USER INTERFACE DESIGN FOR LOCATION-BASED DECISION SERVICES

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ABSTRACT

We have previously introduced the idea of compensatory decision support on mobile devices as going beyond querying and filtering offered by many location-based services (LBS) today. Our Hotel Finder application uses multi-criteria decision-making methods to provide targeted suggestions for selecting facilities that best address the users' personal requirements. In this paper, we compare the Hotel Finder with a new Bar Finder derivative to demonstrate a simplified user interface design for location-based decision services. We describe user preferences in multi-criteria evaluation methods and the user interface elements required to specify them. We then identify ways of omitting particular settings in order to streamline the user interface and, thus, the mobile decision-making process.

KEY WORDS: Location-Based Services, Spatial Decision Support, Multi-Criteria Evaluation, Geographic Information Systems, User Interface Design

1. INTRODUCTION

Location-based services (LBS) combine wireless networking technology and geographic information systems (GIS) functionality and exploit positional information to assist mobile users. Typical applications of LBS include finding the nearest facility of a certain type, finding nearby mobile users, or receiving alerts based on proximity to certain locations and events. Such services use information about the relative positions of the user and the facilities of interest or of other users. Mobile GIS in the wider sense so far are limited to efficient field data collection, e.g. when monitoring natural resources or wildlife species. Clarke (2004) examines the "where" of computing and claims that mobile systems "bring analysis from the laboratory right to the point of data collection".

Although existing LBS provide valuable decision support to mobile users, they do not make full use of existing decision support capacities of GIS. A simple yet powerful set of methods implemented in GIS since the 1990s are multi-criteria evaluation (MCE) methods. These allow users to evaluate decision alternatives (e.g. facilities to visit) based on multiple, compensatory decision criteria (feature attributes). We have previously suggested transferring MCE to the LBS platform (Raubal and Rinner 2004). In Rinner and Raubal (in press), personalized location-based decision strategies have been introduced. The usability and usefulness of such services is highly dependent on an appropriate user interface (UI) design including the cartographic visualization of the results.

For "mapping and guidance services", Cartwright et al. (2001) have identified a "lack of understanding about how to design effective interfaces to such mobile mapping devices". For LBS in particular, the UI design on a small display must balance space requirements of both, a map and a set of tools. An additional bottleneck of mobile services is the limitation of input devices for users. Not all general mobile UI guidelines are applicable to location-based decision services because they often refer to strictly sequential interactions in contrast to the flexible MCE procedures. We therefore work towards guidelines for the UIs of location-based decision services.

With reference to previous work, we provide an overview of the link between spatial decision support methods and LBS in section 2. Section 3 describes user interface elements available on mobile devices, while section 4 discusses user interface variants in conjunction with personalization of LBS. To this end, we will illustrate location-based decision-making with applications to finding and choosing a facility in an urban environment – a Hotel Finder and a Bar Finder service. However, we anticipate that such mobile decision support methods will be most useful in emergency response and other situations with high decision equity, in which timely and accurate response plays a crucial role. The paper concludes with a summary and outlook on future research.

2. SPATIAL DECISION SUPPORT AND LOCATION-BASED SERVICES

While GIS are often used to assist decision-makers, more specific spatial decision support systems (SDSS) have been designed to address semi-structured, i.e. non-trivial, geographically explicit decision problems (Densham 1991). The relationship between GIS and SDSS has been described as one in which GIS are used as generators for specific SDSS (Keenan 1995). Besides generic GIS functionality, such as geographic database management and map output, SDSS also use specialized decision support tools such as multi-criteria decision making techniques. MCE methods have been used by the GIS community since about 1990 and applied to decision problems in urban planning, transportation, environmental management and a host of other fields.

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Advances in wireless communications and geospatial technologies have resulted in the development of information services, which are sensitive to the location of a mobile user. These location-based services allow users to query their location from a mobile terminal, such as a cellular phone or Personal Digital Assistant (PDA), and relate it to the surrounding environment. This facilitates the successful completion of tasks, e.g., informing users about the locations of nearby hotels, restaurants, and cultural sites; support during navigation (Winter et al. 2001); and help using public transport systems. Remarkable benefits may be achieved from the widespread adoption of these services, providing large segments of the population with real-time decision support for purposes ranging from trivial (concierge services, location-sensitive games) to critical (emergency response).

In Raubal and Rinner (2004), we presented version 1 of Hotel Finder, an LBS that included an MCE method and demonstrated the use of compensatory decision criteria on the mobile platform. In version 2 of the Hotel Finder (Rinner and Raubal, in press), we added the ordered weighted averaging (OWA) method for MCE, through which the user could define a personal decision strategy in terms of decision risk and amount of tradeoff between criteria. We established the connection between the decision strategy and the personalization of the mobile application. In this paper, we will compare the Hotel Finder with a new Bar Finder derivative to identify easy-to-use user interface design options. Bar Finder is a service that selects bars based on up to six user-defined criteria.

Since the user interface design reflects the preference settings of the user in the MCE procedure, we will review these tasks first. The user selects criteria on which to base his or her decision. Those criteria are chosen from the attribute data available for alternative locations. To make criteria commensurable, they have to be standardized to the same value ranges. Typically, the range runs from zero to one, where zero represents the least desirable, one the most desirable outcome. Users further have to specify the importance given to each criterion by providing criterion importance weights, and can select a decision strategy by determining OWA weights. In the following section, we will discuss how these tasks are mapped to UI elements.

Control	Description
This is a label.	A *Label* control displays static text such as captions or instructions for using the form.
Fred	A *ComboBox* control displays a single column list of choices that appears to drop down when you click it.
	An *Edit* control accepts one or more lines of information from you or displays one or more lines of information provided by the application.
Fred Barney Wilma Betty	A *ListBox* control displays a single or multicolumn list of choices. The columns of the list box cannot be edited.
Calculate	A *Button* control performs a task when you click it. The text on the button describes its actions.
Checked	A *CheckBox* control allows a user to turn on (check) or turn off (uncheck) an option in the form.
Selected	A *RadioButton* control can be combined with other RadioButton controls to provide an exclusive set of choices.
4/20/2001	A *DateTime* control accepts a date from you, or displays a date provided by the application. A calendar appears to drop down when you click it.
	An *UpDown* control allows you to set a discrete value within a finite range of values, via its buddy Edit control. An UpDown control is oriented vertically.
	A *Slider* control allows you to set a discrete value within a finite range of values, via its buddy Edit control. A Slider control is oriented horizontally.
	An *ImageBox* control displays a static picture on the form, such as a company logo. The supported file formats are: JPEG, Mr. Sid, and bitmap files.
	A *SubTable* control provides basic 1-Many support in a form. It displays a spreadsheet style view of a sub table linked to the current feature using a common link field.

Figure 1: User interface elements available in ArcPad (ESRI ArcPad 6.0.2 Help system)

3. USER INTERFACE ELEMENTS FOR LOCATION-BASED SERVICES

In general, user interface elements should be chosen in such a way that the resulting UI leads to maximum usability. Usability describes the extent to which a user can carry out his/her tasks effectively, efficiently, and pleasantly using a computer system. An adapted checklist for the GIS context based on Ravden and Johnson (1989) includes nine important aspects that a well-designed user interface should meet: visual clarity; consistency; compatibility; informative feedback; explicitness; appropriate functionality; flexibility and control; error prevention and correction; and user guidance and support (European Commission 1998). All of these are also relevant for location-based services.

Mobile phone displays are limited in size and resolution compared to larger screens. Furthermore, services for mobile users have to deal with a great variability of client devices. This leads to various constraints, which must be taken into account when choosing elements for UIs. Cartography, traditionally dealing with detailed and precise representations in the form of paper maps or high-resolution displays, is challenged by these limitations in the design of maps for mobile devices.

In the following we focus on the UI design elements available in the ArcPad mobile GIS—the chosen environment for the Hotel Finder and Bar Finder services (Figure 1). The UI elements include Button, ListBox, ComboBox, Slider, and CheckBox. As shown in the series of forms in Figure 2, Buttons and ListBoxes have been used in Hotel Finder for the selection of decision criteria among the feature attributes. ComboBoxes allow selecting ranges for the standardization of criterion values. Sliders determine criterion importance weights. And lastly, CheckBoxes support the choice of a pre-defined decision strategy.

The user interface components listed above are included in developer-defined forms. Besides those, ArcPad's user interface consists of toolbars, a main map area, and a status bar. The appearance and configuration of toolbars can be controlled by the developer or service provider through configuration files. For the Hotel Finder application, we used a basic mapping toolbar, a custom-designed Hotel Finder toolbar, and the status bar. The map area displayed a city map with hotel locations and – after an evaluation is completed – the results in terms of evaluation scores displayed as text next to the top performing locations.

Figure 2: User interface elements in Hotel Finder (Raubal and Rinner 2004)

4. USER INTERFACE VARIANTS AND PERSONALIZATION

Current research into human-computer interaction on small screens suggests that simplicity in design of the UI and presentation of information is paramount (Chincholle et al. 2002a, Chincholle et al. 2002b, Holland et al. 2002, Pospischil et al. 2002, Luchini et al. 2003, Reichenbacher 2003, Gartner 2004). Simplicity in design is needed to overcome three major challenges of using computer applications in a small screened, mobile environment:

1. Mobile devices are used in a minimal attention environment; users have neither the time nor attention to navigate through complicated menus or to interpret confusing results (Pascoe et al. 2000).
2. The input device, most often a stylus or pen-like device, is imprecise and difficult to use.
3. Most importantly, the screens of mobile devices are small and do not nearly provide the resolution of a desktop monitor.

The purpose of a mobile device is to be able to use it while doing other things. "Moving while using" is the term which Pascoe (2000, p. 417) uses to describe this activity. The user splits his or her attention between using the computer program and other activities, such as walking, talking or observing. The goal of the program should be to take up as little a portion of the user's attention as possible. This can be achieved by automating as many portions of the program as possible, and by making the interface both easy and intuitive to use.

Automation is the process of using the computer to complete common steps. There are several parts of both Hotel Finder and Bar Finder where automation could improve the selection process. Most obvious is the inclusion of the global positioning system (GPS) to automatically locate the user instead of the user having to manually input his/her own position. Personalization is also a powerful way to automate common tasks and streamline the user's interaction with the program (Rodden et al. 1998). Instead of the users choosing MCE weights and strategies while using the device in the field, they can specify their preferences before going out into the field. Then, with the touch of one button they could get their results, without having to reenter their preferences every time they wish to run the program (see Figure 3, Table 1).

Figure 3: Simplified user interface of Bar Finder – use of personalized settings for criterion selection and standardization; use of pre-defined weight classes in the Simple Additive Weighting method

Table 1: Weights and their Labels in Bar Finder

Weight	Label
2	Really Want
1	Want
0	Don't Care
-1	Don't Want
-2	Really Don't Want

Streamlining the UI, by removing redundant choices and repeated steps, reduces the user's interaction with the program, and thus the amount of attention they expand on it. A rather simple way of cutting down on clicks is the drop-down weight selection method present in Bar Finder (see Figure 3). By default, all possible criteria are listed, but with a neutral score. When the user changes the score, the criterion is automatically included in the selection process. This differs from Hotel Finder, where criteria are first selected and then weights assigned in a separate menu, which increases the steps needed to complete the MCE analysis.

The stylus-based input method used by many PDAs is imprecise at selecting and difficult to use for entering text. However, PDA applications can be designed around these challenges. Hotel Finder uses three sliding bars to assign importance to criteria on a scale from zero to one hundred (Rinner and Raubal, in press). While these sliders allow for easy visualization of the relative importance of each criterion, it remains very difficult to assign precise weights. Bar Finder, on the other hand, uses a drop down menu with five pre-specified weights (Table 1). Thus, instead of the user having to guide the slider bar exactly to the desired weight, he or she can simply pick from a small list of weights. This means less interaction with the program and therefore less user attention spent on the program. It also means, however, that users have less choice in expressing their preferences. The designer must find a balance between ease of use and user freedom.

Bar Finder was developed with the intention that a user familiar with computers could pick up the program and use it without training. Its design employs several strategies to reduce complexity. Bar Finder uses a MCE method called "simple additive weighting" (SAW), which multiplies each attribute's score by its weight, and sums the results of all attributes to come up with the final score for each location. SAW returns a simple numerical score – in the case of Bar Finder ranging between -24 and +24 depending on an individual bar's attributes and the weighting scheme that the user selects. Hotel Finder uses an MCE method called "ordered weighted averaging" (OWA), which in addition to taking into account the user-assigned weights also incorporates the user's perception of risk. While OWA allows for a more exact definition of the user's preferences, it is a complicated and non-intuitive method, which can be confusing, especially for first time users.

The difference in MCE methods has a large effect on the UI. Hotel Finder, with its multi-step OWA method, has a dialog with four forms, all of which are used in order to complete the MCE analysis. Bar Finder, on the other hand, only has a single form that needs to be completed in order to return evaluation scores. For example, Hotel Finder lets the user specify standardized values for the selected decision criteria while Bar Finder pre-sets the standardized values without user input (e.g. beer price in Table 2). The assumption here is that a service provider regularly reviews the criterion values (e.g. beer prices) that occur and updates the standardization. It is important that mobile LBS applications, whose audience consists primarily of lay users who will not invest a significant amount of time in training, be as simple and easy to use as possible.

Table 2: Pre-defined standardization of values for decision criterion (beer price, in Canadian Dollars) in Bar Finder

Beer Price	Standardized Score
<= $3.63	4
$3.64 - $5.00	3
$5.01 - $5.07	2
$5.08 - $7.75	1

Both Hotel Finder and Bar Finder use a simple mechanism for displaying the final scores of each location: the score for each point is displayed below it. There are several problems with this method. If the map covers a large area, then the numbers will be unreadable, but if the map is zoomed in so that the scores can be easily read, it is difficult to pan through the entire map to find the highest-ranking score.

The small screens of a mobile device present a problem for cartography. The resolutions of hand held devices are usually between 400% and 1200% less than a desktop computer (Urquhart et al. 2004). There are several options for enhancing the cartographic display. A choropleth map could show scores visually. However, the colors could be hard to read when superimposed over a road-heavy area or at a small enough scale. Similarly, proportional symbol maps would allow for users to quickly interpret scores, but the size of the symbols could potentially clutter up the map, making it hard to determine the exact location of the point of interest if the symbols obscure roads.

5. CONCLUSIONS AND OUTLOOK

In this paper, we compared two location-based decision services in terms of their user interface design. We conclude that the UI that needs to be offered depends to a large extent on the functionality of a tool. The functionality of multi-criteria evaluation on LBS varies with parameters such as chosen MCE method, the degree of detail in criterion weighting, and the availability of user-defined criterion standardization. While the Hotel Finder service uses the complex OWA method, offers continuous weighting, and allows users to provide standardized values, the Bar Finder service uses the simpler SAW method, restricts weighting to a few classes, and offers no standardization option. We have shown in detail how these functional simplifications are reflected in an easy-to-use interface while pointing to the restrictions incurred in terms of the actual decision support provided by the tool.

We plan to conduct human subject tests to assess the UI design of Hotel Finder and Bar Finder. We aim at providing general UI design recommendations for location-based decision support tools. For example, providing two forms of information display might further improve the readability of evaluation results. One form would be a table showing the names of locations and their ranks or scores. This would provide a quick overview of the results so that the users could instantly know which location best meets their preferences. The users could then enter a map mode, which places their choice within a spatial context and allows them to plan a route to reach it, possibly with the help of an automated route-finding program. While having modes adds some complexity to the program, it would enable the user to interpret the results of the analysis faster and with less interaction with the program.

Importance weighting of criteria plays a crucial role in decision-making. We suggest defining criterion weights using categories (such as high/medium/low) represented by radio buttons or drop-down menu options instead of continuous percent values represented by sliders. Users can quickly grasp the differences between fixed categories. We also suggest relaxing the constraints of a spatial filter on decision alternatives through fuzzification. This ensures that good options, which lie just outside a buffer, are also taken into account. Limitations in input devices could be tackled by voice input to communicate decision-making preferences.

In terms of visualization of MCE results, another guideline might be to map interim results at any stage of the MCE process using default settings. In addition, using range-graded symbols instead of proportional symbols for the display of rankings may be more effective because proportional symbol sizes cannot easily be distinguished on a small display. Range-graded symbols with one class for the best-ranked facility, one class for the next two alternatives, and a third class for the remaining feasible alternatives might be the best cartographic option. An indication of which criterion was most influential for the decision outcome could further enhance the usability as users may want to understand the reasons for a particular result.

ACKNOWLEDGEMENTS

This research was partially funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) and by the GEOIDE Network of Centres of Excellence.

REFERENCES

Cartwright, W., Crampton, J., Gartner, G., Miller, S., Mitchell, K., Siekierska, E., and Wood, J., 2001. Geospatial Information Visualization User Interface Issues. *Cartography and Geographic Information Science,* 28(1): 45-60.

Chincholle, D., Eriksson, M., and Burden, A., 2002a. Location-Sensitive Services: It's Now Ready for Prime Time On Cellular Phones! In *DIS '02: Proceedings of the Conference on Designing Interactive Systems*, pp. 331-334.

Chincholle, D., Goldstein, M., Nyberg, M., and Eriksson, M., 2002b. Lost or Found? A Usability Evaluation of a Mobile Navigation and Location-Based Service. In *Mobile HCI '02: Proceedings of the 4th International Symposium on Mobile Human-Computer Interaction*, pp. 211-224.

Clarke, K., 2004. Mobile Mapping and Geographic Information Systems. *Cartography and Geographic Information Science,* 31(3): 131-136.

Densham, P., 1991. Spatial Decision Support Systems. In D.J. Maguire, M.F. Goodchild, and D.W. Rhind (Ed.) Geographical Information Systems: Principles and Applications, Longman, London, pp. 403-412.

European Commission, 1998. Guidelines for Best Practice in User Interface for GIS (ESPRIT/ESSI project no. 21580).

Gartner, G., 2004. Location-Based Mobile Pedestrian Navigation Services - The Role of Multimedia Cartography. In *International Joint Workshop on Ubiquitous, Pervasive and Internet Mapping*, Tokyo, Japan. ICA.

Holland, S., Morse, D. R., and Gedenryd, H., 2002. Direct Combination: A new User Interaction Principal for Mobile and Ubiquitous HCI. In *Mobile HCI '02: Proceedings of the 4th International Symposium on Mobile Human-Computer Interaction*, pp. 108-122.

Keenan, P., 1997. Using a GIS as a DSS Generator. DSSResources.COM, 12/17/2004. Available online at http://dssresources.com/papers/features/keenan/keenan12172004.html [last access: 9.6.2005]

Luchini, K., Quintana, C., and Soloway, E., 2003. Pocket Picomap: A Case Study in Designing and Assessing a Handheld Concept Mapping Tool for Learners. In *CHI '03: Proceedings of the conference on Human factors in computing systems*, pp. 321-328. ACM Press.

Pascoe, J., Ryan, N., and Morse, D., 2000. Using While Moving: HCI Issues in Fieldwork Environments. *ACM Transactions on Computer-Human Interaction*, 7(3): 417-437.

Pospischil, G., Umlauft, M., and Michlmayr, E. 2002. Designing LOLA@, A Mobile Tourist Guide for UMTS. In *Mobile HCI '02: Proceedings of the 4th International Symposium on Mobile Human-Computer Interaction*, pp. 140-154.

Raubal, M. and Rinner, C., 2004. Multi-Criteria Decision Analysis for Location Based Services. In S.A. Brandt (ed.) Proceedings of the 12th International Conference on Geoinformatics, pp. 47-53.

Ravden, S. and Johnson, G., 1989. Evaluating Usability of Human-Computer Interfaces: A Practical Method. Chichester: Ellis Horwood Limited.

Reichenbacher, T., 2003. Adaptive Methods for Mobile Cartography. In *Proceedings of the 21st International Cartographic Conference*, pp. 1311-1323, Durban, South Africa.

Rinner, C. and Raubal, M., in press. Personalized Multi-Criteria Decision Strategies in Location-based Decision Support. *Journal of Geographic Information Sciences* 11(1) (June 2005).

Rodden, T., Cheverst, K., Davies, N., and Dix, A., 1998. Exploiting Context in HCI Design for Mobile Systems. Workshop on Human Computer Interaction with Mobile Devices, 1998.

Urquhart, K., Cartweight, W., Miller, S., Mitchell, K., and Benda, P., 2004. Exploring the Usefulness of Cartographic Representations for Location-Based Services in an Austrian Context. *Journal of Spatial Science*, 49(1): 71-87.

Winter, S., Pontikakis, E., and Raubal, M., 2001. LBS for Real-Time Navigation - A Scenario. *GeoInformatics*, 4: 6-9.