Interactive faceted search and exploration of open social media data on a touchscreen mobile phone

Alexander Kleinen · Ansgar Scherp · Steffen Staab

Abstract A central challenge of semantic ambient media applications is designing smart user interfaces that are able to dynamically deal with an a-priori unknown number of data categories and data instances received live from different Linked Open Data sources while at the same time being intuitive and easy to use. In the mobile world, this challenge is even more difficult as the mobile devices have limited interaction possibilities and smaller display size. In this paper, we tackle this challenge and present the user-centered, iterative design of a mobile application for faceted search and exploration of a large, multi-dimensional data set of open social media on a touchscreen mobile phone. The application is called Mobile Facets and provides live retrieval and interactive search and exploration of resources like places, persons, organizations, and events originating from different, integrated social media sources like DBpedia, Eventful, Upcoming, Flickr, and GeoNames. In contrast to existing work, we do not know in advance the number and type of data categories and data instances that will be received as the data is queried live from the sources. While developing Mobile Facets, we have applied a participatory design with a small group of five users. For the final prototype we have conducted a task-based, formative evaluation with 12 additional subjects to investigate the applicability and usability of our Mobile Facets application.

Keywords Mobile computing · Faceted search and exploration · Social media

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1 Introduction

Mobile users often explore several, distributed and independent open social media data sources to satisfy their mobile information needs when being on a business trip, during vacation, or going out with friends. For example, one may want to retrieve information about a city and its sights from Wikipedia (http://www.wikipedia.org/), see photos related to the sights on Flickr (http://www.flickr.com/), and explore events happening in the city from event directories like Upcoming (http://www.upcoming.org/) and Eventful (http://www.eventful.org/). These data sources are considered open as they offer besides a web-based end user interface also access by some publicly available application programming interface. For example, Wikipedia is provided as Linked Open Data by DBpedia [2]. Linked Open Data [10] also known as Web of Data is a movement started in 2007 to make datasets publicly available and to connect these datasets using the Resource Description Format (RDF) (http://www.w3.org/TR/REC-rdf-syntax/) RDF bases on the same principles as the document web and uses URIs to identify things and relate things to each other. The data hosted by DBpedia can be accessed through a SPARQL endpoint (http://www.w3.org/TR/rdf-sparql-query/). Other data sources like Flickr and Upcoming are integrated and can be accessed using REST calls.

In order to explore large, semantic information spaces [16] like the social media dataset sketched above, the paradigm of faceted search and exploration has been developed in the past [8, 9, 11, 19, 27]. In fact, faceted search and exploration is an established interaction paradigm on desktop computers and has been well studied in the last decades. Using facets, one iteratively cuts a multi-dimensional data space along the different categories, i.e., the different dimensions, it contains in order to reduce its complexity and the number of items to be retrieved [15]. Thus, facets act as filters by returning only those items that are conform with the selected facet(s). This is conducted by applying one or more facets on the information space, filtering out results that are not relevant and showing only those results to the users he or she is interested in. Examples of web applications that make use of facets are, e.g., the shopping platforms Amazon (http://www.amazon.com/) and Ebay (http://www.ebay.com/).

In the mobile world, we have to deal with additional problems in order to provide a mobile faceted search and exploration due to limited interaction possibilities and smaller display size. These limitations are opposed to the complexity and dynamics of the data categories and data instances retrieved from the open social media data sources. This requires an even smarter user interface and intuitive use of facets than on desktop computers. This is a problem, as providing an intuitive and easy to use mobile user interface for faceted search and exploration is hard. In the past, there have been different approaches developed for faceted search and exploration on mobile devices such as [13, 25]. As evaluation data, these systems use a predefined, closed data source only. This means that the data categories and the number of data instances are defined and known in advance. Another mobile application providing faceted search and exploration is the Mobile Cultural Heritage Guide [24]. This application is specifically designed for the cultural heritage domain and focuses on an augmented reality feature for exploring the cultural sights of Amsterdam. In the Web of Data, however, one cannot assume to know the characteristics of the used data source(s) in advance. Rather, the application has to be able to deal with an a-priori unknown number of data categories and data instances while at the same time

providing useful and intuitive to use functionality to the end users. Thus, investigating the development of smart user interfaces that are able to deal with an unknown number of data categories and data instances from the Web of Data and that are at the same time easy and intuitive to use is a central challenge to meet. This challenge is even more difficult in the mobile world due to limited interaction possibilities and smaller display size.

In this paper, we address the challenge of designing smart user interfaces for mobile, semantic ambient media applications [16] by describing the iterative, user-centered design of the Mobile Facets application. The Mobile Facets application allows for an interactive, faceted search and exploration of a large, distributed data set from different, integrated social media sources on a touchscreen mobile phone. It retrieves resources such as places, persons, organizations, and events live from an integration of DBpedia, Eventful, Upcoming, and geo-located Flickr photos and professional content from GeoNames (http://www.geonames.org/). Thus, the number of data categories and data instances is not known in advance and depend on the location at which the query has been executed. In order to cope with the dynamics of the resources retrieved live, the Mobile Facets application provides a flexible user interface for exploring hierarchically organized data categories. The principle idea is to start with a small number of predefined high-level facets and to fill them dynamically with the facets and resources retrieved. Which facets are actually received and filled with resources depends on the users' location when executing the query. For example, it may happen that event information is not available at some rural areas as the event directories only sparsely cover them. In addition, some facets are specific to certain locations, e.g., vineyards, mountains, rivers, and others exist only in some regions. Thus, one of the central design decisions regarding the user interface of the Mobile Facets application was how to best visualize the facets and resources retrieved and how to interactively explore the data space using facets.

In the subsequent section, we discuss the related work. In Section 3, we motivate the need for Mobile Facets by a concrete scenario. The scenario and related work have been used as input for the iterative, user-centered prototype design. It has been carried out with a small group of five users and is described in Section 4. The final prototype is presented in Section 5. A task-based evaluation of the Mobile Facets application with 12 new subjects is presented in Section 6, before we conclude the paper.

2 Related work

The term *facet* is used in different contexts and interpreted differently [17]. Nevertheless, there are common characteristics that can be found in the definitions such as that each facet has a name or at least a proper description and that a facet is referring to a category in order to describe an aspect of a multi-dimensional data space [8]. The facets act as orthogonal filters by returning only those items that are conform with the selected facet(s) [13]. Thus, in each iteration of a faceted search and exploration, the result list is refined by adding another facet. Facets can also be hierarchically organized [17]. For example, the facets Politician and Athlete are sub-facets of the facet Person. If a (child) facet appears in more than one parent facet and if the path from the parent facet to the child facet are disjoint, they are called poly-hierarchical facets [1]. The relationship between parent facets and children facets is of is-a. This

means that each child facet is a specialization of the parent facet. Root facets are those, which do not have further parent facets. They are called high-level facets. Facet categories that do not have further children categories are leave nodes and represent a set of instances. The high-level facets considered in this work are derived from the facets documented in the literature such as [8, 9, 11, 19, 27] and types of data found in the social media data sources, namely Places, Persons, Organizations, and Events.

The principle idea of faceted search and exploration is not new. It has been well studied for desktop computers, e.g., [8, 9, 19, 27] and is also extensively used in Semantic Web desktop applications like /facet [11] or Freebase Parallax (http://www. freebase.com/labs/parallax/). One of the most well-known applications for faceted search and exploration is Flamenco [27]. It allows its users to explore a multi-dimensional information space along a hierarchy of facets. From this and other work, one can derive the requirements for a faceted search and exploration of a multi-dimensional information space [9]. Among the most important requirements are a flexible navigation within the information space, i.e., users can freely decide how to navigate along the facets in the information space, avoiding empty results, and a seamless integration of a keyword-based search.

Regarding mobile faceted search and exploration, we find FaThumb [13], mSpace Mobile [25], and the Mobile Cultural Heritage Guide [24]. FaThumb is a keypad-driven application for mobile faceted search and exploration [13]. The search result is narrowed down iteratively as shown in Fig. 1 by using the number keypad of the

Fig. 1 Keypad-driven FaThumb [13] application

mobile phone. Due to the time when FaThumb has been developed, it does not provide a GPS-based map view or a rich media view, e.g., for showing pictures of the selected items. The application makes use of a single, closed data set, obtained from the Yellow Pages of the US state Washington.

With mSpace Mobile, we find a pen-based mobile application for faceted search and exploration of location-based information [25, 26]. It is designed for personal digital assistants running Microsoft Windows Mobile. The user interface is divided into tiles as shown in Fig. 2. Each tile shows one aspect of the information space such as a list of points of interests, a map, or metadata. The upper tiles serve as navigation within the available facets. By selecting them, the content of the lower tiles changes such as points of interests on the map and information about the selected facet. The mSpace Mobile application makes use of facets extracted from different data sources of the classical music domain and movie databases. The facets are stored in an own database.

The Mobile Cultural Heritage Guide [24] is a tourist guide application for Amsterdam providing an augmented reality view. Users can explore the artists that have lived and worked in the city and have a look at the places today from the perspective of the painters in former times. The application is specifically designed for the cultural heritage domain and does not provide a general interface for mobile faceted search and exploration. Thus, the Mobile Cultural Heritage Guide does not provide a flexible user interface to cope with, e.g., a dynamically filled list of sub-facets where the number of sub-facets is not known in advance or might contain many entries. As data set it uses general knowledge about geo-locations and points of interests as well as specific knowledge about the cultural heritage domain.

Aim of this work is the human-centered development of an user interface for faceted search and exploration in a large, multi-dimensional information space of

Fig. 2 Pen-based mSpace Mobile [25] application

social media data on a touchscreen mobile phone. Applying multiple facets returns a union of data instances from the different data categories selected by the facets. In contrast to FaThumb, mSpace Mobile, and the Mobile Cultural Heritage Guide, it is not known in advance what categories of data are received and how many data instances per category are provided for a given user context. This is because of the social media data sources being live queried instead of using a predefined, closed data set.

Another area of research related to Mobile Facets are cross-media systems and cross-media applications. The goal of cross-media systems is to provide combinations of and communication between interoperable media devices and media applications [3, 20]. Cross-media applications aim at exploring a dedicated information space. An example is the polar fitness system improving people's health and fitness by providing support for planning and conducting training activities [20]. A three-month field study was carried out with 12 users and complemented with interviews and structured diaries to investigate the applicability of the approach to support physical training. An ethnographic study was conducted by Trappeniers et al. [23] to investigate how users interact and make cross-media experiences at their homes and in their city. Questions were asked like how users explore and find new places in a city. The study was carried out based on a qualitative analysis of city-related publications, observing people at interesting places in the city, and conducting expert interviews with city representatives, local people, and commuters. Based on this, a cross-media prototype was developed that allows users to collect multimedia snippets of the city, take them home, and sharing them with their friends. In contrast, Mobile Facets aims at providing support for exploring the large social media data of a city on mobile devices while users are on the go. Tan et al. [22] presented an approach to synchronize and leverage different social media information by hyperlinking the media. Goal of this work is to allow users to author search results mined from various knowledge sources and enabling visualizations of the media. To this end, different techniques such as content mining for web-video, spatio-temporal orchestration of multiple media, and augmenting search results with information when and what something happened is created. However, this work does not aim at making the media information available for search and exploration on mobile devices. In addition, they do not aim at serving typical mobile users' information needs [21] such as searching for point of interests or getting answers to trivia questions. Finally, Soares et al. [3] conducted interviews to identify issues in cross-media applications with the focus to identify and make suggestions for improving the user experience. Central issues identified by Soares et al. are addressed by our work on Mobile Facets such as providing a more natural and easier interaction. In addition, we aim at clearly indicating the type of information the users are currently exploring when using the faceted navigation and other views such as map and list. We also take contextual constraints into account and are presenting in Mobile Facets only those categories and paths in the navigation hierarchy of the data space that are actually present in the user's current surroundings.

3 Scenario

Mobile information needs have been investigated by Sohn et al. in a two-week diary study [21]. Their study revealed 16 different broad categories. In this work, we are addressing two of the most frequent information needs, namely trivia questions and

searching for points of interests. Trivia questions happen, e.g., in user conversations or when a user is approaching some artifact like a billboard or a sight [21]. Examples are getting information about "How many inhabitants has San Francisco?" and "How high is the Daimler Chrysler building in New York?". Searching for points of interests is about finding interesting places. We extend this by event information related to places such as people's birthplace, concerts, or exhibitions. Examples are "What events at historic buildings are happening this weekend?" and "Which actors and athletes were born in the vicinity?". Based on this, we present a scenario of Jim, a business man from London who is visiting Berlin for a fair. He is staying the weekend in Berlin for exploring its sights.

(a) Exploring points of interests   On Saturday morning, Jim takes out his Mobile Facets application and uses the "What's around me?" feature to show places, persons, organizations, and events in his vicinity. He selects the facet Places and refines it to see only sights. Looking at the sights visualized on his mobile map, he decides to go to the Brandburg Gate and to explore some other sights around there. Subsequently, he refines his search to show only ecclesiastical sights. Jim is looking for a specific church in Berlin and views some pictures of it. He checks its exact location and walks towards it.

(b) Searching for celebrities   Having seen a couple of sights, Jim decides to have a rest and goes to the next Starbucks. While enjoying his coffee, he starts searching for famous persons that are related to Berlin. He queries Mobile Facets to show all known places in Berlin where some celebrities were born, live(d), or died. He is in particular interested in actors and sportsmen and adds these as facets to the query to filter the results. He browses through the list of celebrities, looks at some photos of them, and reads background information provided by DBpedia.

(c) Searching for points of interests   Finishing his sightseeing tour on Sunday evening, Jim is heading towards the airport to return to London. While driving in the taxicab, he catches a last view of the huge television tower, one of Berlin's most visible landmarks at the Alexander square. He asks himself, how high the tower actually is and wants to compare it with the height of other sights. He conducts a keyword-based search to show transmission towers, selects the tower at the Alexander square in Berlin and reads the DBpedia abstract. Subsequently, he searches for other sights in Berlin using the "What's around me?" feature to view their height and to compare it with the height of the transmission tower.

(d) Exploring events   While Jim is waiting at the airport for his plane to board, he has a spontaneous idea: he wants to go out in London the coming week. He switches the location context of Mobile Facets from his current location in Berlin to search for events in London. Jim browses through the events visualized on the map using the time-slider widget [18] of Mobile Facets to see if something interesting is happening the next days. He narrows down the event search by selecting the sub-facet Music. Jim selects some of the events shown on the map and finds out that Shakira is playing Friday evening.

(e) Searching events   Jim might go to the particular Shakira concert in London, but he wants to check other locations where Shakira is playing as well. He will be

traveling again in three weeks, this time to Dublin, Ireland. Jim conducts a keyword-based search for events of Shakira in Dublin. He finds out that Shakira is actually playing while he is visiting Dublin. Finally, Jim wants to see what else is happening in Dublin. He changes the location context to Dublin and uses Mobile Facets to show him all other events and points of interests in the city.

4 Participatory prototype design

The iterative, user-centered design of our Mobile Facets application is based on the scenario presented in Section 3 as well as inspired by the existing applications discussed in Section 2. We have started with a paper-based prototype, which has subsequently been implemented as running prototype. The running prototype has been iteratively refined. In each iteration, we have conducted requirements gathering, prototype engineering, and evaluation with a small user group of five subjects. The goal of this iterative, participatory prototype design was identifying usability issues and weaknesses in the control flow of the application at an early stage [7]. In the following, we describe the iterative, user-centered design of Mobile Facets and discuss different design options.

4.1 Design and evaluation

We have applied an iterative design process [12] under continuous involvement of end users for developing the Mobile Facets prototype. The goal was to continuously carry out evaluations in order to detect issues in the design and workflow of the application. To this end, we have asked a small group of five users (one female) to provide early and continuous feedback. The age of the users is between 26 and 35 years (avg. = 29.75, SD = 4.11). The experience in using mobile phones in the group is between good and very good. In addition, two users are experts on user interfaces.

Starting with a paper-based prototype, we have created and continuously improved a running prototype that the users have tried out on a touchscreen mobile phone. In each evaluation session, the users were asked to conduct a series of tasks relevant to the scenario described in Section 3. We have also encouraged the users to think-aloud [14] in order to obtain feedback from their feelings, spontaneous reactions, and thoughts. In addition, we have received feedback from the users in a dialog after the session.

We have detected several usability issues at an early stage of the prototype development such as problems in the control flow of the application and have received feedback on critical design decisions. In the following sections, we discuss the two most important design decisions, namely the design of the users' interaction for **searching and exploring the open social media data using facets** and the **visualization of the selected facets**. Finally, we discuss further comments and feedback received from the evaluation group.
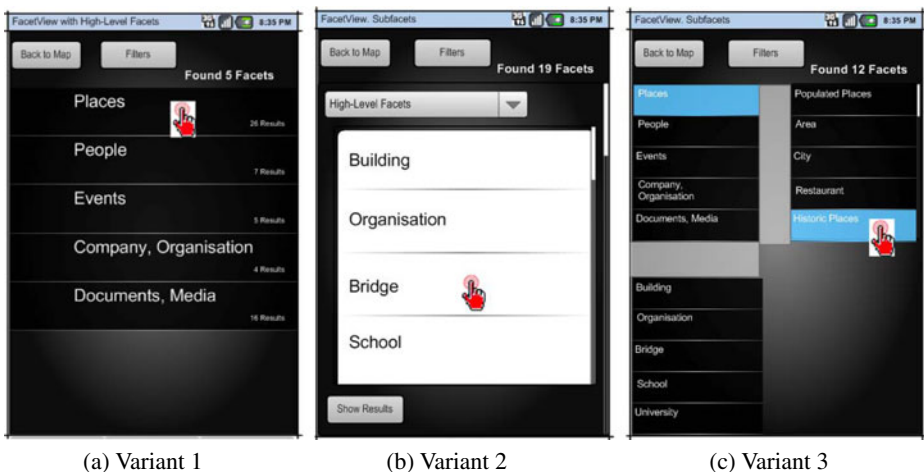
4.2 Search and exploration using facets

The goal of the search and exploration using facets is to enable the users to find interesting places, persons, organizations, and events in their vicinity through a poly-hierarchy

of facets. When navigating in multiple facet hierarchies, users should still be able to keep track of the choices they made and should not feel lost [4]. To achieve this, we have created three different design variants for our mobile search and exploration using facets. In all variants, the users start with the high-level facets Places, Persons, Organizations, and Events.

In the first design variant shown in Fig. 3a, the user clicks on a high level facet such as Places. By this, the user navigates into the facet hierarchy and the sub-facets of Places are shown such as Populated Places, Area, City, and so on. For each facet, the number of results is shown such that the user knows which sub-facets are more populated than others. Please note that in our initial designs, there was a fifth high-level facet Documents/Media that has been removed later. Reason for this removal of the facet was the introduction of a tab for media assets that shows related images (see Section 5). In the second design variant shown in Fig. 3b, the facets are selected by means of pull-down menus. First, a high-level facet is selected like Places. Then, a pull-down menu appears showing the sub-facets of the previously selected facet. The users can select a sub-facet from the list to further refine the result list. The last design variant shown in Fig. 3c is inspired by mSpace Mobile [25]. The screen is divided into several smaller areas for facet selection and exploration. The user starts at the top-left corner to choose from a high-level facet like Places. Subsequently, the right hand side is filled with the sub-facets and the users can choose one from it like Historic Places. The result list is than further narrowed down as shown in the bottom left part of the screen.

The user group found it in principle useful to navigate by means of lists of facets. This was seen as a strong advantage of the first design variant by most users. But the users mentioned that the font should be large. It was also mentioned that it might be cumbersome to navigate through multiple hierarchies of facets which may contain large lists of sub-facets. Advantage of the second approach is that the users see which (sub-)facets have been selected. However, the users disliked that the drop-down menus are dynamically added to the screen. In addition, selecting items from the

(a) Variant 1　　　　　　(b) Variant 2　　　　　　(c) Variant 3

Fig. 3 Different variants for search and exploration using facets

drop-down menus was considered cumbersome. In the third design variant, again the users can keep track of the interactions, i.e., the facets they have selected. However, the problem is that the available space of the screen is limited and thus the interaction with the mobile phone is difficult.

From the three design variants the best rated was the first one. The only disadvantage with the first design variant is that the users do not see which facets were previously selected. This circumstance has received specific consideration when improving the user interface. In the end, a visualization of the selected facets together with the faceted search and exploration as shown in Variant 1 (Fig. 3a) has been integrated in the prototype as described in the subsequent section.

4.3 Visualizing selected facets

In order to support users in keeping track of the facets they have selected, the current state of the system needs to be shown to them appropriately. The user group has been presented two different design variants A and B showing how the selected facets can be visualized.

The design variant A is created such that it can be applied together with all three design variants for faceted search and exploration as presented in the previous section. To see the currently selected facets, the users can click on the "Filter" button shown in the top of the screenshots of Fig. 3a–c. Please note that at that time of the system design, the term "filter" was used to show the currently selected facets. During the iterative design, we have asked the subjects if they would prefer an alternative term and the term "facet" was selected instead. As the latter was considered more appropriate (only one subject disagreed), we use the term facet in the final prototype. Subsequently, a menu pops up depicting the currently selected facets as shown in Fig. 4a. The selected facets are, e.g., Places and its sub-facet Populated Places. To unselect a facet, the checkboxes at the right hand side can be used. When sub-facets such as Populated Places are removed, the system falls back to the higher-level facet, in this case Places. However, when unselecting the facet Places, also the facet Populated Places is unselected as it is a sub-facet of it.

Fig. 4 Different variants for visualizing selected facets

(a) Variant A   (b) Variant B
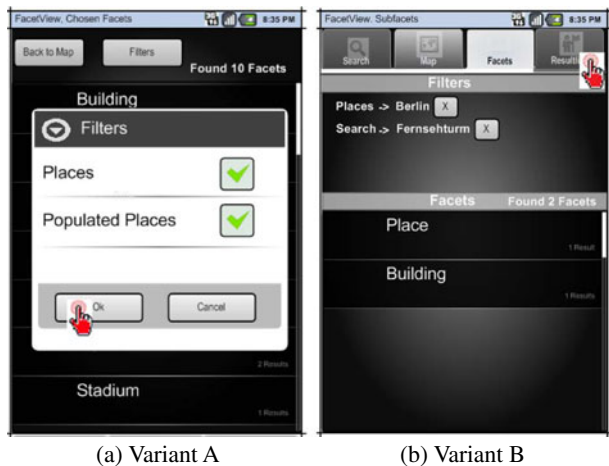
In the design variant B depicted in Fig. 4b, the currently selected facets are shown together with the search and exploration via facets as depicted in Fig. 3a. The user has selected the high-level facet Places and has further narrowed down the result list by choosing the sub-facet Berlin. We have also added a keyword search, in this example a specific kind of sights, namely transmission towers (Search → Fernsehturm). The facets can be unselected, by clicking on the small "X" button on the right hand side of it.

In the design variant A, it was clear how to unselect facets. However, the users did not find it intuitive that the facet Populated Places is a sub-facet of Places. Although a keyword-based search like for the transmission towers was appreciated in general, integrating it into the selected facets as shown in the design variant B (Fig. 4b) was not considered useful. In general, however, the design variant B was considered more intuitive. This also reflects the experiences made with facets in the context of desktop computer applications (see Section 2).

Finally, the question came up what happens when the user clicks on the "X" on the right hand side of the facets of Fig. 4b. Is just the last sub-facet removed from the result list or should the entire hierarchy of selected facets be removed? Here, the evaluations showed that it was more intuitive and useful to remove the entire facet.

Referring to design variant B, it was also discussed how the hierarchy of facets from the high-level facet to its last sub-facet should be visualized. Here, we have created further three design alternatives as depicted in Fig. 5 and asked the users to valuate them. The first alternative shows the complete hierarchy of facets. Depending on the depth of the facet hierarchy, the list of sub-facets shown can be very long. To avoid this problem, the second alternative uses "[...]" to hide the middle sub-facets and only shows the high-level facet and the last sub-facet. This design alternative allows both to keep an overview of which high-level facets have been selected and to which specific sub-facet it has been narrowed down. Finally, the third design alternative only shows the last selected sub-facet.

For the first design variant, the users assumed that the system is searching for Places, Populated Places, Building, and Stadium. But as this is a hierarchy of sub-facets only entities of facet Stadium are shown. The second design variant alleviates this problem. However, here the context of the facet Stadium is unclear, i.e., where in the hierarchy of facets it belongs to. The same holds true for the third variant. The second design alternative was considered useful when the list of facets is too long to show it on the screen. After explaining the different design alternatives to the user group, in particular how the first design variant is to be understood, there was a common agreement that the first design alternative is the best choice.

4.4 Further Comments

There were a couple of further comments mentioned during the evaluations of our prototype that identified several usability problems and issues in interacting with the

Fig. 5 Three design alternatives for visualizing facet hierarchies
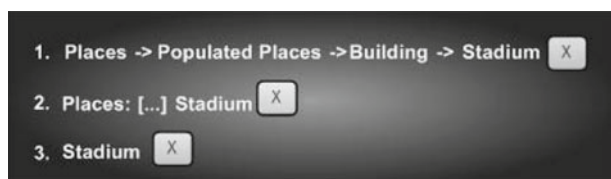
application. For example, besides searching and exploring the information space via facets, the users wanted to have a keyword search as well. This coincides with other studies on faceted search and exploration on desktop computers [9]. We suggested a live preview of the results when typing in a keyword, which was considered a useful feature.

No specific adaptation of the user interface is provided when rotating the device. This was not considered an issue as the application is assumed to be predominantly used in portait position while beeing on the move.

Some users were confused by the terminology, namely the use of the two terms facets and filters. As said above, we decided to use the term facet only although in literature and existing applications the term filter is also found like with the DBpedia browser of Neofonie (http://dbpedia.neofonie.com/). Similar to other location-based applications like Google Maps, our Mobile Facets application only searches within the area of the current map view. In our evaluation group, most users found this intuitive, only one disagreed. When starting the Mobile Facets prototype, the map view was the first one shown to the users. However, as no query has been executed yet, the map was empty. This was not considered useful by the user group and thus the facet view for search and exploration is shown when starting the Mobile Facets application.

5 Final design of the Mobile Facets prototype

Result of the iterative, user-centered design of Mobile Facets is a prototype application for faceted search and exploration of places, persons, organizations, and events on a touchscreen mobile phone. To show the usefulness and usability of the Mobile Facets application, we have conducted a formative evaluation with 12 additional subjects. Before we describe the formative evaluation in Section 6, we present in this section the design and functionality of the Mobile Facets prototype along the tabs it provides, namely faceted search and exploration, map view, result list view, and photo view. Finally, we present the detailed view of resources. The users can switch arbitrarily between the tabs by clicking on the corresponding icon at the top of the application.

Tab 1: Faceted search and exploration   When starting the Mobile Facets application, the first tab for faceted search and exploration is shown to the user as depicted in Fig. 6a. The screen is divided into two parts as discussed in the iterative design of the prototype in Sections 4.2 and 4.3. In the upper area, the facets and sub-facets selected by the user are shown. In the example in Fig. 6a, the user has selected the facets Educational Institution and Museums in Berlin. The resulting resources are all organizations of educational background merged with all places that are museums in the city of Berlin. By clicking on the cross next to the facets, the entire facet is removed. In addition, the user can remove all currently selected facets or add a new facet using the "+" icon. The number of items retrieved, i.e., the number of sub-facets or instances is shown under the facets. For example, there are eleven Museums in Berlin.

The lower area of Fig. 6a shows the available facets and allows the users to select and explore the information space using facets. The facets are initially filled when

(a) Facet View: High-level facets, Sub-facets, and Instances   (b) Keyword Search
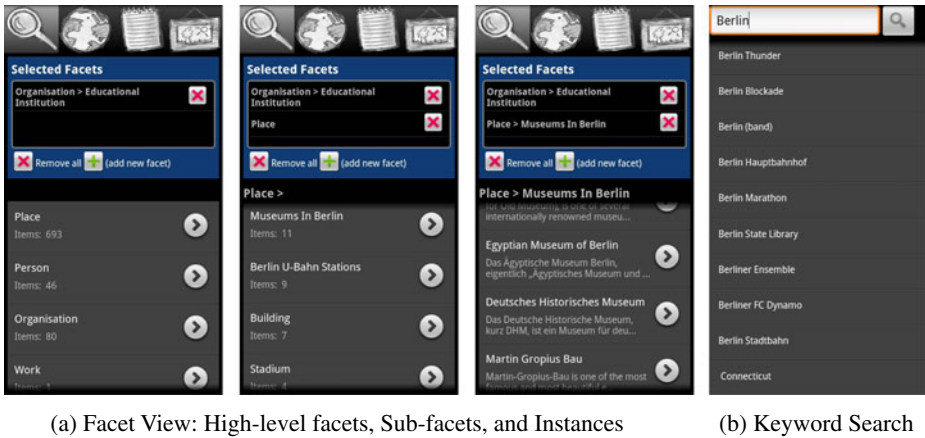
Fig. 6 Final prototype of Mobile Facets application

starting the application or by executing a "What's around me?" query from the applications menu (no screenshot provided). One starts with selecting a high-level facet and narrows down the result set using sub-facets. Figure 6a (left) shows the high-level facets Places, Persons, Organizations, and Events and the selected facet Organisation → Educational Institution. The user selects the high-level facet Place. Subsequently, the sub-facets of Place in Berlin such as Museums in Berlin, Berlin U-Bahn Stations, and others are shown as depicted in Fig. 6a (middle). The user clicks on the facet Museums in Berlin and the instances of this facet are shown as depicted in Fig. 6a (right). By clicking on one of the instances, the details of this resource are shown.

Besides using facets for search and exploration in the information space, also a keyword search is offered as depicted in Fig. 6b. The keyword search is independent of the current location of the user and allows one to find people, places, organizations, and events. It provides a live view of the results once the user starts typing in a keyword. The live view not only searches in the titles of the resources but also exploits semantic relationships. For example, in the query of "Berlin" in Fig. 6b the state Connecticut in New England is also found as there is a town in this state that is called Berlin.

Tab 2: Map view   Once the users have selected appropriate facets using the tab described in the previous section, they can visualize the results on a map. To this end, the users click on the map view tab, which allows standard map-based interaction such as zooming and panning as depicted in Fig. 7a. The map view shows all search results that have a geo-location like places and organizations. When clicking on a point of interest, its details are shown. The blue stars shown on the map are events, i.e., point of interests that are of interest during a specific period of time like a concert or an exhibition. The Mobile Facets application provides a time-slider widget [18] to browse through time, which is located at the bottom of Fig. 7a. The events are rendered depending on the temporal distance to the currently selected date of the time-slider widget. Events happening today are shown in shaded blue-red whereas events happening up to 30 days in the future are more and more bright. This provides the users with immediate feedback about when events are happening.

| (a) Map View | (b) Result List View | (c) Photo View | (d) Details View |
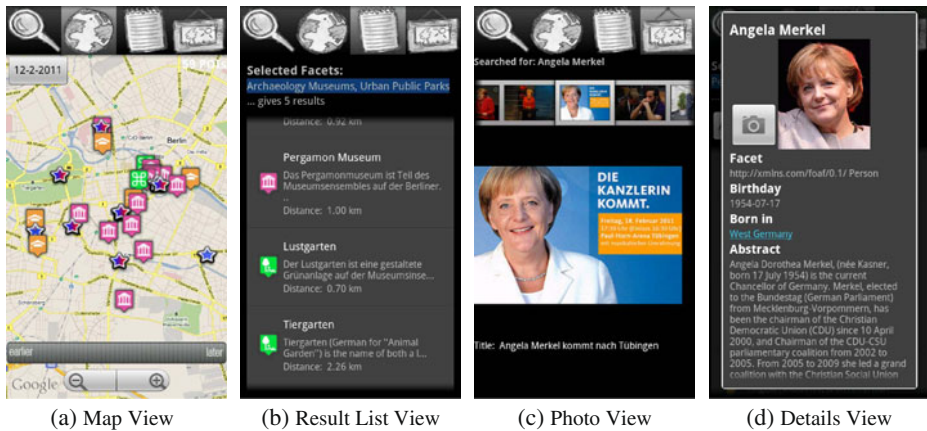
Fig. 7 Final prototype of Mobile Facets application

Tab 3: Result list view Besides a faceted search and exploration and map view of the results, there is also a plain list view of matching resources as shown in Fig. 7b. It contains all resources of the currently selected facets. The resources shown in the result list view can be any instances of the high-level facets or its sub-facets. In the example, the facets Archaeology Museums and Urban Public Parks in Berlin are selected and its five results are shown in the list. The users can click on the results, which again opens the details view.

Tab 4: Photo view The photo view depicted in Fig. 7c is the last tab in the Mobile Facets application and shows images from Flickr that have been taken in the vicinity. A gallery of photos is shown at the top. Users can scroll through it and click on images they like to see in larger resolution.

Details view The details view of a resource can be opened from all tabs of the Mobile Facets application. Depending on the type of resource, the details view shows different information: For DBpedia resources, i.e., places, organizations, and persons described on Wikipedia, the details view provides a title, thumbnail (if available), link to the article's web page, abstract, and others. As an example, Fig. 7d shows the details of Germany's chancellor Angela Merkel. The users can click on the photo icon to switch to the photo view. For resources with a location, also an icon to switch to the map view is provided. For event resources, the details view shows the event category, start date, end date, address of the venue, and the event description (no screenshot provided).

6 Task-based evaluation of the Mobile Facets prototype

To show the usability and usefulness of the Mobile Facets application, we have conducted a task-based evaluation [14] of the application with 12 subjects. In this section, we present the design of the evaluation and discuss its results.

6.1 Test subjects

The age of the 12 subjects (two female) has been between 22 and 34 years (avg. = 27.83, SD = 3.78). They are students and PhD students at our university and one educator. The subjects of the final prototype evaluation have not participated in the iterative design and evaluation described in Section 4. All users had some experience with a keypad-based phone. Six of them said that they are used to touchscreen mobile phones. None of the users consider themselves experts in using mobile applications or mobile phones. None of the subjects have used or seen the Mobile Facets application before. However, they were familiar with the facet concept on desktop computers.

6.2 Data corpus and data integration

As a data corpus, we use publicly available sources of social media data and a geo-location website, namely DBpedia, the event directories Eventful and Upcoming, geo-located Flickr photos, and content from GeoNames. The data is queried and integrated live from the data sources. Thus, we cannot make any assumptions about which facets and how many data resources the Mobile Facets application receives in a specific contextual situation. The data is social as it is generated by users, but with GeoNames, Eventful, and Upcoming it also contains professional data. The abstract categories of the social media data sources used by Mobile Facets are manually associated and thus hard-wired to the high-level facets, namely Places, Persons, Organizations, and Events. However, the sub-concepts and thus sub-facets and the instances are retrieved and added live from the social media data sources. The data infrastructure of Mobile Facets is designed such that it allows for an easy integration of further open (social media) data sources available via, e.g., REST interface or SPARQL endpoint. In a future extension of Mobile Facets, we plan to replace this initial hard-wiring of the social media data sources with the high-level facets by an automatic mapping.

Probably the most important data source we use is DBpedia, a structured representation of the Wikipedia (http://en.wikipedia.org/) infoboxes using RDF. We use the English language version of DBpedia with 3.4 million resources. They are retrieved by means of using the rdf:type property that classifies resources to the DBpedia vocabulary. Selected concepts defined in the DBpedia vocabulary are statically associated with the high-level facets of Mobile Facets. For example, dbpedia-owl:Place maps to the Places facet. By this, all sub-concepts of dbpedia-owl:Place like dbpedia-owl:Town, dbpedia-owl:Settlement, and dbpedia-owl:PopulatedPlace are shown under the high-level facet Places as corresponding sub-facets. Other concepts like dbpedia-owl:Company and dbpedia-owl:Non-ProfitOrganisation map to the Organizations facet. All sub-classes of these DBpedia concepts are also dynamically added as sub-facets in the Mobile Facets application. Locations of resources are received using the properties geo:lat and geo:long (e.g., in free keyword-based search). To determine the location of resources other DBpedia properties are also queried like dbpedia-owl:birthPlace for persons, dbpedia-owl:campus for educational institutions, and dbpedia-owl:hometown for organizations. To display resources from DBpedia, we use the title as defined using rdfs:label. Other information like the abstract of DBpedia resources are received using the dbpedia-owl:abstract

property or the homepage of a resource from the foaf:homepage property. The dbpedia-owl:birthDate and dbpedia-owl:deathDate properties are used to receive the date of birth and date of death of persons. The dbpedia-owl:thumbnail shows a thumbnail of a resource.

Eventful and Upcoming are platforms that allow registered private and commercial users to create and share event descriptions. Resources from Eventful and Upcoming are associated with the Events facet. Eventful provides different sub-facets of Events like Music, Performing/Visual Arts, and Education. Similarly, Upcoming also provides private and commercial event descriptions and categorical information for the events that are used to further specify the Events facet. Venues received from Eventful and Upcoming are found under the Places facet.

GeoNames is a comprehensive database containing 2.8 million populated places of the world. Resources retrieved from GeoNames are associated under the Places facet. Flickr is a social photo sharing platform with more than 5 billion photos. For Mobile Facets, we are using those photos which have a geo-tag.

6.3 Tasks

As with the initial evaluation, the evaluation of the final prototype was carried out by conducting tasks along the scenario described in Section 3. For each paragraph (a)–(e) in the scenario, we have defined between three to seven tasks such as searching and browsing interesting sights, refining results using facets, reading information about people, exploring events, and others. In total, 25 tasks were defined. Subsequently to finishing a set of tasks (a)–(e), the users were asked specific questions related to the tasks and providing general feedback on the usability of the application. While conducting the tasks, the subjects were allowed to ask questions to the instructor in case something was unclear. In addition, the subjects were motivated to think aloud. All subjects conducted the same tasks.

6.4 Evaluation and results

The evaluation was carried out as a controlled laboratory experiment. Each evaluation session took between 30 and 60 min. The subjects could conduct the evaluation tasks derived from the scenario in Section 3 at a speed convenient for them. They have also been instructed that it is not the goal of the evaluation to measure the efficiency but to obtain qualitative feedback on how they like and feel supported by the application in conducting the tasks.

After starting the application for the first time, a two to three minute introduction to Mobile Facets was given. The introduction started with a presentation of the faceted mobile search and exploration and the different tabs of the application. Subsequently, the users acquainted themselves with the touchscreen mobile phone and could play around with the application. Subsequently, the actual evaluation began. To this end, the subjects have received a list with detailed instructions of the tasks they had to perform. All users were able to accomplish the tasks. However, some tasks were more difficult to solve than others due to the interaction workflow with the application as well as quality of the provided facet information. We present and discuss the results along the set of tasks (a)–(e). The qualitative feedback was captured using an evaluation questionnaire based on IsoMetrics-L [6] using a

standard 5-point Likert scale. In this scale, a value of one means strongly disagree and the value five is a strong agreement. For each task (a)–(e), we have captured the feedback separately.

(a) Exploring points of interest In the first set of tasks, the users had to select the facet Place and then a sub-facet of it to choose a specific category of point of interests. The users had to switch to the map view and explore the points of interest on the map. The users were asked to valuate if the approach for refining the result set using faceted search and exploration is intuitive to use. When the application starts the first time, it immediately searches for facets in the vicinity. All subjects agreed or strongly agreed that this is a useful feature (avg. = 4.75, SD = 0.2). Regarding the question if the facet tab provides all required features for faceted search and exploration, the users rated it average (avg. = 3.42, SD = 0.28). Reasons for this was that the users wanted besides a sorting of the sub-facets by number of resources found also an alphabetical sorting. In addition, the users stated that the data contains ambiguities. For example, the facet Places has the sub-facets Populated Places, Settlement, and Town. As the facets are retrieved live from the open social media data sources, the Mobile Facets application has no influence about the kind of facets and the quality of facets and resources provided. When conducting the task to find a specific church in Berlin (see the scenario in Section 3), the subjects had difficulties finding it as there were many resources found. The church was associated under the facet Landmark, which many users did not find intuitive. Thus, in a future work, the data quality of the facets should be improved.

(b) Searching for celebrities In the next task set, the users were asked to add the facet Persons to the currently selected Place facet and further refine this facet to Politician and Athlete. Most people find this feature useful (avg. = 4.22, SD = 0.41).

(c) Searching for points of interests For searching transmission towers in Berlin, the users conducted a keyword-based text search with a live view of the search results. This means that when the users enter the keyword, a result list is immediately shown similar to Google's instant search. This feature was rated high by the subjects (avg. = 4.59, SD = 0.28), confirming that users like to have a keyword search besides faceted search and exploration as for faceted search on desktop computers (cf. [9]). For the "What's around me?" feature, some subjects said that they liked to see a short message on the screen saying that the search is only conducted on the currently selected area of the map. These subjects have chosen a too small area of the map when initiating the query. The fact that the search is only conducted on the current map area was explained to the subjects at the beginning of the evaluation. However, many subjects expected when searching for, e.g., towers, that the system does a retrieval on all instances independent of the user's current location and selected map area. To alleviate this issue, a message could be added to Mobile Facets.

(d) Exploring events In this task, the users had to change the location context from Berlin to London in order to explore events there. Mobile Facets offers two options to change the location. Either a keyword query for *london* is executed and then the facets are filled with the target location or one changes the location by manually panning the map and using the "What's around me?" feature to fill the facets. To our surprise all subjects except one decided to use the map panning option to change

the location context. Using a keyword search was considered more cumbersome than panning the map from Berlin to London. Exploring events using the time-slider widget was considered very intuitive. The subjects immediately understood the interaction metaphor to change the time in order to find out what is happening in the next days. The visualization of events using blue stars that fade out the further away the currently selected date from the event date is and the use of blue-red shaded stars depicting events happening today was considered appropriate (avg. = 3.68, SD = 0.37).

(e) Searching events Searching for events in remote locations was considered a very important feature (avg. = 4.46, SD = 0.28). In the concrete context of Dublin, however, it was criticized that some points of interests were not very interesting such as the neighborhoods of Dublin. Here again one has to refer to the varying quality and openness of the social data sources used, which is not under control of the Mobile Facets application.

Finally, we have asked the subjects to judge the subjective usability of the Mobile Facets application. These measures have been captured for each task block (a)–(e) separately. Table 1 shows the average and standard deviation of the ratings on the applications' usability over the five task blocks (a)–(e). Thus, it is a measure how coherent the usability of the Mobile Facets application is. The four questions in Table 1 measure how appropriate the number of steps are to accomplish the task, how intuitive it was to conduct the task, how well the Mobile Facets application supported the subjects in conducting the tasks, and if the application behaves as expected. The ratings are good, i.e., between 3.8 and 4.02.

6.5 Concluding discussion

The results of our evaluation show that it is possible to create an intuitive to use application for mobile faceted search and exploration of a large, social media data set on a touchscreen mobile phone. Applying facets for exploring a large, multi-dimensional data set is an established interaction metaphor on desktop computers for web sites like Amazon and Ebay (see Section 2). To our surprise the evaluation of Mobile Facets revealed that some subjects initially had difficulties transferring the known concept of faceted search and exploration from desktop computers to the mobile application. However, after successfully conducting some mobile faceted search and exploration tasks, this was no further problem. A general criticism was that the feature for conducting a "What's around me?" search should be faster and that it should be possible to sort the facets also alphabetically. In addition, when there are no or only very few search results in the map area, the Mobile Facets application could automatically increase the area to retrieve more results.

Table 1 Subjective usability of Mobile Facets

	Avg	SD
The number of steps to accomplish a task is appropriate.	4.02	0.76
The steps required for conducting a task are intuitive.	3.95	0.87
The application supports me in conducting the tasks.	3.96	0.89
The application behaves as expected.	3.8	0.97

However, more important was the feedback on the facet quality. As the application uses different open social media data sources that are queried live, the Mobile Facets application is not in control of what kind of data is provided and how many resources are returned. For example, in the scenario there is the task block (a) to explore points of interest. Some of these points of interests such as a church are associated under the facet Landmark, which is retrieved from DBpedia. Also a church can be considered in general a landmark, it would be more intuitive to find the church under a facet like Churches or Sacred Buildings as well. When searching for celebrities in task block (b), about 25 sub-facets were found for the high-level facet Persons. Exploring these sub-facets for celebrities required scrolling over multiple screens. In addition, several sub-facets such as actors and athletes had to be selected for viewing the celebrities as a dedicated celebrity facet is not provided. To improve the data quality of the open social media sources, semantic ranking techniques like TripleRank [5] could be applied on the facets in the future.

7 Conclusions and future work

In this paper, we have presented the iterative, user-centered design and task-based evaluation of Mobile Facets, a mobile application for faceted search and exploration of a large data set of open social media data on touchscreen mobile phones. The facets and data instances are retrieved live from different sources allowing to apply Mobile Facets at any location in the world covered by Wikipedia, GeoNames, Eventful, Upcoming, or Flickr. However, this live retrieval of facets and instances also means that one does not know in advance the number and type of facets and resources retrieved from the social media sources. The Mobile Facets application copes with this dynamics of the open social media data by searching and exploring the data using facets. As such, the design of the Mobile Facets application tackles a core challenge of the Semantic Web, namely creating smart user interfaces that are able to deal with an a-priori unknown number of data categories and data instances. In addition, the design of an application for faceted search and exploration on a mobile device is significantly harder and more complex than for a desktop computer. This is due to the fact that the interaction possibilities with the mobile device are limited and the display size is smaller. The initial prototyping phase of Mobile Facets with a small user group of five subjects helped significantly to design the user interface for a faceted search and exploration of open social media data on touchscreen mobile phones. The evaluation of the final prototype with 12 additional subjects indicates the general applicability and usability of the selected approach.

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