Walking down a Different Path: Route Recommendation based on Visual and Facility based Diversity

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ABSTRACT

For a traveler to enjoy a trip in a city, one important factor is the diversity of sceneries and facilities along the route. Current navigation systems can provide the shortest route between two points, as well as scenic or safe routes. However, diversity is largely ignored in existing works. In this paper, we present a system that provides diversity-based route recommendation. It measures visual-based diversity and facility-based diversity with information extracted from publicly available data such as Google Street View images and FourSquare venues. As we will show, the current prototype system is able to provide diversity-based route recommendation for city areas in San Fransisco and Kyoto.

CCS CONCEPTS

• **Information systems** → *Web applications*; *Recommender systems*;

KEYWORDS

Walking Navigation System, Route Recommendation, Visual Diversity

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1 INTRODUCTION

The increasingly availability of geo-spatial and user generated location-based data combined with advances in mobile and GPS technology have led to the rapid growth and adoption of navigation services such as route planners and travel assistant tools. Such systems have become increasingly commonplace in our daily lives, improving our ability to navigate efficiently within a spatial environment by providing us with routes which are efficient, cheap and safe. While initial research into navigation systems emphasized on providing users with the most efficient routes from a utilitarian standpoint (i.e., identifying routes which are less time-consuming and cheap (see [1]) or are low on environmental impact [2]), later studies have begun to explore how routes could instead be recommended based on their hedonistic qualities. Such navigation systems aim instead to provide users with a more pleasurable walking experience. For instance, Quercia et al. [7] described a route recommendation process based on the aesthetics qualities within a route such as beauty and quietness. In another example, the Scenic Planner was developed to recommend routes which contain the best scenic views [3].

The enjoyment from traveling along a route is not only limited to passing through famous landmarks and beautiful landscape, but might also come from the discovery of unfamiliar and surprising elements within the route. SmellyMaps for example, describes a novel way capturing the urban "smellscape", thus providing a way for users to exploring a city based on smell [8].

One could argue how the ability to experience difference aspects of a landscape such as this during a trip might lead to more satisfying journey. The more diverse experiences a route has to offer, the more chances for discovery and exploration they could provide. Therefore, one might argue how a diverse route could have the potential to provide travelers with a more interesting journey. Prior studies have found similar results which support this notion, such as how land-use mix diversity (whether the neighborhood has access to a wide mixed range of residential, office, commercial and public spaces) is related to higher walkability in a neighborhood [5].

However, few route recommendation systems have been developed based on the notion of diversity. Such a system could not only be useful in providing a joyful walking experience for local residents looking to relieve stress by going for a short walk, but could find value in the area of tourism. Much of the existing systems developed in this area have focused on providing travelers with walking routes that allow them to pass through and efficiently visit

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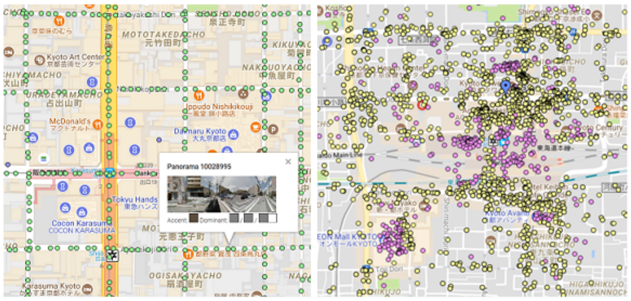

Figure 1: An example of the panoramic views available in Kyoto (Left) and the different facilities existing near Kyoto station (Right).

tourist attractions and city landmarks [6]. We would argue however that it would be equally interesting to give tourists as much a varied view of the city as possible, given their typically short period of stay within a city. As such, we propose a novel route recommendation system in this paper based on the notion of diversity within a route.

2 DIVERSITY BASED ROUTE RECOMMENDATION

This paper presents a novel route recommendation system based on diversity. The proposed route system contains two main routing features, the first of which would recommend to users routes which are most visually diverse (Visual diversity routing). In the second feature (Facility based diversity routing), the system would rank the routes based on the diversity in the type of facilities (restaurants, shops, parks and tourist attractions etc.) existing alongside the route and would recommend the route with the highest facility based diversity.

2.1 Visual Diversity based Routing

The visual diversity of a given route was calculated based on two main criteria, the color-based similarity of the landscape along the route and the diversity of the "tags" of objects detected when walking along the route. To obtain information about the landscape that could be viewed when walking along the route, panoramic data from the paths in that route were obtained using the Google Street View image API [1]. The panoramic image consists of three street view images (each with a camera heading of 0, 120 and 240 degrees, respectively) joined together, showing the straight, left and right views of the surrounding landscape. The panoramic image was obtained for each node of the path of the route (the node information in the path was obtained using OpenStreetMap data). Fig. 1 (left) shows an example of the panoramic data available in the streets of Kyoto, Japan. An example of the panoramic image at a specific node is shown on the Google map info window.

To calculate the visual similarity of the landscape, the panoramic images were analyzed using the Microsoft Azure cognitive services [2], in particular, the computer vision API. The service provides information about the various objects which could be found in the landscape (in the form of tags such as parking, beach, apartment building, forest etc.) and the color characteristics of the landscape image (such as the dominant foreground color, background color and any accent colors within an image). The tag list data was used to calculate the tag similarity score (with the aim of recommending routes which are associated with as much diverse tags as possible) and the color characteristic data was used to calculate the color similarity score (with the aim of recommending routes with as much diverse landscape color as possible). The combined color and tag similarity score was used to represent the overall visual similarity of a route.

To calculate the tag similarity score, we compare tags of each panoramic image on the route to the average tags of the route. The Azure API assigns a confidence score between [0, 1] to each tag in its analysis results, indicating how confident it is about the tag being correct. This confidence score is used as the basis for calculating the average and the similarity. The average tag is thus summing the confidence score of all tags, which is then normalized by the number of panoramic images. The similarity between each panoramic image tag and the average tag is calculated as the cosine similarity. Finally, the tag similarity score is given as the average score of the similarity score between each panoramic image tag and the average tag.

To calculate the color similarity score, we first reduce panoramic images to 64 colors and create color histogram. We then calculate the average histogram by averaging all panoramic images on the route. After obtaining the average histogram, we calculate the similarity between each panoramic image and the average histogram by using *histogram intersection*:

$$\text{histogram similarity} = \frac{\sum_{i=0}^{63} min(H_1[i], H_{avg}[i])}{\sum_{i=0}^{63} H_1[i]} \tag{1}$$

where H_1 is the histogram of the panoramic image, and H_{avg} is the average histogram of the route. Finally the color similarity is taken as the average histogram similarity between panoramic images on the route and the average histogram.

Overall, the combined visual similarity score of the route was calculated using Eq. 2:

$$VisualSimilarity = TW * TagSim + (1.0 - TW) * ColorSim \tag{2}$$

with $TagSim$ referring to the tag similarity score of the route, $ColorSim$ referring to the color similarity score of the route. TW refers to the user selectable tag weight parameter (0 to 1) that denotes the importance of the tag similarity score in the overall calculation of the visual diversity of a route. Fig. 2 shows an example of three different routes from a location on Howard Street to Union Square in the city of San Francisco which are ranked based on their visual similarity score. The system would recommend route 1 to users as this route has the lowest visual similarity score.

2.2 Facility Diversity based Routing

The degree of facility based diversity within a route was calculated by using weighted entropy to measure the diversity in the types of facilities which exist alongside a given route. Information regarding what facilities exist within a city and the what type of facilities they

[1]https://developers.google.com/maps/documentation/streetview/
[2]https://azure.microsoft.com/en-us/services/cognitive-services/

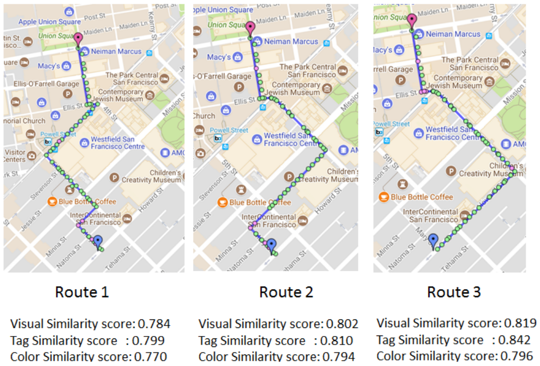

Figure 2: An example of three different routes in San Francisco and their visual, tag and color similarity scores

are was obtained using the Foursquare API [3]. Fig. 1 (Right) shows an example of the facilities existing around the main train station in the city of Kyoto (Kyoto Station) in Japan.

Data from the "Categories" field of the response from the Foursquare Search Venues API was used to ascertain the type of each facility. The type returned in this way is the lowest level node in the category hierarchy defined by Foursquare. Examples of these facility types include Grocery Store, Office, Pharmacy, Medical Center, Performing Arts Venue and Buddhist Temple. When calculating the facility based diversity score for a specific route, each Foursquare venue was considered related to the path in a route if the perpendicular distance from that facility to the path was less than 20 meters. The facility based diversity score of the route was calculated using weighted entropy, with the number of users who visited that specific category of facility (data of which was obtained using the Foursquare API) being normalized using $\log_2$ and used as the weight in the entropy calculation. We use acid package from R[4] to calculate the weighted entropy, setting parameter α to 1. Finally, routing was carried out using Dijkstra's algorithm [4]. Fig. 3 shows an example of three different routes from the main Kyoto train station to the Omiya Road intersection and their corresponding Facility based diversity entropy value.

3 DEMONSTRATION SYSTEM PROTOTYPE

A prototype of the diversity based navigation system has been developed and deployed as a web application. The prototype can be accessed online at Demo Site 1[5] for the area of San Francisco and at Demo Site 2[6] for the city of Kyoto, Japan. We use data from OpenStreetMap for the whole cities, and collect Google Street View (GSV) images and Foursquare venues that cover the center region of the cities. A summary of data collected is shown in Tab. 1.

The web application prototype can be open in a standard web browser without any additional software or hardware. When using the system, users are able to access both the visual diversity routing and the facility diversity routing features within the prototype

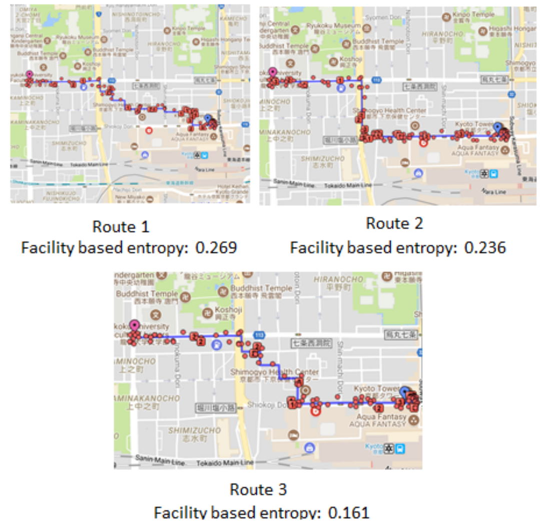

Figure 3: An example of three different routes in Kyoto and their facility based entropy score

Table 1: Number of GSV and Foursquare data collected

	GSV images	Foursquare venues
San Francisco	44,446	53,429
Kyoto	18,957	30,125

system. They would be able to select two points within the cities of Kyoto and San Francisco and would receive recommendations of high diversity routes between those points.

3.1 The Visual Diversity Route Recommendation Feature

To illustrate how the route recommendation feature for visual diversity could be used in our prototype and describe how a user could benefit from the feature, we present a usage scenario. In this scenario, a local resident of Kyoto would like a change of pace from the usual route he/she takes to go to work. The resident had gotten bored from the old walking routine and would like to experience something new on his/her path to work. The resident would like to take a route which allows him/her to pass through different landscapes (green landscapes such as forests, blue landscape such as small lakes and gray landscape such as buildings etc.) and gives him/her a chance to see as many different things as possible. The resident therefore uses the visual diversity based route recommendation feature on our prototype system.

An overview of this feature is shown in Fig. 4. To use the system, the resident first specifies a starting point and destination point on the map. Next, the resident would select the desired routing type (in this case the **"Maximum visual difference along the route"**) and press the **"Navigate"** button. The route with the highest visual diversity would be presented on the map for the resident. Each of the panoramic landscape views used in the calculation of the visual similarity score is shown as a dot on the map. The resident could

[3]https://developer.foursquare.com/docs/venues/search
[4]https://www.rdocumentation.org/packages/acid/versions/1.1/topics/weighted.entropy
[5]http://delab.kyoto-su.ac.jp/nav/sf/map
[6]http://delab.kyoto-su.ac.jp/nav/kyoto/map

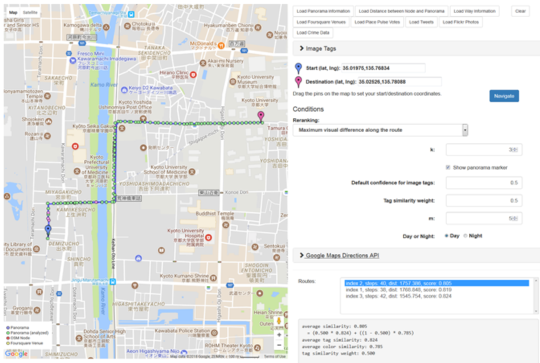

Figure 4: An overview of the visual diversity based route recommendation feature in our system.

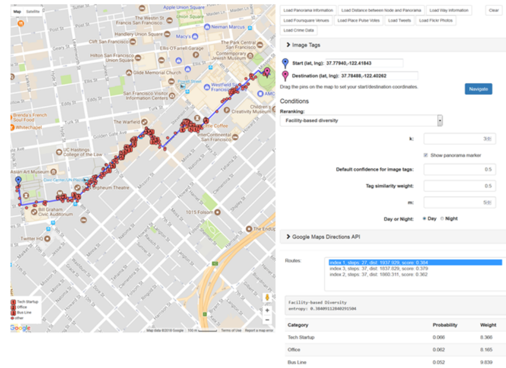

Figure 5: An overview of the facility based diversity route recommendation feature in our system.

learn more about what views to expect when walking along the route by clicking on any of the dots. Doing so will show an info window where the resident could see the panoramic image. If the user is not satisfied with the proposed route, he/she could examine other candidate routes with high visual diversity by clicking on the alternative routes in the **"Route Textbox"**.

3.2 The Facility based Diversity Route Recommendation Feature

Another usage scenario is provided to explain how the facility based diversity route recommendation feature in our prototype could be used and how a user could benefit from it. In this scenario, a tourist has come to visit San Francisco and is planning to enjoy a walk from San Francisco city hall to Yerba Buena Gardens. Overall, the tourist wishes to explore as many different facilities as possible which exist in the area of San Francisco (Stores, Art Galleries, Libraries, Parks etc.) as he/she would like to compare it with the ones at home. As the tourist would not have a lot of time to spend in this area, he/she would like to make the walk as meaningful as possible and would like to find a route which gives him/her a chance to see and visit as wide a range of facilities as possible. Therefore, the tourist uses the facility based diversity route recommendation feature.

An overview of this feature is shown in Fig. 5. When using the feature in our prototype, the tourist first specifies a starting point and a destination point on the map and then selects the desired routing type (in this case, **"Facility-based diversity"**) and presses the **"Navigate"** button. The route with the highest facility-based diversity would be shown on the map. The different facilities which were detected along the route using Foursquare would be shown as dots on the map, while the top three categories of facilities on the route would be represented as squares embedded with the corresponding ranking number. If the tourist wishes to learn more about a specific venue, he/she could click on one of the dots which would redirect the tourist to a venue information page that contains detailed information about the facility such as the geo-spatial location (address etc.) of the facility and information about how many Foursquare users have visited the facility. The tourist could also learn about what different types of facilities they could expect to see when walking along the route by looking at the facility category list on the bottom right side of the screen. On the recommended route in this scenario, the tourist has a high chance of seeing Tech startups, offices, coffee shops and Art galleries.

4 CONCLUSION

In this demonstration paper, we have discussed the development of a route recommendation system based on visual and facility based diversity. A web application prototype of the system was developed for the area of Kyoto and San Francisco. Through this system, users are able to receive recommendations of routes with high diversity between any two points on the map. Future work would involve implementation of more complex similarity measures for images as well as analysis of diversity of topics discussed in tweets issued along the route.

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