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Insights into Visualizing Trajectory Recommendation Rankings

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ABSTRACT

Maps are the center point of many ancient and current visualizations. Recently, increased usage of mobile devices has promoted application of map-based visualizations, specially for navigation and point of interest representation. The types of representations on these maps however have not changed significantly. In this paper we discuss our studies on map visualizations in the context of visualizing trajectories and their ranking order for a trip recommender system. We have asked set of participants to demonstrate how they perceive trajectory recommendations and how they represent their rankings. We hope our findings help trip recommender tool designers to choose more human centered visual representations.

1. INTRODUCTION

Trajectory visualization is not new and has been subject of many ancient documents and visual depictions. It dates back to development and use of maps where cartographers used different ways to highlight certain paths and places on maps [3].In recent years, frequent use of mobile devices has triggered widespread adaptation of digital maps. Hence, the visual depictions on maps have gained more importance, for example as navigation aid or identification of places of interest. These map based visualizations are often targeted to specific application of the map. For example navigation systems generally provide a binary representations of trajectory recommendations, i.e. they highlight the (assumed) best option with a distinctive color, and represent other alternative options with less distinctive color. An example of such representation in Google Maps is provided in Figure 1. Such representation tend to capture ranking by means of dual coding and textual information representations. For example distance or travel duration of each route is separately depicted on the trajectory.

In this paper we look at more general application of map based visualization and trajectory representations in the context of a trip recommender system. We study how end users of such systems would like to receive certain recommendations. More specifically, we investigate the possibilities and different approaches to representing trajectory recommendations and rankings of trajectories. We do so by conducting a user study to investigating user preferences in representing path recommendation rankings.

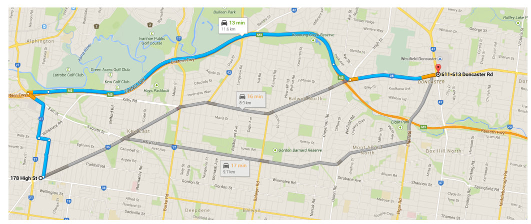

Figure 1: Google Map representation of three trajectories.

This paper is organized as follows: Section 2 briefly discusses background on trajectory and route visualizations. Section 3 outlines our study and discusses the preliminary results. Finally, Section 4 concludes the paper and outlines our future work.

2. BACKGROUND

A trajectory refers to the meaningful parts of a path that a moving object makes during its movement observation. In *Visual Analytics of Movement*, Andrienko et al. provide a selection of approaches for representing set of attributes on trajectories [2]. For example, using varying strokes, colors and opacity, space-time cubes, and clustering of trajectories. Tominski et al. proposed to show different attributes of a trajectory as stacks of trajectory bands [13]. In their approach, a 2D map serves as a reference for the spatial context, and the trajectories are visualized as stacked 3D trajectory bands. This approach is among the few that address multiple attributes. However, it is most effective when attributes of only one trajectory is being investigated. Otherwise, the image will be cluttered and the actual map will not be visible. These representations are not generally designed for recommending possible paths and are rather targeted to visual analytics; i.e. expert users use them to gain insights. LineUp, provides an interactive technique for creating and visualizing multi attribute rankings [5]. It uses bar graphs to represent rankings and stacked bar graphs to incorporate multiple attributes in the ranking representation. Users can alter the effects of each attribute on the rankings by interacting with the visualization. Other approaches (e.g. TrajRank [9] and OnMyway [12]) provide an interactive user interface to show rankings alongside the maps and trajectories. Users would interact with the trajectories to see details of varying

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attributes.

Route visualizations provide directions from one (or set of) location to another. Agrawala et al. analyzed a variety hand-written route visualizations. They discovered that the focus of route visualizations is more on roads, turning points and local landmarks [1]. As a result, distance, angle and shape of roads were generally distorted and considered to clutter the map [1]. A good example of rout maps is subway maps. Subway maps are designed to relay how many stops are there between your current location and your destination and the composition of different subway lines, rather than shape of the routs or the actual distance between stops [14]. Other approaches proposed using detail lenses to show different steps of the trip via magnified lenses [6]. Liu et al. proposed series of visualizations to analyze route diversity [8], i.e different routes to reach the same destination. Their visualizations were targeted to display the high dimensional attributes and statistics associated with different routes to help users analyze diversity patterns. As a result no raking or indication of possible individual routes was provided.

The most-effective tourist maps include only those elements that are semantically meaningful (such as the home of a well-known writer), visually distinctive (such as an oddly shaped or colored building), or placed in a structurally important location (such as a building at a prominent intersection) [11]. Previous approaches have been mostly focused on how to generate these recommendations rather than novel ways of representing them to users [4]. For example *Next Stop Recommender* uses pins to demonstrate locations of interest and different colors to distinguish between routes [10]. Or *MyTravelPal* displays clusters of areas of interest over geographical regions [7]. Users can then click on these clusters and zoom-in on the areas. These focus on background technique rather than representation motivated us to study how users perceive trajectory recommendations. This study is outlined in the following section.

3. STUDY

When representing list-wise item recommendations, it is common practice to represent the more interesting items at the top and the least interesting ones at the bottom. Trajectory recommendations are often displayed on maps. As a result, the list-wise ordering of the recommendations is not possible. This will mandate the use of distinctive visual representations to demonstrate rankings.

Designing visualizations for ranking is challenging as it is not always obvious how users interpret visual representations, or if different users would perceive the same ranking order. This has also been mentioned by Jacques Bertin in his 1983 book *Semiology of Graphics: Diagrams, Networks, Maps* [3]: *When a variable is ordered, it is not necessary to consult the legend to be able to order the categories. It is obvious that this is before that and after the other.*

Consequently, we designed our user study to see how users perceive trajectory recommendations. We used this study to examine user's understanding of how order of recommendations should be represented. This could also be seen as an opinion survey into possible design choices for trajectory recommendation representations. In the following subsections we describe this user study design and our findings.

3.1 Experiment Setup

We designed an experiment to see how participants would represent a list of trajectory recommendations to a friend. In this experiment, we presented each participant with a depiction of an imaginary map with three paths to go from A to B as in Figure 2. To scope the possibilities to visual and annotational representations, we requested that participants only use drawings and markings rather than textual directional informations. For example, they were asked not to show order by numbers or write text that points to the trajectory of choice, e.g. "take this road". The instruction provided to each participant read:

Consider the paths in the above figure. There are three possible paths connecting City A to City B marked by 1 to 3. The order to which path is better is 2-3-1, that is 2 is the best path and 1 is the worst.
Assume that you want to recommend this order to your friend. If your only way of communication is via the picture and you cannot write the order in words, how would you show the order on the map?
There is no limitation in use of graphical symbols.

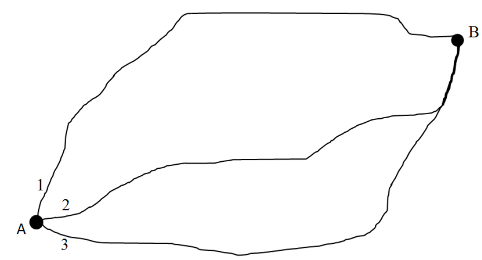


Figure 2: Experiment trajectories. Participants needed to mark the three trajectories according to a given order.

We then provided each participant with the map and set of markers with different colors in case they needed to use varying colors. They were then told to draw as many methods as they can think of.

3.2 Participants

Participants were recruited based on convenience sampling, i.e. we asked our friends and colleagues to participate. Overall 25 participants were recruited (age range 23-58). Some participants were in groups (two groups with 2 participants and a group of 3 participants) and others were recruited individually. Groups were given only one sheet to mark on and were asked to discuss amongst themselves.

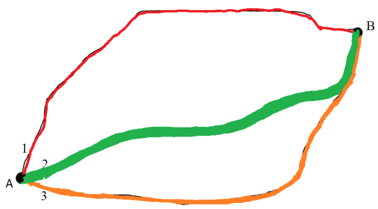
Table 1: Brief demographics of participants

	Gender	IT background	Non-IT
Male	17	9	8
Female	8	6	2
Total	25	15	10

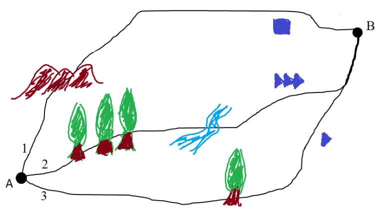
Table 1 provides a brief demographics of the participants. We have grouped our participants based on their background in Information Technology (IT). We should also note that only two participants had not used navigation devices before. The rest had experienced or were currently using at least one navigation device or application.

3.3 Results and discussion

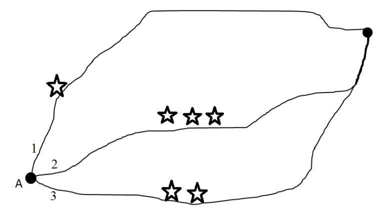
From our 25 participants, we have collected 50 sample (non-distinctive) methods of representing trajectory recom-



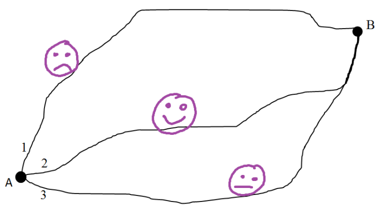
(a) Stroke, color, and dashed lines, appeared 18 times.



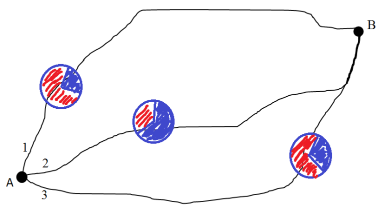
(b) Context based glyphs, appeared 13 times.



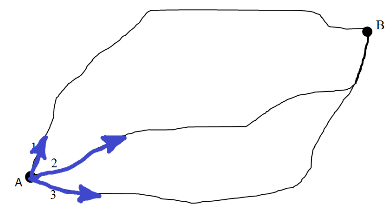
(c) Shapes and rankings, appeared 8 times.



(d) Emoticons, appeared 7 times.



(e) Charts, appeared 4 times.



(f) Arrows, appeared once.

Figure 3: Samples of trajectory recommendation representations and their frequency of appearance in results.

mendations. Some participants proposed only one method and some proposed multiple methods. Some participants provided multiple versions of each method; We here group them as different representations for the same method. These collectively account for 72 representations. We have extracted and characterized these methods into six visualizations groups depending on their number of appearance; five as seen on Figure 3 a-e, and an "other" category. In the following we describe these methods in more details.

Use of strokes, color, and dashed lines was the predominant method of choice by our participants, with each category being mentioned 6, 10, and 2 respectively. Some participants used dual coding, i.e. combination of these methods to reiterate their ranking representation. For example, some used different strokes and marked the top priority by green, middle rank by yellow, and lowest rank by red. We believe the high number of appearance of this category may have been affected by our participants' experience with navigations systems (23 out of 25 had experience with at least one navigation system). Only one participant mentioned color-blindness and proposed using dashed lines with varying strokes as a result.

Second most proposed representation was the context-based glyphs. Often we were asked by the participants "What is the basis for this ranking". We would then describe that there is no specific basis for why one path is better than the other, but we assume that there is an agreement between you and recipient of the annotated picture. Then they would come up with various contexts to show goodness of each choice based on their category of choice. For example, the better choice was represented by scenery (e.g. trees, rivers and lakes as in Figure 3(b)), or type of the road (high way, toll road). A user mentioned that based on what is understood and accepted in their culture, a mountainous road is a hard road to take. As a result proposed showing the bad choice by mountains. Some other examples pointed to the characteristics of the road. For example, longer distance was demonstrated by number of kilometers, faster route was demonstrated by turtle-rabbit-horse combination or hour glass (sand clock), or fast forward and stop as demonstrated by blue shapes in Figure 3(b). Choice of travel was also grouped as context based methods. For example traveling by bus, bike or vehicle. Three participants used traffic sings and claimed these signs are accepted and used worldwide and hence are good representations for rankings. Accordingly speed limits, distance, and traffic stop sign was used.

Use of shapes for ranking appeared 8 times. For example, stars to represent the scale, or number of thumb-ups. It was mentioned that hotel review rankings or users' experience with social media *like* system has had an effect on this choice. With shapes, e.g. stars, it is possible to demonstrate the scale as well. For example empty stars can denote the full scale and the ranking would be demonstrated by filled stars, or by highlighting the area surrounding the stars as in energy ratings. Consequently, it is possible to provide fuzzy rankings, e.g. filling half of the shape.

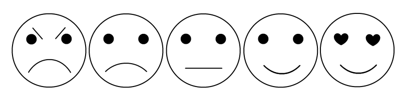


Figure 4: Representing a 5 point Likert scale by emoticons (smiley faces).

Among interesting findings of this study is the proposal to use emoticons (or emoji) to represent order of recommendations. This way the smiley face would represent the top choice, and for example a neutral face would show the middle option. Participants mostly agreed that emoticons are very easy to understand and they assume the recipient of the picture would understand it too, regardless of the context or basis of the ranking. When asked what if the choices were more than three by the instructor, some participants even came up with new smiley faces. We are also observing increased use of smiley faces in web based surveys as a replacement for Likert scales. Figure 4 provides an example of such representation. It is presumed that this representation is more understandable for general public specifically when the target audience is spread across a wide range of age and demographics.

Charts appeared four times as a representation for ranking. From these four, two used bar chart metaphor, another stacked bar chart to depict multiple categories, and one used pie chart. The bar chart examples showed the goodness as the height of the bar as in a histogram. The other two, proposed showing multiple categories by charts (stacked and pie) accompanied by a legend. The pie chart example demonstrated on Figure 3(e) is one example of such representations.

A participant proposed using arrows to demonstrate order. It was proposed to show goodness by the length of the arrow (as in Figure 3(f)). Among other methods were use of fractions for example 10/10 (10 out of 10), using full circle for best option and demonstrating lower ranks with partially filled circle (as in different phases of moon eclipse), , and use of Olympic medal tally (gold/silver/bronze) for each route.

We deliberately designed the paths in a way that two paths converge at some point. This was to see how users would perceive this as a factor in deciding the graphical annotations. Our findings indicate that it was not a significant decision factor for users. We believe this could be due to most our users not noticing this convergence.

In a trip recommender system, trajectory visualizations may need to represent multiple categories. For example scenery, modes of transport, distance, and travel duration among others. Hence, an approach that can include more than one attribute in ranking representation would be highly desired. From our results, context-based representations can fit this category of representation nicely by depicting the actual reason for high ranks on the map. For example using trees and rivers to demonstrate scenery, together with freeway and toll signs to demonstrate road conditions. There is however a limit in how much context can be depicted on the map before it becomes cluttered. Or how to differentiate good and better options; Do we show the better option with bigger context demonstration, or increase the number of context (e.g. show more trees). Most of our participants demonstrated more than one attribute when proposing context based visualizations. Only one participant using stroke and color noticed this and proposed to highlight areas of the road that are good by green and the rest red and let the user decide goodness based on proportion of green and red strokes on the trajectories.

4. CONCLUSION AND FUTURE WORK

In this paper, we have studied user preference in representing ranking of trajectory recommendations. We have conducted an opinion survey with participants from a wide range of age groups. This survey was targeted to investigate how they would represent the rankings on a proposed map. The results demonstrate that our participants preferred the use of color, stroke, transparency and use of context on the visualization the most. We will continue to investigate this further with more participants.

Representing recommendations is a key influencer for users to actually use the recommended items. Therefore, a major part of our future work will be dedicated to designing new approaches for representation of trajectory recommendations. These representations will make use of the finding of the investigations presented by this paper. We will then conduct a comprehensive user study to evaluate how users find the new visualizations compared to the most currently used visualizations by navigation and trip recommender systems.

Acknowledgment

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