Testing Moving Map Algorithms

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Abstract
This position paper introduces the challenges in designing and conducting an ecologically valid study of the impacts of GPS moving map rotations on the performance of way-finding and orientation tasks. A process for running a less valid lab study (preliminary lab assessment) will be described followed by a more focused ecologically valid field study. The advantages and limitations of the approaches are discussed.

Keywords
Spatial cognition, way finding, orientation, GPS, moving map, field-testing, ecological validity

Introduction
Can a less valid lab study be used as a basis for a more focused and ecologically valid field study? Can the findings of such a lab study be used without further validation? These are the issues addressed in this position paper.

Background
Navigation systems available on Personal Digital Assistants (PDAs), driven by GPS systems to support orientation and way finding, use several algorithms for map rotation. With the help of these systems, users do not have to perform mental rotations of north-up maps and can, therefore, undertake navigation with fewer errors. Given the variety of a map rotation schemes, it

figure 1. The emulated moving map display on a GPS-driven PDA.

was assumed that some of the map rotation schemes would support users in orientation and way finding tasks better than others. Six different map rotation algorithms were developed to test this assumption. The main difference between the algorithms was the threshold by which a rotation was triggered relative to a user's movements. The map rotations are described below:

- No Threshold: The map rotates with every change in the user's orientation.
- Right Angle: The map rotates only when the user changes orientation by 90, 180, and/or 270 degrees.
- Minimum Threshold: The map rotates only if the difference in the heading value (direction the user has rotated) is greater than the preset threshold for rotation.
- Maximum Threshold: The map rotates but will only rotate to a maximum rotation specified by the user.
- Min/Max Threshold: A combination of the Minimum and Maximum threshold schemes.
- Adaptive Threshold: The minimum and maximum threshold values are calculated automatically according to the history of the user's past headings.

The Challenges

We were faced with two inter-related challenges: 1. How can we measure the impact of the different rotation algorithms on way finding and orientation performance in an ecologically valid manner? 2. How can we technically track and record performance in the field?

The immediate answer was to design and run a field study in which participants would actually perform way-finding tasks and test their orientation. However, running such a field study introduced the following problems: 1. What would be an ecologically valid experimental manipulation that will force map rotation while using it to way-find? 2. How can we isolate the potential impact of the map rotation algorithm from other possible impacts on way-finding and orientation performance? 3. How can we test all six rotation algorithms? Should it be a within or a between-participant design?

The experimental design problems proved to be more challenging than the technical problems. In view of this, it was decided to divide the project into two phases: a lab study to be followed up with a smaller, more focused field study.

Lab Study

Rationale

The lab study tested the six rotation algorithms with the aim of finding the extent to which users were able to perceive differences between them for a task of pedestrian navigation. With this approach we hoped to achieve the following: 1. Identify the algorithms that are distinguished perceptually and field test only those; 2. Identify users' preferences with respect to the different rotation algorithms.

Method

The approach was to use an on-screen emulation of a GPS-driven PDA with moving map display (see figure 1). Eight sequences or simulated walks around the Carleton University campus were produced using a sequence generator program based on GPS coordinates and developed in C++. The sequences depicted a simulated user walking in a zigzag or curved pattern of movement and included four different locations on the campus. Participants recruited for the study were requested to observe a short animated clip of a simulated walking person around campus. Each participant was presented with eight sequences (simulated path of a person walking on campus) and six rotation schemes per sequence for a total of 48 simulated walks. Participants were asked to provide two ratings on a scale after each sequence was played. The scales asked two questions:

- How well did the map rotation match the movements of the holder of the Pocket PC (in the animated clip)?
- How confident are you in indicating the building or landmark you are now facing?

The purpose of these scales was to determine if users could perceive the difference between different rotation schemes and whether they had a strong preference or dislike for any particular rotation scheme.   The scales were continuous, un-marked lines anchored with the two extreme dimension categories on either side of the continuum.

Findings

The mean ratings of question 1 for each algorithm and sequence type (curve, zigzag) were computed and analyzed. It appears that the right angle algorithm was the worst for both zigzag and curve patterns of movement. The top two ratings for the curve sequences were for the no threshold and min algorithms, respectively, while the top two ratings for the zigzag pattern movements were for the min-max and max only algorithms. The third highest rating for both zigzag and curve patterns of movement were for the adaptive algorithm.

The findings of the lab study are in line with researchers who have indicated that a good navigation service should include more than orientation and location to assist users in their way-finding [1], [2]. Whereas previous research indicated that rotation helps to lower the cognitive burden of the navigator [3], [4], this study implied that adaptive rotation schemes in moving maps needs in-depth consideration of the factors affecting rotation schemes such as the type of movements necessary to reach a destination. Curved movements may require rotation schemes that are different from zigzag movements.

Planned Field Study

The field study seeks to confirm the findings of the lab study and validate if users' perceptions and preferences are in line with their way-finding and orientation performance using the various rotation schemes with an actual GPS enabled PDA.

The study will be a 6 X 2 mixed design where a group of 25 participants will be asked to perform 6 way-finding tasks on the Carleton campus using a curved pattern of movement and another group of 25 participants will be asked to perform 6 way-finding tasks using a zigzag pattern of movement. A way-finding task consists of navigating from one landmark such as a building on the map to another building on the map. There will be a designated start, mid and end point for each way-finding task. The 6 rotation schemes used for each way-finding task will be assigned randomly such that each participant will have had experience with all six rotation schemes. They will encounter one type of algorithm per way-finding sequence. Three "alignment" or orientation questions will be asked while performing each way-finding task. This is where a participant will be asked to align themselves to the building that is highlighted and flashing on the map. The orientation tasks will correspond with the start, mid and end points of the way-finding route. When participants arrive at a point, which triggers the flashing of a building for an alignment task, they will push a button indicating they have seen the flashing and will align themselves with the target flashing on the map. Once the participants have aligned themselves they will push the stop button and continue their way-finding task. Participant's routes and performance on alignment tasks while navigating using the PDA GPS enabled device will be automatically recorded for further analysis.

Lessons Learned and Open Issues

Did the lab study provide any valid findings that can be utilized to address the research questions? The findings make sense and are in line with some previous research findings. In addition, the results of the laboratory study can help in building some new adaptive rotation schemes and testing them on users by asking them to perform navigation tasks. However, one may claim that the findings only represent perceptions and preferences and cannot be applied to actual way finding and orientation.

Did the lab study help in scoping and focusing the field study? In our assessment, the lab study failed to help us select, confidently, one or two map rotation algorithms for a more valid field test. In addition, it failed to help resolve some of the experimental design challenges we are still facing with the field study. While findings of the filed study may verify and validate the key findings of the lab study, the efficacy of the process we are following in this project is still an open question.

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