Supplementary Materials: Landmark Salience Calculation and Landmark Selection

Hua Liao and Weihua Dong

It is important to point out that the purpose of this paper is not to develop a landmark salience algorithm or to propose an automatic 3D map generation method. We adopted existing models to calculate landmark salience and then used the salience calculation results as criteria to select landmarks for 3D model construction. These processes formed the first and second steps of our 3D map design. In this study, we adopted Raubal and Winter's general framework [1] to measure landmark salience in this study.

1. Method

According to Raubal and Winter [1], landmark salience is composed of three components: visual, semantic and structural salience. In this section, we briefly present the steps of our calculation. Please refer to Raubal and Winter [1] and Nothegger, et al. [2] for a comprehensive view of the method.

1.1. Visual Salience

A landmark is visually prominent if its visual features such as color, size, and height strongly contrast with the features of its neighbors in the surrounding environment. Four metrics are included to measure visual salience: color (C), shape (S), height (H), and façade area (A). See Equation (S1).

$$Salience_{visual} = w_1 * C + w_2 * S + w_3 * H + w_4 * A, \sum w = 1 \quad \text{(S1)}$$

Where *C, S, H*, and *A* denotes color, shape, height, and façade area, respectively. Equal weights were used in this study.

(1) **Color**. We first took photos of the buildings and adjusted all the brightness values to a similar level. We then took the main RGB (red, green, and blue) values of each building. The RGB values were converted to HSV (hue, saturation, and value) values. Finally, the color score of a building can be calculated by using Equation (S2):

$$score = \frac{|x - med(x)|}{med(x)} \quad \text{(S2)}$$

where x denotes the mean value of H, S and V channels, *med(x)* is the median of color values for all the visible buildings in a scene. Since the visual salience indicates contrast with surroundings, so we use the deviation of a color from the median.

(2) **Shape**. Shape is simply measured by the *length / width ratio* and *roof type*. The roof type is a Boolean value. If the shape of roof is different from a common flat rectangle, the roof type is assigned 1, otherwise assigned 0. We then use Equation (2) to calculate the shape factor value.

(3) **Height**. Because the actual heights of the buildings were publicly unavailable, we use screen pixels to approximate building height. Height values were normalized to lie in the range [0, 1].

(4) **Façade area**. Façade area was calculated by multiplying the perimeter of the building and its height. Façade values were also normalized to [0, 1].

1.2. Semantic Salience

Semantic attractions comprise of *cultural and historical importance,* and *explicit marks*. We calculated the mean value of these two metrics as the semantic salience.

Cultural and historical importance. In Nothegger, Winter and Raubal [2], cultural or historic attractions were stratified into four levels:

0: Nothing interesting
1: Building has historic facade
2: Building is culturally notable (use, age, known architect, etc.)
3: Building is highlighted in a travel guide

Cultural and historical importance of buildings was assigned the corresponding ordinal values. Instead, in our paper, we used the results of a public questionnaire survey by Zhao, et al. [3]. In this survey, respondents were required to rate the significance level of a POI category as landmarks in an environment on a 5-point scale (from 1: “not significant” to 5: “quite significant”). They termed this significance level as “public cognition degree” (PCD). Results from 233 respondents were normalized as shown in Table S1. Based on these results, we used the PCDs to indicate as the cultural and historical importance of buildings.

Table S1. Results of the public questionnaire survey (source: [3]).

POI Category	Public Cognition Degree (PCD)
Transportation hub	1.0000
Cultural or historic attraction	0.8245
Shopping center	0.8146
Educational institution	0.6706
Urban park	0.6548
Luxury hotel	0.5562
Major hospital	0.5069
Leisure venue	0.5010
Important government building	0.3550
Tall building	0.3057
Residence community	0.0000

Explicit marks. This is a Boolean value. If a building has an explicit mark (e.g., “Middle School”), it is assigned the value 1, otherwise it is assigned the value 0.

1.3. Structural Salience

A structurally salient landmark is a landmark that is located at a prominent position and is important to form the spatial structure of the environment [1]. According to Lynch’s theory [4], nodes, edges, and regions are possible salient structural elements in a city. In Raubal and Winter [1]’s model, a node’s structural attraction is measured by its degree in a network (number of incoming and outgoing edges). However, this measurement is for nodes such as intersections rather than individual landmarks. In Nothegger, Winter and Raubal [2]’s examples, structural salience was not considered.

Klippel and Winter [5] distinguished distant / off-route landmarks and close / on-route landmarks. On-route landmarks can be further divided into landmarks at nodes (*node landmarks*) and landmarks between nodes (*segment landmarks*). It is suggested that node landmarks are more important than other types of landmarks. This aspect serves to provide an initial indication of structural salience. Based on this characterization, we excluded distant landmarks and focused on node landmarks that are located at places where re-orientation is or is not required. In other words, in the current stage, we used structural salience as a binary classifier but did not quantify structural salience in the overall landmark salience measurement.

1.4. Overall Salience

The overall salience is measured using Equation (S3):

$$Salience = w_1 * S_{visual} + w_2 * S_{semantic}, \sum w = 1 \quad \text{(S3)}$$

Where S_{visual} and $S_{semantic}$ denote visual salience and semantic salience, respectively. We used equal weights in this study. It should be noted that the overall salience scores of two buildings could be compared only if these two buildings are at the same crossroad.

2. Example

We take buildings at the Crossroad 1 and Crossroad 2 for example (Figure S1). The street view of these buildings is shown in Figures S2 and S3, respectively. The individual and overall scores for these two crossroads are shown in Table S2. It can be seen that at the Crossroad 1, Building D has the highest overall salience because it is a middle school with an explicit mark on it. Building A ranks second with unique color and an explicit mark on it. It is the starting point of the pre-defined route. At the Crossroad 2, Building G is with the highest overall salience because of its large façade area, unique shape, and semantic attraction. Therefore, Buildings A, D, and G are selected for 3D landmark construction for these two crossroads.

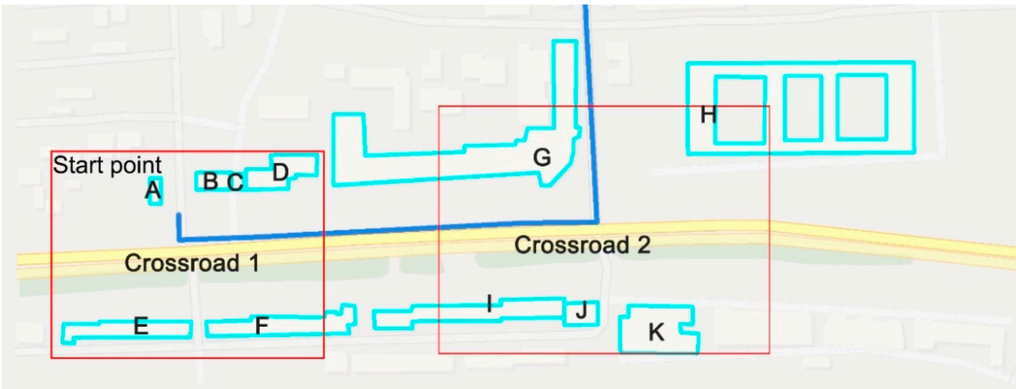

Figure S1. Buildings of the Crossroad 1 and the Crossroad 2.

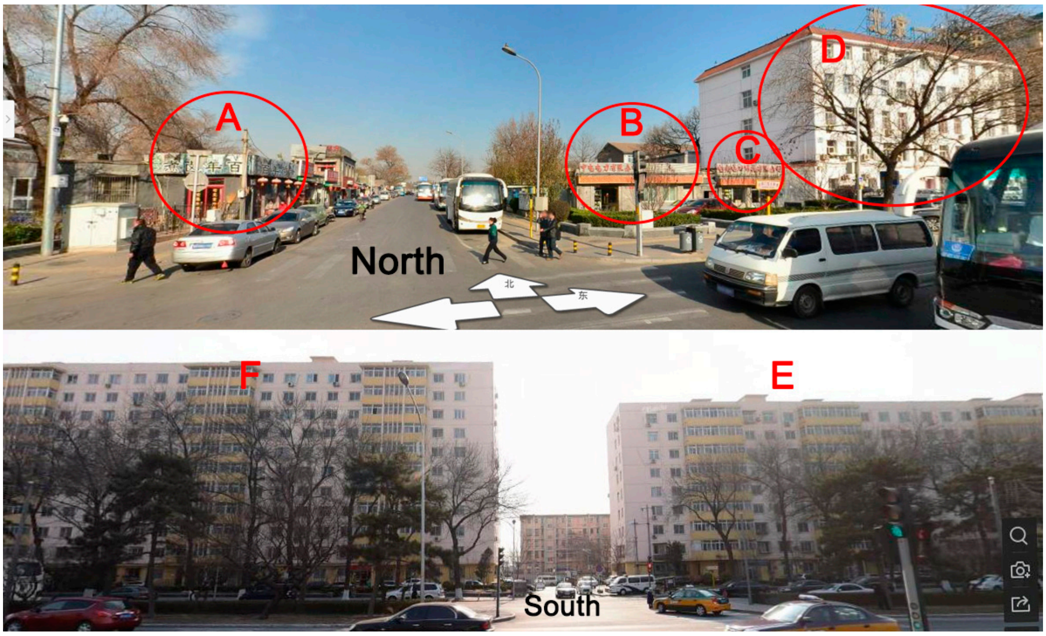

Figure S2. Street view of the Crossroad 1. Building A-F correspond to those labeled in Figure S1. The pictures were from Baidu Map (http://ditu.baidu.com) under free license for non-commercial use.

Figure S3. Street view of the Crossroad 2. Building G-K correspond to those labeled in Figure S1. The pictures were from Baidu Map (http://ditu.baidu.com) under free license for non-commercial use.

Table S2. Landmark salience in the Crossroad 1 and Crossroad 2.

Crossroad	Building	Color	Façade Area	Height	Shape	Visual Attraction	Semantic Attraction	Overall Salience
Crossroad 1	A	1.00	0.00	0.00	0.00	0.25	0.50	0.375
	B	0.00	0.01	0.00	0.00	0.13	0.50	0.313
	C	0.00	0.00	0.00	0.00	0.13	0.50	0.313
	D	0.00	0.25	0.40	0.00	0.16	0.84	**0.499**
	E	0.06	0.67	0.80	0.00	0.42	0.00	0.211
	F	0.75	1.00	1.00	0.00	0.73	0.00	0.364
Crossroad 2	G	0.00	0.78	0.70	1.00	0.50	0.68	**0.587**
	H	0.46	1.00	0.60	0.00	0.57	0.18	0.375
	I	0.42	0.53	1.00	0.00	0.54	0.00	0.270
	J	1.00	0.00	0.00	0.00	0.25	0.50	0.375
	K	0.81	0.02	0.00	0.00	0.33	0.00	0.166

References

1. Raubal, M.; Winter, S. Enriching wayfinding instructions with local landmarks. In *Giscience 2002, LNCS 2478*; Egenhofer, M.J.; Mark, D.M., Eds.; Springer: Berlin/Heidelberg, Germany, 2002; pp. 243–259.
2. Nothegger, C.; Winter, S.; Raubal, M. Selection of salient features for route directions. *Spatial Cognition and Computation* **2004**, *4*, 113–136.
3. Zhao, W.; Li, Q.; Li, B. Extracting hierarchical landmarks from urban poi data. *Journal of Remote Sensing* **2011**, *15*, 973–988.
4. Lynch, K. *The Image of the City*. MIT Press: USA, 1960; Volume 11.
5. Klippel, A.; Winter, S. Structural salience of landmarks for route directions. In *Spatial Information Theory*, Springer: 2005; pp. 347–362.