased task completion rate and SUS score by 10 and 38% respectively (Figure 15). The guideline # 3 was found to have significant effect on all three: task completion time ($W = 195$, $Z = 3.35$, $p < 0.001$, $r = 0.53$), task completion rate ($\chi^2(1, N = 40) = 13.14$, $p < 0.001$), and SUS score ($W = 6$, $Z = -3.64$, $p < 0.001$, $r = 0.58$). Obtained results supported Hypothesis 1b.

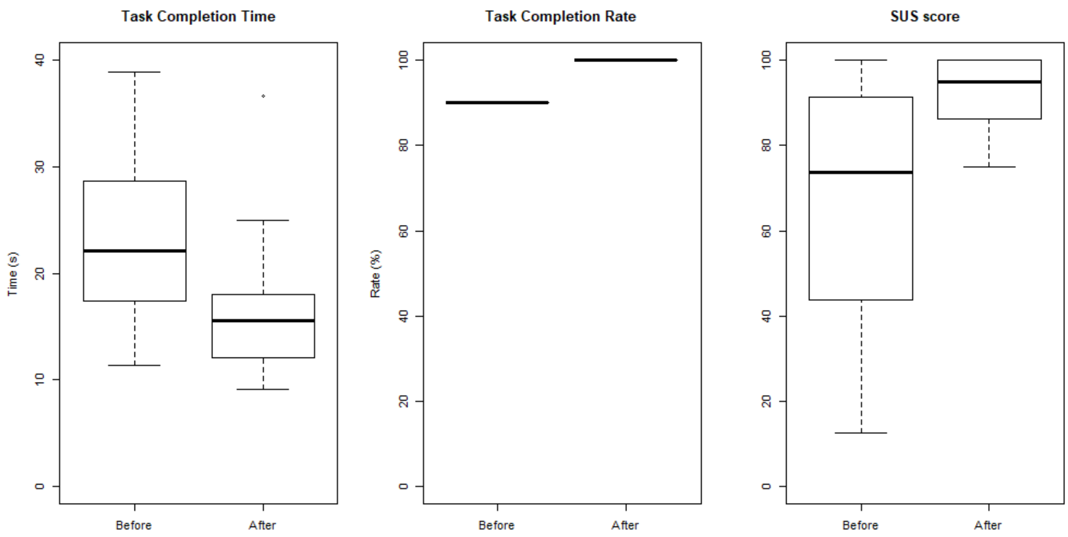


Figure 15. Task completion time and rate, and SUS scores for Prototype 3 (before) and Prototype 4 (after) applying the guideline # 3.

Prototypes 5 and 6. Tapping outside small feature info to close it appeared to be challenging for users in comparison to using visible “X” button. On average, applying the guideline reduced task completion time by 42%, and increased task completion rate and SUS score by 45 and 22% respectively (Figure 16). The guideline # 4 was found to have significant effect on all three: task completion time (W = 196, Z = 3.40, $p < 0.001$, r = 0.54), task completion rate ($\chi^2(1, N = 40) = 9.09$, $p < 0.005$), and SUS score (W = 26.5, Z = -2.58, p = 0.01, r = 0.41).

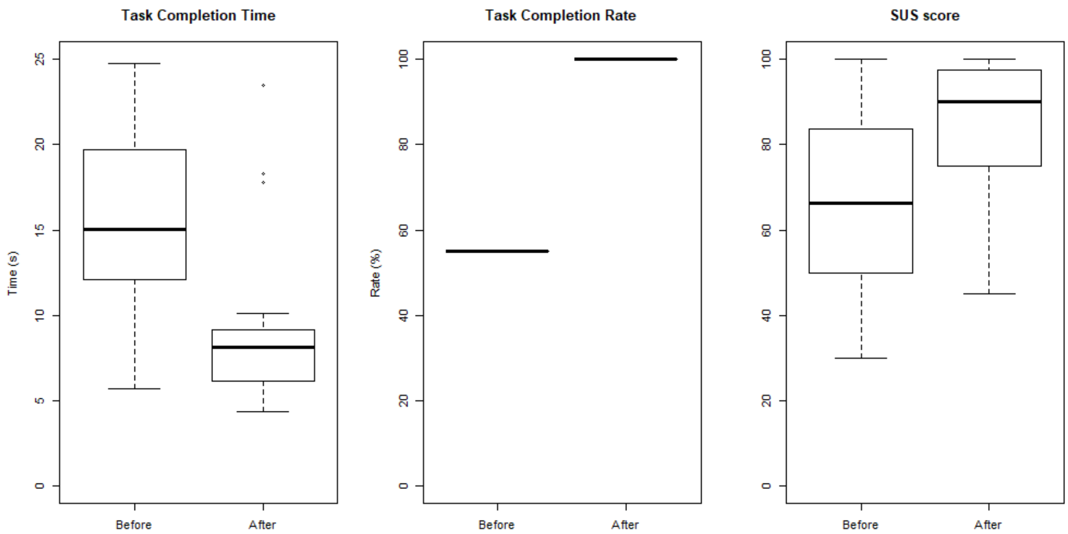


Figure 16. Task completion time and rate, and SUS scores for Prototype 6 (before) and Prototype 5 (after) applying the guideline # 4.

Prototypes 7 and 8. It was natural for users to close feature info using Android system's "Back" button. Thus, introducing "Back to the map" button WITHIN fullscreen feature info yielded smaller effect than described in the previous paragraph. On average, applying the guideline reduced task completion time by 31%, and increased task completion rate and SUS score by 5% and 13% respectively (Figure 17). The guideline # 4 was found to have significant effect on task completion time (W = 180, Z = 2.8, $p < 0.005$, r = 0.44), task completion rate ($\chi^2(1, N = 40) = 12.19$, $p < 0.001$), and SUS score (W = 36.5, Z = -2.13, $p < 0.05$, r = 0.38).

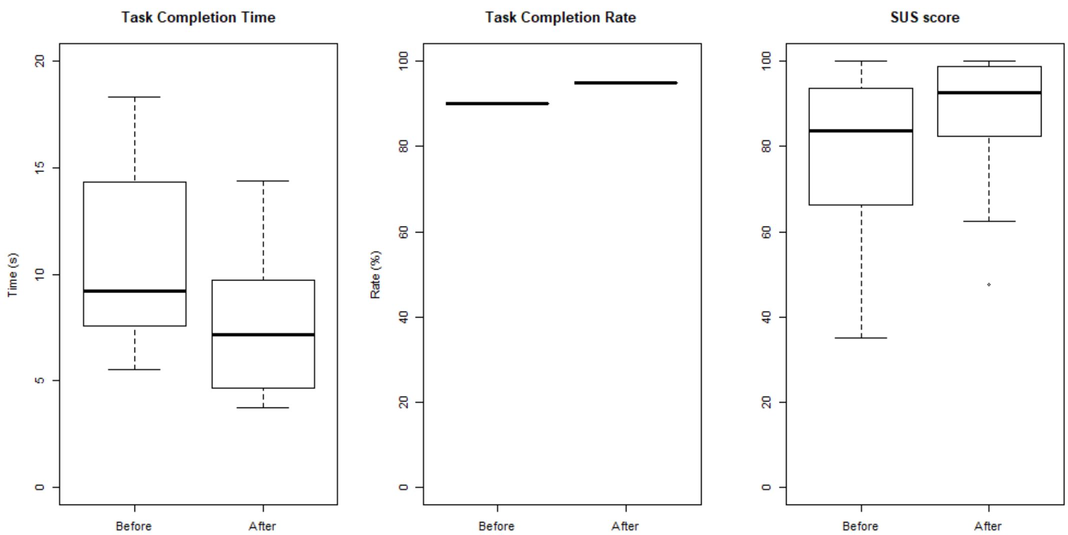


Figure 17. Task completion time and rate, and SUS scores for Prototype 8 (before) and Prototype 7 (after) applying the guideline # 4.

Overall, results obtained from testing Prototypes 5, 6, 7, and 8 supported Hypothesis 2.

Prototypes 9 and 10. Because feature info was small and users could see the map, it was very easy to point out the highlighted map feature after it was selected. On average, applying the guideline reduced task completion time by 48%, and increased task completion rate and SUS score by 65% and 57% respectively (Figure 18). The guideline # 8 was found to have significant effect both on task completion time (W = 210, Z = 3.91, $p < 0.001$, r = 0.62) and SUS score (W = 0, Z = -3.86, $p < 0.001$, r = 0.61). It was also found to have insignificant effect on task completion rate ($\chi^2(1, N = 40) = 1.09$, $p > 0.05$).

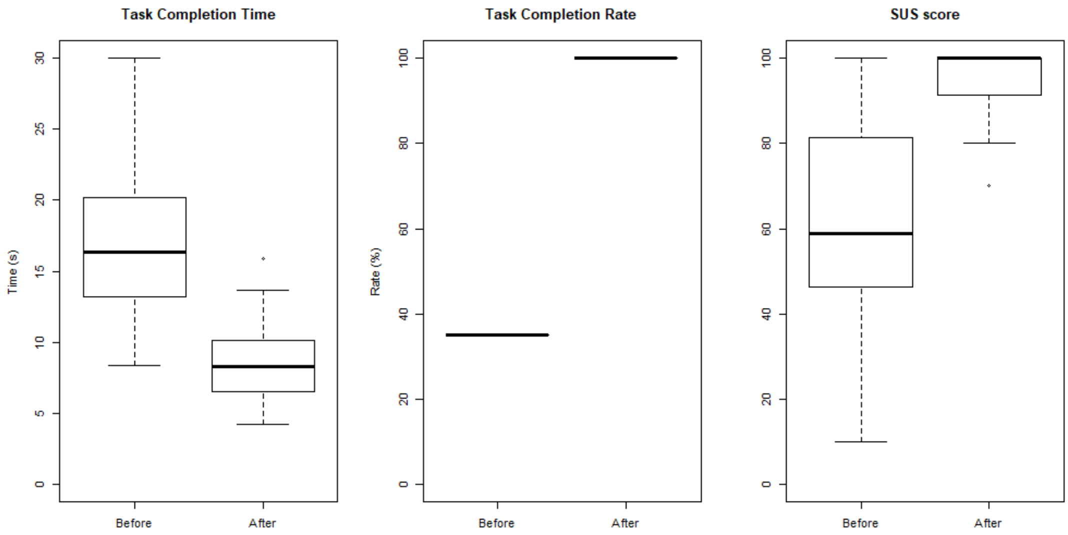


Figure 18. Task completion time and rate, and SUS scores for Prototype 9 (before) and Prototype 10 (after) applying the guideline #8.

Prototypes 11 and 12. Because feature info was fullscreen and needed to be closed before returning to map view, it was more challenging to point out the map feature that was selected. Sometimes it led to confusion because the feature info window was already closed, but the marker was still highlighted. One user commented: *"I'd prefer seeing the marker highlighted before the [fullscreen] feature info window comes up. Maybe highlight the marker first, and then after a short delay make the [fullscreen] feature info window appear"*. On average, applying the guideline allowed reduced task completion time by 27%, and increased task completion rate and SUS score by 25% and 16% respectively (Figure 19). The guideline # 8 was found to have significant effect on task completion time (W = 170, Z = 2.43, p = 0.01, r = 0.38), task completion rate ($\chi^2(1, N = 40) = 5.76$, $p < 0.05$), and SUS score (W = 26, Z = -2.40, $p < 0.05$, r = 0.38). Another critical comment was: "*Changing only the color of the selected marker may not be obvious [because of lack of contrast]. Changing color and making it bigger would be much better"*.

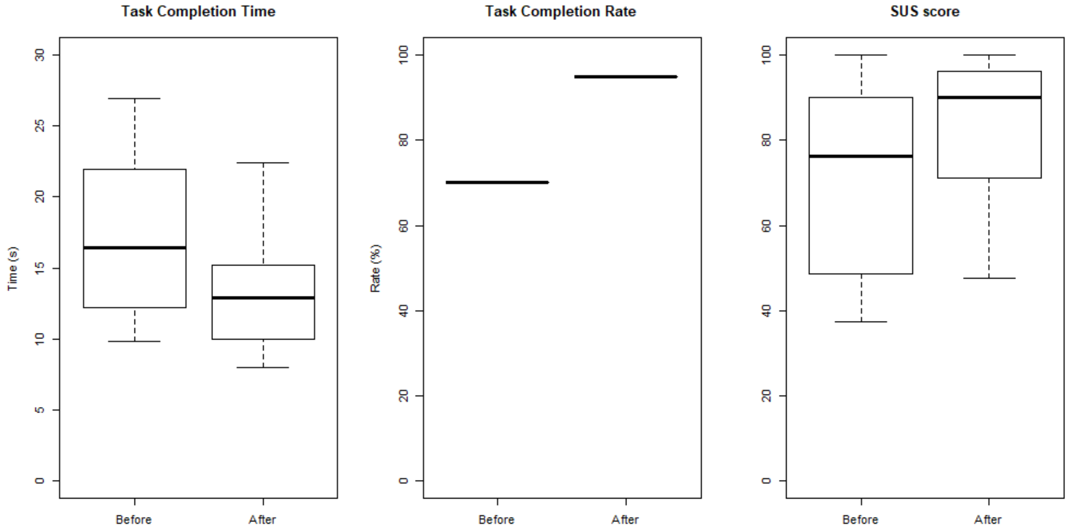


Figure 19. Task completion time and rate, and SUS scores for Prototype 11 (before) and Prototype 12 (after) applying the guideline #8.

Overall, results obtained from testing Prototypes 9, 10, 11, and 12 supported Hypothesis 3.

The correlation between GIS experience and users' performance and perception was identified as weak (all r's ≤ ±0.5). The functionality of the prototypes was limited since they were only used as proof of concept. Fidelity may have affected users' perception and led to high standard deviation of SUS scores. The chosen prototyping software (POP 2.0 - Prototyping on Paper app) may have affected users' performance as it did not support scrolling and users had to tap when they wanted to scroll. Nevertheless, users succeeded in completing the tasks and excluded this shortcoming from consideration when evaluating the prototypes.

Summarising usability test results, all three guidelines (#3, #4, and #8) appeared capable of improving the visualization and usability of feature info interfaces. Several implications for designing feature infos were drawn. First, maximized (or fullscreen) window size is recommended for displaying long text and forms. Second, the salience of the control (or button) to close feature info is an important factor in its interface design. Third, strong visual feedback proved to be helpful in establishing a mental connection between a selected map feature and its open feature info window. Although the application of guidelines in this usability test demonstrated significant positive effect on user performance and perception, it is worth reminding that the test was conducted in a lab-based environment. There is a possible risk that unobserved normal performance could yield different results as suggested by Lazar, Feng, and Hochheiser [42]. Another limitation comes from participants' demographic characteristics, i.e. all of them were university students of the same age group. The results of the evaluation might have been different if other user groups took part in the usability test.

Regardless of what type of control to open/close feature info is chosen; it would be useful to demonstrate it and other core functionalities to user during onboarding. Since feature info discoverability was noted as one of the biggest usability problems, we suggest that further research prioritizes finding ways of introducing the tool to users. Future work consists of concept testing the rest of the proposed guidelines. Although the usability test was conducted using tourist applications, it is also possible to apply established feature info guidelines to mobile apps of other domains.

All results of this thesis are summarized in Table 8. Answers provided to both of the research questions are an important contribution to the literature for two reasons. First, because they facilitate closing the existing "interaction design" gap in feature info design literature. Second, because they are intended for improving the

Table 8. Results obtained in this thesis linked to the research questions

Research question	# 1: What usability problems occur when users interact with feature info in mobile tourist applications?	#2: How solutions addressing these problems can be generalized into usability guidelines for feature info design?
Main result	34 usability problems related mostly to interaction technique, placement, layout	9 design guidelines with 7 of them focusing on interaction design

usability of mobile maps and taking full advantage of the mobile technology considering its limitations. These reasons were the motivation for this master thesis, seen in Section 1.3. Although some ideas presented explicitly help the con terra app (i.e. results of the participatory design), it is feasible to apply them to any other mobile map application provided its feature info faces similar challenges and appropriate adjustments are considered.

8. CONCLUSION

This thesis was dedicated to improving the usability of feature info interfaces in mobile tourist map applications. Dimensions that affect feature info usability were established. Existing general recommendations for feature info design from academic and industry sources were consolidated.

The main contribution was nine feature info design guidelines that were produced to tackle specific usability problems. The guidelines mostly focused on interaction design of feature infos, an area that received little attention from research community. In addition, the guidelines were tailored specifically for mobile devices considering their technical particularities. The usability problems were detected during heuristic evaluation of five systematically selected mobile tourist applications. In addition, a user interview was conducted, where one of those five applications was further scrutinized. Because certain problems lacked obvious solutions, two usability experts were asked to share their experience of feature info development for mobile map-based applications. Their responses, existing solutions in evaluated applications, and supporting academic literature provided the basis for the guidelines.

Three out of nine guidelines were selected for concept testing and initial evidence of their potential to solve usability problems was obtained. The concepts produced a significant positive effect on feature info usability, i.e. reduced time necessary to complete predefined tasks, increased chances of completing tasks successfully, and were generally well received by the participants. The remaining six guidelines should also undergo testing prior to being implemented in map products. Although the guidelines were derived from and tested on tourist applications, they could be applied to any other domain, provided they match design goals established by mobile map developers. Once applied, an additional study could be carried out to collect feature info usability data from a real-world session where users will interact with a mobile map application unobserved (e.g. A/B testing). Another area for future research could be feature info interfaces in mobile 3D maps.

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APPENDIX

A. List of usability problems detected during heuristic evaluation

	Con terra app	Mobile Google Maps website	TripAdvisor	Google Maps	Foursquare
Visibility of system status.	Text can’t be seen fully, because feature name takes up the majority of space (Severity: 4)				
Match between system and the real world.	Ambiguous attribute names (Severity: 4)		Use of terminology (e.g. "GreenLeader Bronze") without provided explanation (Severity: 2)		
User control and freedom.	“Close” button is too small and touch unfriendly (Severity: 3)		When accidentally pressing the "Review" button, there is no way to discard a review, only submit (Severity: 2)	When trying to continue reading “About” section, the app takes you to “Describe this place” window (Severity: 4)	
	"Maximized" windows covers the map and offers less space to view feature info than the "minimized" one (Severity: 3)				
	Tiny scrolling area in feature info allows user to view only one line of text at a time (Severity: 4)				
	When feature info window is maximized, it’s impossible to scroll down because the header takes up all available space (Severity: 4)				

Consistency and standards.	Mix of German and English words (Severity: 4)		“Nearest” station is not available for all landmarks. Only for those around Cologne Central station (Severity: 3)		
	Feature Info is not available for all POIs (no feedback upon touch) (Severity: 4)				
	Misspelling (Severity: 3)				
	Missing spaces or dashes between words (Severity: 3)				
Error prevention.					Directions button does not work at all (Severity: 4)
Recognition rather than recall.	When selecting a feature, it is impossible to distinguish between the selected and the rest of the features. User has to remember what feature was selected when going from feature info dialogue back to the map (Severity: 4)				
Flexibility and efficiency of use.	Context is ambiguous: some polygons have an "% of the total area" field - is total area the precinct or city? (Severity: 3)		It is possible to get lost within "About" map view (you are presented with a map and a minimized feature info, once feature info is clicked, you return into the same position you were previously at. But to return to the general map with all features on it, the user will have to click the “back” button three times (Severity: 3)		

	The menu in the bottom right corner of feature info is somewhat hidden. It’s not clear what "1 of 3" means: pages / features? (Severity: 3)		Same problem (as described above) with the "Address" field (Severity: 3)		
Aesthetic and minimalist design.	Very little information presented (Severity: 3)		“Nearest” station – you expect to see one station, but instead you have a “forward” button that shows you a list comprised of only one station in a strange way (Severity: 3)	When in the “Photos” tab, "Videos" are among one of the subtabs. Confusing name. (Severity: 2)	
	Heading has very large margins – wasted space (Severity: 4)		Different visual design of feature info for every operational layer (Severity: 0)	Slightly different design of feature info for different operational layers (Severity: 0)	
	Feature name is broken into multiple lines because doesn’t fit the text box size (Severity: 4)				
Help users recognize, diagnose, and recover from errors	Missing information in some fields and no indication that it is missing/when it will be added (Severity: 4)	When no feature info for a POI is available, a feature info for a previously viewed POI is shown (Severity: 4)	Missing information about some POIs (no About field) (Severity: 2)		
Help and documentation.					
Total number of errors found	**17**	**1**	**8**	**3**	**1**
Major or catastrophic problems:	**16**	**1**	**4**	**1**	**1**

B. Level of detail and actions offered in feature info in evaluated mobile applications

	Google Maps	**Mobile version of Google Maps website**	**TripAdvisor**	**Foursquare**	**con terra app**
Level of detail					
Address	Yes	Yes	Yes	Yes	Yes
Open hours		Yes	Yes	Yes	
Type	Yes	Yes	Yes	Yes	Yes
Photos	Yes	Yes	Yes	Yes	
Videos	Yes	Yes			
Review highlights	Yes	Yes	Yes	Yes	
Review summary	Yes	Yes	Yes	Yes	
Reviews	Yes	Yes	Yes	Yes	
Rank	Yes	Yes	Yes	Yes	
Rating categories			Yes	Yes	
Popular times	Yes			Yes	
Phone	Yes	Yes	Yes	Yes	
Email			Yes		
Website	Yes	Yes	Yes	Yes	Yes
Social media				Yes	
Similar place suggestions	Yes		Yes	Yes	
Nearest station			Yes		
About	Yes	Yes	Yes		
Suggested duration	Yes		Yes		
Questions and answers	Yes		Yes		
Recently viewed			Yes		
Accessibility	Yes				
Amenities	Yes				
Crowd	Yes				
Integration with other websites	Yes		Yes		
Upcoming events	Yes				

Features within the currently viewed				Yes	
Actions					
Directions	Yes	Yes	Yes	Yes	
Call	Yes	Yes	Yes	Yes	
Leave a review	Yes		Yes	Yes	
Add more information	Yes		Yes	Yes	
Add to a list	Yes	Yes	Yes	Yes	
Check in				Yes	
Rate	Yes		Yes	Yes	
Add photo	Yes		Yes	Yes	
Filter photos	Yes	Yes		Yes	
Sort photos				Yes	
Upvote photo			Yes		
Add tag to photo				Yes	
Search reviews			Yes		
Translate reviews			Yes	Yes	
Filter reviews			Yes	Yes	
Sort reviews				Yes	
Share reviews	Yes				
Upvote reviews	Yes	Yes	Yes	Yes	
Make reservations			Yes		
Ask question	Yes		Yes		
Answer question	Yes		Yes		
Upvote question	Yes		Yes		
Share	Yes		Yes		
Save to favorites	Yes				
Total	**35**	**17**	**36**	**30**	**3**

C. User questionnaire

Please answer the questions below in the corresponding answer boxes.

1. Feature Info is a dialogue window that displays background information about any selected POI. How can feature info help when retrieving additional background information about single geographic entities?

2. List any issues that you encountered while working with the feature info window.

3. How did you like the design of the feature info window interface?

4. How did you like that the background information was presented as a table?

5. How would you describe your experience using the feature info window interface? What aspects appealed to you the most and the least?

6. Why do you think feature info windows should have maximized and minimized options?

7. How often did you need the map in this application?

8. What will you choose: viewing all markers on the map or having a list of objects sorted based on proximity to you? Please explain your choice.

9. What information was missing in the feature info windows you browsed?

10. How does the app provide context for the information presented in the feature info window?

11. Why would you want to view background information in an interactive way? E.g. as infographics. Feel free to list your own examples.

12. When was the last time the background information was updated?

D. Expert questionnaire

Please answer the questions below in the corresponding answer boxes.

1. When designing mobile map-based apps, do you implement user-centered design approach? How?

2. When designing mobile map apps for your clients, do you create custom feature info windows based on their needs? Are they custom only in content presented or also in visual design?

Part 1: Visual design

3. What kind of issues do you face when designing a feature info for mobile apps? E.g. screen real estate in mobile devices

4. Do you think users should be given freedom to customize the look and/or content of the feature info window? Why?

5. Have you faced situations when map is better and when feature list is better?

6. How do you judge the optimal settings for the following design elements of the feature info for mobile devices (smartphones):
    a. Shape
    b. Shape dimensions (size or percentage of the map covered)
    c. Position (top, bottom, next to the selected feature)?

7. Is it always necessary to have a full-screen (maximized) mode for the feature info?

8. How do you emphasize the feature info to attract users' attention?

Part 2: Content

You may answer the questions below in relation to your most recent project that involved the design of feature info.

9. How do you identify minimum necessary background information to be displayed in the feature info window?

10. How much functionality should feature info window have?

11. What content types other than text, hyperlinks, and image files do you incorporate into feature info?

12. Do you think textual information should be presented in the form of table (see example below) or narrative? Please explain your opinion.
    e.g. City: Moscow
    Population: 10 million

13. Why do you think providing context in the feature info is important? (e.g. min and max values, time reference – "closed now", distance to the POI from user's current location).

14. Is there any specific hierarchy in which content should be presented?

Part 3: Usability

15. Have you ever conducted any usability studies for feature info window interface in mobile map-based applications? Please describe most common problems / insights of these studies.

16. What issues can users encounter when they are trying to view background information in mobile map-based applications?

E. Tasks designed for prototype usability test

Prototype	Task description
1.	You want to call the LWL museum to ask about current exhibition. Please use the app to find the telephone number of LWL museum.
2.	You are thinking about visiting the LWL museum but would like to check it’s rating first. Please use the app to find the review score.
3.	You and your friend want to go to Cineplex movie theater and watch Jumanji: Welcome to the Jungle at 17:00. Please use the app to reserve tickets.
4.	You and your friends want to go to Cineplex movie theater and watch Jumanji: Welcome to the Jungle at 23:00. Please use the app to reserve tickets.
5.	You want to go to a wine bar. There’s only one bar open right now. Is it a wine bar? If not, close the window.
6.	You want to go out for beers. There’s only one bar open right now. Do they serve craft beer? If not, close the window.
7.	You want to have dinner at a Korean restaurant. There’s only one restaurant open right now. Do they serve Korean cuisine? If not, close the window.
8.	You want to have dinner at a Russian restaurant. There’s only one restaurant open right now. Do they serve Russian cuisine? If not, close the window.
9.	You want to go to a night club. Pick one of the clubs on the map and check it out. After you done, please look back at the map. Can you point to the exact club that you picked?
10.	You want to go to a night club. Pick one of the clubs on the map and check it out. After you done, please look back at the map. Can you point to the exact club that you picked?
11.	You are located at Komodienstrasse. Browse souvenir shops and pick one that is located on the same street. After that please return back to the map. Can you point to the exact shop that you picked?
12.	You are located at AlterMarkt. Browse souvenir shops and pick one that is located on the same street. After that please return back to the map. Can you point to the exact shop that you picked?

F. Declaration of Academic Integrity

I hereby confirm that this thesis on "Feature Info – Improving the visualization and usability of GIS background information in the context of a mobile tourist application" is solely my own work and that I have used no sources or aids other than the ones stated.

All passages in my thesis for which other sources, including electronic media, have been used, be it direct quotes or content references, have been acknowledged as such and the sources cited.

13.02.2018,

G.Litvinova

(date and signature of student)

I agree to have my thesis checked in order to rule out potential similarities with other works and to have my thesis stored in a database for this purpose.

13.02.2018,

G.Litvinova

(date and signature of student)