Optimal Route Selection with Route Planners: Results of a Desktop Usability Study

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ABSTRACT

Route planners request user input about preferred route characteristics in order to provide the user with the optimal route. Although navigators have a general idea about what constitutes the optimal route, this may be difficult to express in the search interface. Further, the relative importance of route selection criteria for a user often depends on the route alternatives actually found between start and destination. Based on a desktop study, this research examines how dynamic exploration of a pre-computed set of feasible routes supports the user in getting an overview of existing routes, how allowing users to weight criteria can help them to retrieve optimal routes, and how context information about route alternatives provided during route choice reduces ineffective steps while settings search parameters in the user interface.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Representation]: User Interfaces – Evaluation/methodology, Graphical user interfaces (GUI).

General Terms
Design, Experimentation, Human Factors

Keywords
Dynamic route exploration, context information, spatial decision support

1. INTRODUCTION

Route planners help the user to identify the best route among several available alternatives under consideration of various evaluation criteria. Evaluation criteria involve the measuring of route attributes, such as the route length or the total number of turns. A combination of weighted evaluation criteria gives the objective function which needs to be maximized or minimized in an optimization problem. This paper presents and evaluates some alternative approaches and extensions to common route planner designs that are expected to increase the user’s capability in identifying and specifying the optimal route. It focuses on route planners for cyclists, where a small street network (with an area of approximately 4x2 km²) is sufficient to simulate realistic intra-urban trips and to identify some general preferences regarding the user interface design.

Decision rules provide the basis for sorting and ranking the decision alternatives under consideration of route attributes and user preferences [7], where distinction is made between compensatory and non-compensatory decision rules. Eliminatory constraints eliminate those decision alternatives from further consideration that do not meet thresholds set for evaluation criteria. The importance of eliminatory constraints in the design of route planners was demonstrated in an earlier study [6]. Existing route planner interfaces vary in the decision rules they support, independent of the transportation mode. Most bicycle route planners, such as ViaMichelin, use a default optimization criterion hidden from the user, or they allow the user to select a single optimization criterion, such as shortest path or a path close to tourist routes. Fewer bicycle route planners provide an additional function for importance weighting of criteria, such as between fast, scenic, and short routes, or for setting eliminatory constraints, such as avoiding traffic lights.

Results from an earlier study indicate that the route choice behavior of cyclists in urban environments includes a compensatory decision component [4]. This suggests that importance weighting of criteria is an essential functionality for intuitive route planners. This can, for example, be implemented through slider bars, which will be evaluated in the empirical study of this paper. A shortcoming of existing route planners is that the user cannot dynamically explore the set of feasible routes, although various visual decision analysis tools, such as CommonGIS [1], include dynamic query functionality as a standard function. Exploratory search provides immediate feedback to the user in form of an updated query result, and emanates a sense of control the user gains over the query [8]. The clarity of the user interface can be increased through extra information which adds a new piece of structure to the system and makes it simpler to use. The use of dynamic route exploration and annotated context information will be evaluated in the presented desktop study as well.

The term dynamic route exploration as used in this paper refers to pre-trip route planning and should not be confused with dynamic updating of the route during the traversal of the route, as it may be
necessary through a blocked road. Google Maps\(^1\) provides another
type of dynamic route exploration, where the user can add
additional waypoints between start and destination during route
planning, and the application immediately updates the best route
leading through the new waypoint.

2. USABILITY STUDY
A route planner application was programmed in Delphi and run
on a desktop PC. It provides seven user interface designs, which
can be activated one at a time for user evaluation. The underlying
data set uses part of the street network of Vienna, Austria. Besides
various attributes for street segments and intersections, the route
search algorithm considers one-way and turn restrictions.

The 30 participants were undergraduates from Saint Cloud State
University, Minnesota, in an introductory GIS course who
participated in the study to receive partial course credit. Ages
ranged from 19 to 49 years (median = 22.5).

Participants were following the instructions displayed on a Web
browser, which guided them in a random order through the seven
route planners. Participants had unlimited time to explore the
functionality of each route planner design. After the exploration
of all seven designs, the route planners were re-opened in the
same sequence as before. With the route planner open,
participants were then asked to complete a paper questionnaire for
the corresponding design, which yielded seven sets of
questionnaires from each participant.

2.1 Hypotheses
Based on the shortcomings identified in current route planner
designs (section 1), we suggest some route search functionalities
to improve various facets of user interface design.

**Hypothesis 1.** Slider bars are more supportive of defining the
optimal route than radio buttons or hyperlinks that provide no
multicriteria weighting functionality.

**Hypothesis 2.** Designs with dynamic exploration are more supportive of providing an overview of existing route alternatives
than designs without dynamic exploration.

**Hypothesis 3.** Context information helps the user to predict the
effect of changes in the search parameters on the search result.

2.2 Questionnaire Setup
For each of the seven route planner designs, participants were
asked to rate the following statements on a scale of 0 (not agree)
to 10 (fully agree):

a. A search result with this design gives the optimal route and
realizes the user’s intended preferences in the best possible way.
b. This design is good for getting an overview of existing route
alternatives.
c. If a search parameter is changed (e.g., slider bar, radio
button) the user can predict and assess the effect of the changes
on the search outcome.
d. This design requires too much waiting to get a search result.

3. ROUTE PLANNER DESIGNS
Based on the three hypotheses three major design characteristics
were used for the group designs. These design characteristics are
represented in the three capitalized columns in Table 1.

- Frequency of computation (FREQ): The first group
designs 1 and 2) triggers a new route computation each time a
search parameter is changed, whereas the latter group (designs 3-
7) allows dynamic exploration of feasible routes within a pre-
computed route set.

- Weighting functionality (WE). Designs with slider bars
designs 2, 4-7) allow the user to define compromise routes. On
the contrary, designs with radio buttons (1) or hyperlinks (3)
allow the user to specify only one search criterion at a time.

- Context information (CONT): Three designs (5-7)
provide different variations of context information, expressing the
potential or sensitivity of slider bars for changing respectively
improving the search result.

<table>
<thead>
<tr>
<th>#</th>
<th>FREQ</th>
<th>WE</th>
<th>CONT</th>
<th>Type</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>on-demand</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>pre-computation</td>
<td>yes</td>
<td>no</td>
<td>potential</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>range lines</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>range numbers</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>yes</td>
<td>no</td>
<td>sensitivity</td>
<td>range lines</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>yes</td>
<td>no</td>
<td>tic marks</td>
<td>range numbers</td>
<td>10</td>
</tr>
</tbody>
</table>

Analysis of user responses show how the combinations of three
major parameters (five out of eight possible combinations are
used) and three different context types will affect the following
dependent variables: find the optimal route, get an overview of
route alternatives, predict the effects of changed parameters.

3.1 Implemented route selection criteria
The number of route selection criteria that car drivers, cyclists,
and pedestrians consider in route choice is large [3; 4]. In order to
reduce this large number in the user interface, route selection
criteria can be split into two tiers [5]. Higher-level criteria are
more general and composed of one or several lower-level criteria.
This two-tiered approach, which allows the user to set preferences
either on a more general or on a more detailed level, is realized in
all seven designs (Table 2).

Due to the diverse nature of criteria provided in the route planner,
several algorithms are combined in the computation of the optimal
path respectively the Pareto optimal set of paths. Whereas
some shortest path (SP) algorithms can handle negative edge cost,
such as the Bellman-Moore-Ford algorithm, negative cycles,
which usually occur in real street networks, make the problem
intractable. Negative cost are caused by the existence of features
that are perceived as benefit criteria, such as sights along a route.
To find routes that maximize benefit criteria, a genetic algorithm
was implemented that starts from an initial population of paths
generated through random walking [2]. To minimize intersection-
related cost, the street network graph is on the fly converted to a
line graph [9]. Based on the user’s settings of preference weights,
the route with the highest utility is finally retrieved through a
linear combination of desirability ratings of attribute levels.

\(^1\) http://maps.google.com/
Table 2. Two-tiered structure of route selection criteria

<table>
<thead>
<tr>
<th>Segment-related</th>
<th>Intersection-related</th>
<th>Lower-level</th>
<th>Higher-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>travel distance</td>
<td>traffic lights</td>
<td>fast</td>
<td></td>
</tr>
<tr>
<td>number of sights</td>
<td>turns</td>
<td>safe</td>
<td></td>
</tr>
<tr>
<td>% of separate bicycle paths</td>
<td>turn complexity</td>
<td>simple</td>
<td></td>
</tr>
<tr>
<td>% of routes with little traffic</td>
<td>% of parks</td>
<td>attractive</td>
<td></td>
</tr>
<tr>
<td>% of parks</td>
<td>% of flat streets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of paved streets</td>
<td>% of shopping streets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% without tramway</td>
<td>% with direction of car flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of shopping streets</td>
<td>% of paved streets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of parks</td>
<td>% of flat streets</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2 Functionality of the user interface designs

In all seven designs the user selects start (S) and destination (D) from a map. After this, search parameters can be specified (for designs 1 and 2) and the optimal route is computed. Alternatively, a set of feasible routes is pre-computed (for designs 3-7), based on which the user can make the selection.

In design 1, the user can select one optimization criterion by clicking one of the radio buttons, which triggers the computation. Similarly, design 3 allows the user to select only one optimization criterion. However, design 3 pre-computes a set of feasible routes once the user has defined start and destination. From this route set, the user can select the optimization criterion through clicking a hyperlink which retrieves the corresponding route from the route set and updates the route immediately on the map.

Designs 5 and 6 expand the functionality of design 4 through annotated context information about feasible route alternatives that indicates the potential for a criterion to improve the returned route. Design 5 (Figure 1a) uses numerical labels to indicate the range of values for each criterion, based on the pre-computed route set. The left number below a slider bar shows the value for the worst alternative regarding the criterion under consideration, and the right number shows the one for the best alternative. Numbers in boldface indicate the attribute values for the currently visualized route. To overcome the disadvantage of too many numbers to be read, range lines on the slider bars could be used as a visual aid instead (Figure 1b). Figure 1 compares the visualization of context information of route alternatives for the same start-destination pair (only a part of lower level criteria is shown). A small range of attribute values is mapped to a short range line.

Design 7 (Figure 2) uses tic marks to indicate the sensitivity of slider bars, as it can be found in other spatial exploratory tools [1]. Based on the current position of all slider bars and the pre-computed routes, the application computes for each slider bar the minimum amount it needs to be dragged to the left (dark tic mark) or right (light tic mark) in order to retrieve the next closest optimal route with changed weight settings. A non-existent tic mark on the left or right indicates that a change of the slider bar in that direction will not affect the search result.

4. RESULTS

As predicted in hypothesis 1, designs with slider bars (2, 4-7) were rated more helpful in specifying the optimal route than designs without slider bars, i.e., radio buttons (design 1) or hyperlinks (design 3) (mean 2,4-7=7.47, mean 1,3=5.97, p=0.000, Independent Samples T-Test). The results suggest that the superiority of designs with slider bars is independent of whether or whether not dynamic exploration is provided (Figure 3).

Hypothesis 2 predicts that designs with dynamic browsing functionality (3-7) provide a better overview of existing routes than designs without (design 1 and 2). As expected the mean rating was higher for the first group (7.01 vs. 6.64), but differences were not significant (p>0.241). Design 7 which combines dynamic exploration and tic marks performed best (Figure 4). It was significantly higher rated than designs 1-5.
(p<0.05), and a statistical trend for a higher rating than design 6 was identified (p<0.10) (One-Way ANOVA Post Hoc Tests).

![Figure 3. Support in specifying the optimal route](image)

![Figure 4. Support in getting an overview of routes](image)

With regard to hypothesis 3, two groups of designs can be distinguished. The first group (1-radio button; 2-slider bar; 3-hyperlink; 4-slider bar) does not provide context information, whereas the second group comprises designs 5-7 that provide slider bars and context information (see Figure 1 and Figure 2). A comparison of means shows a statistical trend for better predictability with the second group (mean1-4=6.34, mean5-7=6.92, p=.078, One-Way ANOVA). Design 7 received the highest ratings (Figure 5) and performed significantly better than designs 1-5 (p<0.05) (One-Way ANOVA Post Hoc Tests).

![Figure 5. Rated ability to predict the effects of changed search parameters](image)

5. CONCLUSIONS
The study showed that one single design cannot perform well on all evaluated items. With only few route options and compromise routes between start and destination, a design without pre-computation will be more efficient and slider bars are not necessary. On the contrary, if there is a large variety of feasible routes, a pre-computation of routes as well as slider bars are useful because this allows a more thorough exploration of route options. Tic marks were identified useful in assessing the effect of changed parameters, and in providing an overview of route alternatives.

6. ACKNOWLEDGMENTS
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7. REFERENCES