Decision Improvement through Multi-Criteria Strategies in Mobile Location-Based Services

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Abstract

Multi-criteria decision analysis enhances location-based queries to a more personalized level. However, while there are assumptions on how such analysis supports people in their decision-making during the performance of spatio-temporal tasks, these assumptions have only been based on models so far. This paper focuses on the benefits and drawbacks of a personalized mobile location-based decision service by evaluating the results of a human subject test. The test described three different user scenarios and was performed using a Smartphone. The prototype application featured multi-criteria decision support for the task of finding suitable hotels in the city of Münster, Germany.

1 Introduction

Mobile location-based services (mLBS) are wireless services which use the location of a handheld device to deliver applications exploiting geospatial information about a user's surrounding environment, their proximity and distance to other entities in space (URQUHART, MILLER et al. 2003). Relating the user's position to the surrounding environment facilitates the successful completion of spatio-temporal tasks. Tremendous benefits may be achieved from the widespread adoption of these services, providing large segments of the population real-time decision support for purposes ranging from trivial (wayfinding services) to critical (emergency response). MLBS increasingly provide assistance in decision support based upon the user's context (RINNER and RAUBAL 2004; RINNER, RAUBAL et al. 2005). However, while these services often encompass multiple thematic layers to choose from (e.g. airports, bus stations, restaurants...), they still assist the user's decision-making based on a small number of constraints — mostly only distance and one additional thematic attribute.

(RAUBAL and RINNER 2004) introduced a way to enhance location-based queries beyond standard single-attribute solutions through an approach that gathers user preferences in a qualitative way. These qualitative preferences were used as input for a multi-criteria decision analysis (MALCZEWSKI 1999). It allowed the user to take several relevant attributes into account during the decision-making process and let her assign weights to define their relative importance. While this approach has been modeled in a case study, no human subject tests have been designed to evaluate whether multi-criteria decision support facilitates decision-making and how it should be communicated.

Based on the original ArcPad®[1] version of the *Hotel Finder* (RINNER and RAUBAL 2004), we implemented a novel .NET prototype that offers a broader spectrum of user interface customization and accesses the Microsoft® VirtualEarth™(VE)[2] tile server. This is a mapping and location service, which combines MapPoint Service with satellite and aerial imagery.

This paper presents the results of a human subject test with more than 70 participants based on the described technical configuration. Aside from the overall benefit of multi-criteria decision support compared to common ways of finding points of interest, users were asked to evaluate each step of the analysis process concerning its intuitive use, accessibility, and readability. The paper consists of three main parts: after a short overview of the prototype and its provided features, the test setup is explained considering different user groups, their age structure, and the test environment. Finally, the evaluation of the test results is presented and discussed, together with open questions and directions for future work.

2 Prototype description

We implemented a C#-based prototype of the personalized mLBS using Microsoft® NET Compact Framework 2.0. The prototype was designed for running on a Windows Mobile 5 Smartphone. Map data is loaded by accessing the VE tile server (figure 1). The raw map gets enriched by a hotel layer that includes position, average price, provision of private baths, latest check-out time, phone number, address, and a photograph of each hotel. The hotel layer is stored in an object-relational SQL database. For the prototype and testing however, the layer was implemented directly as an array list. Map navigation is kept as simple as possible and limited to zooming and panning. However, since the user's position always also corresponds to the centre of the map, panning is virtually automatic when using GPS. This way we intended to minimize user interaction and to reduce the map's complexity to represent only the relevant information. These are important facts, because of the given constraints of the small display size and the number of stops subjects make while on-route should be reduced to a minimum (DILLEMUTH 2005).

After starting the program, the hotel layer is loaded onto the tile map (figure 2a). By clicking on a hotel map icon, a window will be displayed, listing information regarding the selected hotel. This window consists of two tab panes: The first tab pane includes the hotel name, a link to the hotel's webpage, the address, and a photograph (figure 2b). The second tab pane lists the criteria, the score, and the ranking. The main menu features two buttons for either returning to the main map or calculating the shortest path to this hotel and presenting it on the main map.

[1] http://www.esri.com/software/arcgis/arcpad/index.html
[2] http://www.microsoft.com/virtualearth/default.mspx

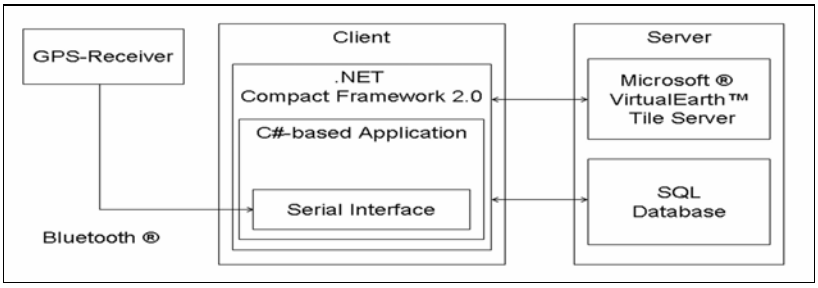


Figure 1: System Architecture. A classical Client-Server Architecture. The client in the human subject test is a *T-Mobile MDA Pro* Smartphone.

Clicking on the hotel icon in the toolbar initiates the hotel finding process, which encompasses five steps (figure 2c). To ensure safe user guidance the window of each step features the same basic structure. The main menu enables the user to either go back to the previous step or continue with the next step. All steps provide additional explanation displayed in a notification event triggered by clicking on the corresponding help button.

In the first step the user selects criteria she wishes to be taken into account for the analysis. The different criteria are listed as checkbox items. As soon as at least one criterion is selected, the user is able to proceed by pressing the “continue” button in the main menu. The test data set was limited to three criteria: *average price*, *private bath*, and *latest check-out time*.

The next window handles the standardization of the selected criteria. Each standardization is defined in a dedicated tab pane whereas the design of each pane depends on the criteria’s scale of measurement. For example, the criterion “Private Bath” has only Boolean values. Thus its pane only provides the option to specify the qualitative variables good, fair, or poor through “yes” or “no”. In the pane of “Price” on the other hand, the user is able to define a good, fair, and poor level by setting the minimum and maximum value of each level. As addition to the regular help button, a simple text box was added to the standardization panes, which informs the user about inconsistencies, such as overlapping or negative intervals. As long as any tab panes’ text boxes are empty, the user is unable to continue with the next step.

Step three suggests a way to specify the weights of the selected criteria. The user specifies these weights by sliders. While the sliders do not have any labels themselves, moving them will yield an update of the corresponding text-boxes above. These display the value of each criterion’s weight on a percent range. All weights add up to 100 %.

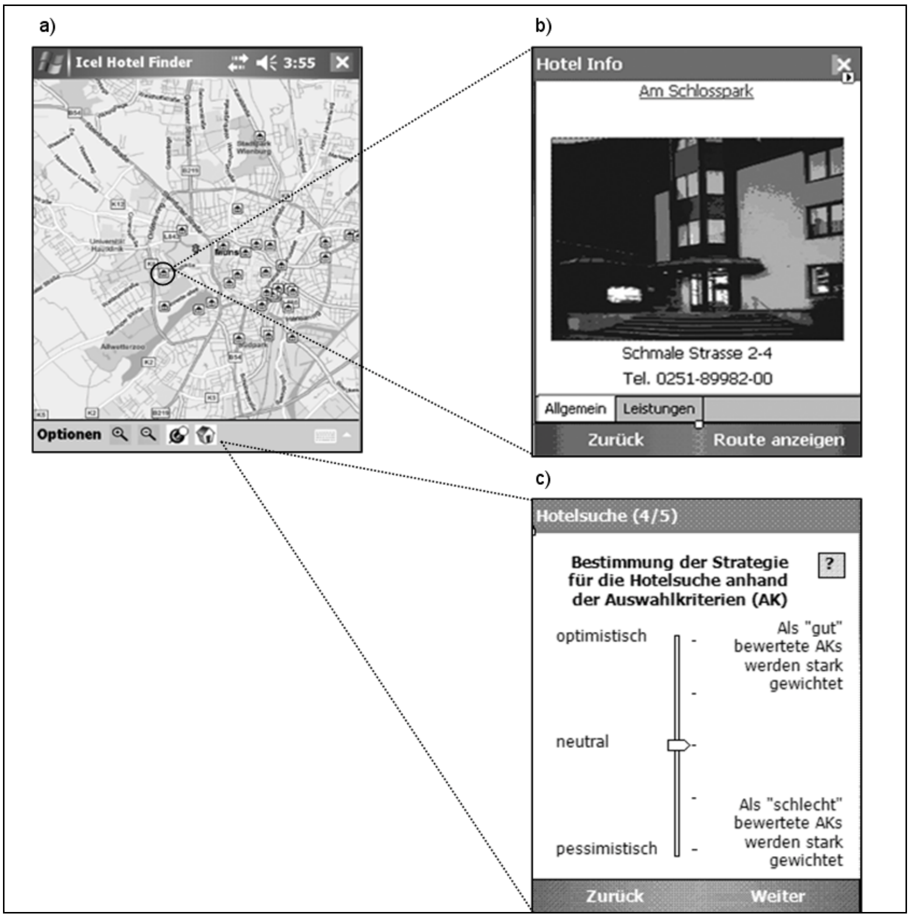


Figure 2: Overview-map of the city of Münster (Germany) with icons of available hotels (a), the POI-Info of a selected hotel (b), and the fourth step (i.e., choosing a decision strategy) of the hotel finding process (c).

The fourth step allows the user to interact with a slider for selecting which decision strategy based upon the OWA (Ordered Weighted Averaging) method is to be applied during the multi-criteria analysis (YAGER 1988; RINNER and MALCZEWSKI 2002) (figure 2c). OWA allows the user to specify a set of weights representing the relative importance of criteria according to the user's preferences (RINNER and RAUBAL 2004). It is characterized by a set of order weights in addition to the importance weights mentioned before. For the human subject test we provided "optimistic", "moderately optimistic", "neutral", "moderately pessimistic" and "pessimistic" strategies as described in figure 2c.

In the final window the user's selections are summarized and displayed in a scroll pane. Once the user is content with her selections she can start the multi-criteria decision analysis by clicking the "Find Hotel" main menu button. After the processing has finished the resulting scores are temporarily stored in the hotels array list and the information window of the highest ranked hotel is displayed, featuring a score and ranking entry. The user can now either trigger the shortest path calculation or go back to the main map. By pressing the "Find Route" button, the shortest path from the user's current position to the hotel is calculated and shown on the map. After the hotel finding process, the three highest ranked hotels are displayed on the map. Their order is expressed by different colors of the hotel symbols. By deleting the remaining hotel symbols from the map we wanted to maintain a good readability.

3 Human subject test

Mobile location-based services increasingly provide assistance in decision support based upon the user's context (ZIPF 2002; LI and LONGLEY 2006). Some research has focused on data content, while other studies have emphasized the role of multimedia communication (LI and LONGLEY 2006) or of ensuring usefulness of applications (WEALANDS, MILLER et al. 2007). However, so far very few objective tests have been carried out concerning usage and behaviour (LI and LONGLEY 2006). In this paper, the results of a human subject test are presented, with regard to a hotel-finding task in an unfamiliar environment within a mLBS-application.

3.1 Methods

Our main hypothesis with regard to the presented prototype is that the *integration of multi-criteria decision analysis leads to improved decision support for the user compared to decision-making based on one single criterion*. Three different scenarios were designed for the test to ensure that the subjects choose different criteria and weightings dependent on their context. Scenario 1 concerns a student, who is looking for an inexpensive hotel room for the night. The tourist of scenario 2 is looking for a comfortable hotel room near the main station, so that she can continue her trip on the next day as early as possible. In the third scenario a business traveler has missed a meeting and needs to stay in town for one more night. She is looking for a comfortable hotel room.

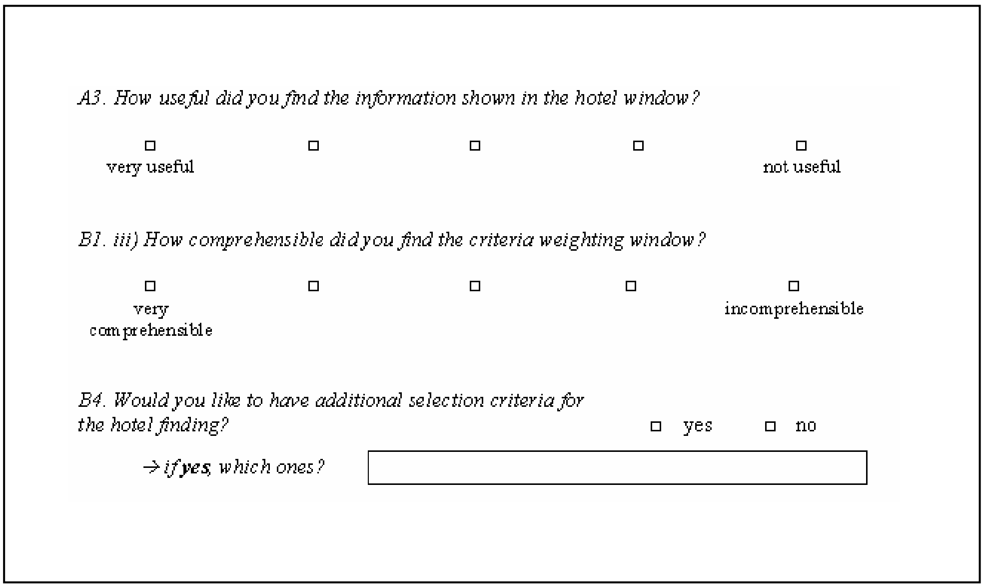
Seventy subjects were recruited for the test entitled *Hotel-Finder*. The subjects consisted of 43 males and 27 females. The mean age of the 70 subjects was 28.8 with a range from 17 to 59 years. The mean female age was 29.8 and the mean age for males was 28.2. Thirty-three subjects were experienced users with regard to handling a Smartphone, the remaining thirty-seven subjects had no previous experiences in handling a mobile device. Experienced users means having basic knowledge in using Windows Mobile or a Smartphone. On the other hand, inexperienced users are those, who neither know Windows Mobile nor had ever used a Smartphone or any other kind of mobile device besides a mobile phone.

At the beginning of the test every subject received the mobile device[3] with the started prototype and a questionnaire. The particular questionnaires started with a description of the particular scenario, such as the one for the tourist:

[3] T-Mobile MDA Pro (http://www.t-mobile.de/)

"Imagine you are a tourist on a train from Dortmund (Germany) to Osnabrück (Germany). Since you are on vacation, you decide to get off at Münster, where you want to stay overnight and spend the next day sightseeing before continuing on to Osnabrück. Arriving at the Münster train station you are looking for an appropriate hotel for the night. This is the time where the location-based service enters the game."

The questionnaires were distributed randomly among the subjects (MONTELLO and SUTTON 2006). Originally, there were 25 questionnaires for each scenario. Because of some errors in submitted questionnaires, there were at the end 23 each for the student and tourist scenario, and 24 for the business traveler scenario, which were part of the evaluation. The first step for the subject was to read the instructions, where the specific scenario and the hotel finding task were described in a few sentences. Written instructions are preferred by subjects over spoken instructions (HARRISON 1995). Afterwards, every subject accomplished the five steps of the hotel finding tasks as mentioned above. The last step was to fill out the 15 questions of the questionnaire (figure 3) concerning the hotel finding task before. An important aspect in accomplishing the different questions was that the subjects answered the questions from the special point-of view of their explicit scenario. Every test took between 10 and 15 minutes.


A3. How useful did you find the information shown in the hotel window?

very useful — not useful

B1. iii) How comprehensible did you find the criteria weighting window?

very comprehensible — incomprehensible

B4. Would you like to have additional selection criteria for the hotel finding? yes no

→ *if **yes**, which ones?*

Figure 3: Example questions of the questionnaire.

3.2 Results

The survey has demonstrated that the majority of users considered decision support based upon multi-criteria analysis to be helpful: 54 out of 70 users stated that it would mean an improvement over conventional decision strategies, such as finding hotels through internet search or travel agencies (figure 4).

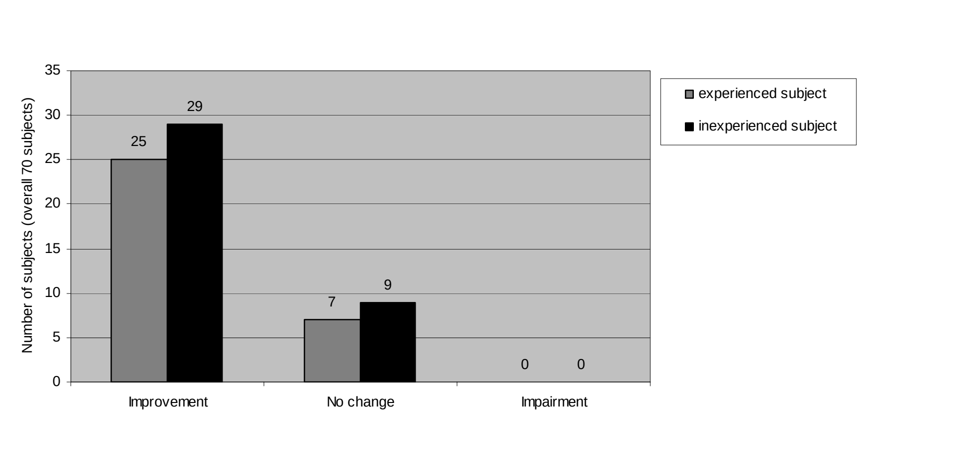


Figure 4: Overall evaluation of the hotel finding task with the multi-criteria decision strategy in comparison to alternative approaches.

However, while most users were satisfied with the overall user interface, they had difficulties understanding the way how multi-criteria based hotel finding was presented. The average time spent on all five steps was two minutes. Especially the selection of a decision strategy seems to lack self-explanation and needs to be redesigned to provide for better communication. On the other hand, most of the 28 users who accessed the help functions considered them to be supportive in the corresponding step.

As for the criteria, the test demonstrated that the given criteria are not sufficient for a user-oriented decision analysis on hotels. Most users missed additional information concerning the rooms (e.g. phone, internet, TV or photography of the room) and service descriptions, such as breakfast or category.

Multiple users suggested an interactive wizard for user guidance. This would allow keeping up with the complex steps of multi-criteria decision support without confusing the user. Another point that had been mentioned was the missing description of each hotel’s score after the multi-criteria analysis. Instead of showing an abstract score value in the hotel information window, there should only be the ranking of within the set of hotels considered in the analysis (e.g. “Rank 3 out of 12”).

Overall there have been many suggestions for improvement on map interface, map functions, and additional decision criteria (figure 5) whereas the usefulness of multi-criteria decision analysis itself was seconded by almost all users.

Suggestion	#
Strategy window is hard to understand	14
Show access to bus network	13
Shorter loading times	13
Wizard for user guidance	12
Distance to points of interests/landmarks	11
Implementation on Java compliant cell phones	10
Show photos and services in a combined window	9
Support of thematic queries in the map	9
Spatial buffers	5
Show special offers	4

Figure 5: Suggestions for improvement and the number of subjects who mentioned them.

4 Discussion and Future Work

The results of the human subject test demonstrate that applying the multi-criteria decision strategy enhances people's decision support in unfamiliar environments. The ability to take multiple criteria into account while looking for the "best" point of interest enriches mobile location-based services by the capability of supporting personal spatial decision-making. No user considered this approach as an impairment.

While the usefulness of multi-criteria decision support has become quite clear, the menu structure and design itself needs to be reconsidered. Especially the selection and meaning of decision strategy and criteria weighting was less comprehensive than expected. Further research and testing is needed for learning how to communicate these complex steps properly.

The inherent complexity of multi-criteria decision support also yields the problem of reusability: instead of making the user go through the same steps again and again, standardized or individual profiles should save the current user's preferences. This would yield an even higher level of personal decision-making. Evaluation of individual profiles could be used for getting the average values needed for a standard profile.

Another issue concerns the applicability of this kind of analysis on a more abstract level and use for different tasks, e.g., for finding suitable restaurants instead of hotels. This could be done by tagging those fields in the dataset that are usable for the multi-criteria decision. However, the problem of a dynamically building graphical user interface (GUI) is still present, which means that the GUI needs to be redesigned depending on how many different attributes the user selects as criteria.

Last but not least, future work needs to focus on enhancing the multi-criteria analysis on a spatial level. While geographic information systems provide powerful tools to do spatial analysis depending upon multiple locations (e.g., intersection area of two or more buffers), location-based services are still limited to one spatial criterion. The capability of providing user-defined spatial buffers to delineate the area where the multi-criteria analysis should be applied would improve the spatial level of a personalized mLBS.

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