Path guidance based on landmark user preference fuzzy entropy weight model

Chang Wei¹ and Bo Wei*¹
¹Guangxi Key Laboratory of Spatial Information and Geomatics, Guilin University of Technology, Guilin, Guangxi, 541000, China
*Corresponding author’s e-mail: superweibo@glut.edu.cn

Abstract. Compared with electronic map or static point of interest (POI), the path guidance integrating landmarks with salience features can reduce the cognitive burden better. However, due to the influence of various factors on the significance of landmarks, specific mathematical formulas need to be constructed, and there is no unified formula construction standard. To solve this problem, considering the consistency of the idea between multiple factor comprehensive of landmark and multiple constraint optimal scheme decision of fuzzy decision, this paper constructs a fuzzy entropy weight model of landmark based on user preferences, which the actual values of landmark significance are converted to vague set values, and the weights of landmark factors are determined by fuzzy entropy of Vague soft sets. Subsequently, the landmark preference model and path guidance model are obtained and applied in the case of path guidance. Compared with the mathematical formula, the constructed landmark user preference model by fuzzy entropy of Vague soft sets reduces the construction complexity, and is an effective method to realize landmark preference and apply in path guidance.

1. Introduction
As the most basic spatial knowledge, landmark plays an important role in the expression and reasoning of spatial knowledge and is the representatives of the surrounding space [1,2]. The research of spatial cognition shows that landmark as a path cue can increase pedestrian familiarity with the path and convey an enlightening tip when people make a path choice, and is often used as a reference for path guide communication and spatial reasoning[3].

At the decision point of path guidance, there are usually several landmarks for reference. Since different landmarks have different significance, it is inevitable to involve a problem of landmark preference, which is usually solved by sorting landmarks according to their significance. The evaluation of landmark significance finally needs to be reflected by a comprehensive evaluation value of various influencing factors of landmark significance. On the basis of the formal model, Raubal et al. [4]proposed the average value or weighted average value of the influence factors calculated from the same landmark is taken as the comprehensive evaluation value of the landmark. Based on literature [4], Nothegger et al. [3] improved the calculation method of comprehensive evaluation value in literature [4], which a landmark scoring function model based on mean absolute variance was established to integrate multiple influencing factors and calculate the score of each landmark, and the finally comprehensive evaluation value was obtained to achieve the ranking of landmarks. Zhao et al. [5]and Wang et al.[6] put forward their point of interest (POI) significance measurement models or calculation models respectively, which are based on weighted summation. All of the above models
need to construct specific mathematical formulas, but there is no unified formula construction standard.

The comprehensive evaluation value of a landmark is obtained by using the mathematical models, which is essentially a process of integrating various influencing factors of landmark significance. In other words, the values of multiple influencing factors are integrated into a comprehensive evaluation value, and the landmark is sorted and selected according to the comprehensive evaluation value. This method of landmark selection is consistent with the idea of Vague soft sets decision making method \[7\] that makes the optimal decision of alternative schemes according to the given multiple constraints. In this paper, a landmark preference model by considering user preferences is constructed based on Vague soft set fuzzy entropy, and the landmark information of path guidance is formed by landmarks selected by the model.

2. Methods

2.1. Fuzzy entropy of Vague soft sets

Vague soft sets \[8\] is a combination of Vague sets \[9\] and soft sets \[10\]. Vague sets was proposed by Gau and Buehrer in 1993, and it is represented by a true membership function \(t_A(u)\), a false membership function \(f_A(u)\) and an unknown degree \(\pi_A(u)\) for the support, objection and neutrality of people's voting model, respectively, where \(u\) represents any element in the domain \(U\) and \(A\) is a Vague set over \(U\), which satisfies \(0 \leq t_A(u) + f_A(u) \leq 1\) and \(\pi_A(u) = 1 - t_A(u) - f_A(u)\). A Vague set can be shorthand for \(A = \{[t_A(u), 1 - f_A(u)]\}\), expressed with VS\((U)\), and \([t_A(u), 1 - f_A(u)]\) is called a vague values. Let \(P(U)\) be a power set of \(U\) and \(E\) be a parameter set. If \(A \subseteq E\) and \(F: A \rightarrow P(U)\) is a mapping, then \((F, A)\) is a soft set on \(U\), and \(VSS(U)\) is called a vague values. Corresponding to the fuzzy entropy of fuzzy sets and Vague sets, there is fuzzy entropy of Vague soft set also, which is usually developed from vague entropy of Vague sets. Let \(U = \{u_1, u_2, ..., u_n\}\) be the domain and \(E = \{e_1, e_2, ..., e_m\}\) be the parameter set. If \((F, E) = \{F(e)\}|i=1,2, ..., m\) is Vague soft set family, then vague entropy \(H(F, E)\) of Vague soft sets is expressed as \[11\]:

\[
\text{1} \sum_{i=1}^{m} \text{HS}(F, E) = \frac{1}{m} \sum_{i=1}^{m} H_i(F, E)
\]

where

\[
H_i(F, E) = \frac{1}{n} \sum_{j=1}^{n} \left[ 1 + \frac{1}{2} \left( \pi_{F(e_i)}(u_j) - (t_{F(e_i)}(u_j) - f_{F(e_i)}(u_j))^2 \right) \right]
\]

2.2. Landmark significance model

According to the types of influencing factors for the significance of different landmarks, three models can be adopted to represent the landmark respectively\[3\], which are calculation model, representative value model and fuzzy representation model. Some mathematical formulas is used in the calculation model, including facet area factor \(\alpha = \int x| x \in \text{landmark front} \), shape factor \(\beta_1 = \text{facet height/facet width} \), shape deviation \(\beta_2 = (\text{facet minimum encasing rectangle - } \alpha) / \text{facet minimum encasing rectangle} \) and visibility \(\delta = \sum x| x \in \text{visual} \). The representative value model is directly represented by representative values, including RGB mode color factor \(r = \{R, G, B\}\) and symbolic factor \(\zeta = \{T, F\}\). The fuzzy representation model represents the boolean model with or without obvious signs, such as historical and cultural importance factor \(\varepsilon = \{0, 1, 2, 3, 4\}\).

2.3. Landmark user preference fuzzy entropy weight model

Let there be \(n\) landmarks. If each landmark has \(m\) landmark significance values, then the fuzzy entropy weights of each landmark factor is \[12\] \((i=1,2, ..., m; j=1,2, ..., n)\) :
When a significance value of landmark is actual value, it needs to be converted to a vague value. If it is a high optimal index[13], the following equation (4) is used for normalization. If it is a low optimal index[14], the following equation (5) is used for normalization:

\[ \sigma_y = \left( \frac{s_i}{\max(s_j)} \right)^2 \] (4)

\[ \sigma_y = \begin{cases} 1 - \left( \frac{s_i}{\max(s_j)} \right)^2, & \min(s_j) = 0 \\ (\min(s_j)/s_j)^2, & \min(s_j) \neq 0 \end{cases} \] (5)

where \( s_{ij} \) represents the actual significance value of landmark, and \( s_j \) represents the actual significance value of all landmarks in the \( j \)th factor (\( i=1,2, \ldots, m; j=1,2, \ldots, n \)).

The normalized landmark significance value \( \sigma_{ij} \) is converted into a vague value \([ t_A(\mu), 1-f_A(\mu) ]\) according to the following equation (6)[15]:

\[ t_A(u) = (\sigma_{ij})^{1/2}, 1-f_A(u) = (\sigma_{ij})^{1/2} \] (6)

The landmark factor weight \( \omega_i \) reflects the objectivity determined by fuzzy entropy, but does not reflect the user's subjectivity. From the perspective of user preferences, the topic weight \( \xi_i \) is added to each factor to get the user preference fuzzy entropy weight model:

\[ \gamma_i = \xi_i \omega_i = \kappa_i \sum_{i=1}^{m} (1-H_i(F,E))^{-1} \] (7)

where the topic weight \( \xi_i = \kappa_i / \sum_{i=1}^{n} \kappa_i \), and \( \kappa_i \) represents the topic parameter, which is taken a value in the range of \([1, 5]\) according to the user's preferences for a factor (\( i=1,2, \ldots, m; j=1,2, \ldots, n \)).

2.4. Landmark preference model

Let there be \( n \) landmarks, and each landmark has \( m \) landmark significance values. Taken (0, 1) as the optimal reference point[16], and the landmark preference model is obtained based on geometric distance:

\[ C_j = \sqrt{2} - \left[ \left( D_j^+ - 0 \right)^2 + \left( D_j^- - 1 \right)^2 \right]^{1/2} \] (8)

where \( C_j (j=1, 2, \ldots, n) \) represents the scoring value of the \( j \)th landmark. The greater the value of \( C_j \), the more priority is given to the selection of landmark. For high optimal index, \( D_j^+ \) and \( D_j^- \) represent the positive and negative distances of high optimal index of the \( j \)th landmark, respectively:

\[ D_j^+ = \left[ \sum_{i=1}^{m} \gamma_i (1-\sigma_j)^2 \right]^{1/2} \] (9)

\[ D_j^- = \left[ \sum_{i=1}^{m} \gamma_i (0-\sigma_j)^2 \right]^{1/2} \] (10)

For low optimal index, \( D_j^+ \) and \( D_j^- \) represent the positive and negative distances of low optimal index of the \( j \)th landmark, respectively:

\[ D_j^+ = \left[ \sum_{i=1}^{m} \gamma_i (0-\sigma_j)^2 \right]^{1/2} \] (11)
\[ D_j = \left[ \sum_{i=1}^{m} \gamma_i (1-\sigma_j)^2 \right]^{1/2} \] (12)

2.5. Path Guidance Model
If there are successively \( z \) nodes between the starting and ending points of a guide path, and each node has \( n \) landmarks, then the path guidance model composed of preferred landmarks based on each node is as follows:

\[ P = \{ P_s, P_1, P_2, \ldots, P_z, P_e \} = \{ P_s, \max(C^1_j), \max(C^2_j), \ldots, \max(C^n_j), P_e \} \]

where \( P_s \) and \( P_e \) represent the starting point and end point of the guide path respectively, and \( \max(C^j_j) \) represents the maximum score value of \( C_j \) \((j=1, 2, \ldots, n)\) of all landmarks in the \( j^{th} \) node, which represents the optimal landmark. Therefore, \( P \) is a set of landmarks, which represents the path guidance information composed of starting and ending points and \( z \) optimal landmarks of each node in sequence.

3. Path guidance application
The path is from the south gate of Yucai Campus of Guangxi Normal University to the west gate of Pingfeng Campus of Guilin University of Technology and consists of 5 nodes and 21 landmarks in total, where 5 landmarks in the \( 4^{th} \) node of the path are listed in Table 1. According to the landmark significance model above, seven landmark significance values are calculated for each landmark, including facet area factor \( \alpha \), shape factor \( \beta_1 \), shape deviation \( \beta_2 \), visibility factor \( \delta \), color factor \( r \), symbolic factor \( \zeta \) and historical and cultural importance factor \( \epsilon \).

| Landmark symbol | \( \alpha \) | \( \beta_1 \) | \( \beta_2 \) | \( r \) | \( \delta \) | \( \zeta \) | \( \epsilon \) |
|-----------------|-------------|-------------|-------------|-----|-----|-----|-----|
| Landmark 14     | 22.5        | 0.9         | 0           | 0.5782 | 80 | 0   | 0   |
| Landmark 15     | 120         | 0.8333      | 0           | 0.2603 | 130 | 1   | 2   |
| Landmark 16     | 31.5        | 0.6429      | 0           | 0.0868 | 80 | 0   | 0   |
| Landmark 17     | 40.5        | 0.5         | 0           | 0.4201 | 40 | 0   | 0   |
| Landmark 18     | 45          | 0.45        | 0           | 0.2603 | 50 | 0   | 0   |

According to the high optimal index \( (v_1) \) and low optimal index \( (v_2) \), Vague soft sets are established. Equations (4) ~ (6) are used to convert landmark significance values into vague values. Table 2 shows the vague values of landmark 14 and landmark 15 corresponding to the transformation in Table 1, where \( \beta_2 \) is all 0, and its corresponding vague values are directly assigned \([0, 0]\).

Table 2. Vague soft set representation of landmark significance values in the 4th node

| Landmark symbol | Index symbol \( v_1 \) | Index symbol \( v_2 \) | \( \alpha \) | \( \beta_1 \) | \( \beta_2 \) | \( r \) | \( \delta \) | \( \zeta \) | \( \epsilon \) |
|-----------------|------------------------|------------------------|-------------|-------------|-------------|-----|-----|-----|-----|
| Landmark 14     | \([0.0012, 0.1875] \) | \([0.4625, 0.6400] \) | \([1, 1] \) | \([0, 0] \) | \([1, 1] \) | \([0.1434, 0.6154] \) | \([0, 0] \) | \([0, 0] \) |
| Landmark 15     | \([0.0012, 0.1875] \) | \([0.0850, 0.3000] \) | \([1, 1] \) | \([0, 0] \) | \([1, 1] \) | \([0.0625, 0.5000] \) | \([0, 0] \) | \([0, 0] \) |
Let user preferences be the symbolic factor $\zeta$ and historical and cultural importance factor $\varepsilon$. The topic weight values of them are set to 5, and the other topic weight values are set to 1. The scores of each landmark calculated by equation (8) according to the high optimal index ($v_1$) and low optimal index ($v_2$) are shown in Table 3, where the optimal landmark in the 4th node is landmark 15.

### Table 3. Scores of landmarks in the 4th node

| Index domain | Landmark 14 | Landmark 15 | Landmark 16 | Landmark 17 | Landmark 18 |
|--------------|-------------|-------------|-------------|-------------|-------------|
| $v_1$        | 0.4943      | 0.7495      | 0.3809      | 0.3853      | 0.3762      |
| $v_2$        | 0.4620      | 0.7565      | 0.3826      | 0.4083      | 0.3787      |
| ($v_1$&$v_2$) | 0.4781      | 0.7530      | 0.3817      | 0.3968      | 0.3774      |

Like the 4th node, the optimal landmarks of the rest of nodes in the path can be obtained by using the same methods. According to the path guidance model, the path guidance information composed of the starting point, the ending point and the optimal landmarks in all five nodes of the path is the south gate of Yucai Campus of Guangxi Normal University - landmark 2 - landmark 5 - landmark 8 - landmark 15 - landmark 20 – the west gate of Pingfeng Campus of Guilin University of Technology.

### 4. Conclusions

Landmark is the synthesis of multiple significance factors, such as calculation model, representative value model and fuzzy representation model. It is difficult to construct a unified formula to measure and calculate the significance evaluation of landmark. In this paper, Vague soft set fuzzy entropy is used to determine the weights of significance influencing factors, and the topic weights are added to optimize the weights of significance influencing factors by considering user preferences, and the landmark preference model and path guidance model are obtained. Starting from the actual data of significance, the landmark preference is realized under the general framework of fuzzy decision-making method, which reduces the complexity of constructing the optimization model of landmark and is easy to integrate user preferences, and provides an idea of landmark preference for path guidance and path guidance information construction.

### Acknowledgments

This work was supported by the National Natural Science Foundation of China (grant numbers 41961063 and 41461085); the “BaGui Scholars” Special Funds of Guangxi Province (grant number 2019-79); the Natural Science Foundation of Guangxi Province (grant number 2016GXNSFAA380035); the Foundation of Guangxi Key Laboratory of Spatial Information and Geomatics (grant number 16-380-25-04); and the Doctoral Foundation of Guilin University of Technology (grant number 1996015).

### References

[1] Siegel A W, White S H. (1975) The development of spatial representations of large-scale environments[C]. Advances in child development and behavior. Vol. 10: 9-55.
[2] Gong Y X, Liu Y, Wu L, et al. (2010) Spatial Position Description Based on Weighted Voronoi Diagram and Landmark [J]. Geography and Geo-Information Science, 26(4): 21-26.
[3] Nothegger C, Winter S, Raubal M.(2004) Computation of the salience of features[J]. Spatial Cognition and Computation, 4: 113-136.
[4] Raubal M, Winter S.(2002) Enriching wayfinding instructions with local landmarks[C]. In: M. J. Egenhofer, &D. M. Mark (Eds.), Geographic information science of Lecture Notes in Computer Science, Berlin, Vol. 2478: 243-259.
[5] Zhao W F, Li Q Q, Li B J.(2011) Extraction of Hierarchical Landmarks Using Urban POI Data [J]. Journal of Remote Sensing, 15(5): 981-988.
[6] WANG M, HU Q W, LI Q Q, et al.(2016) Hierarchical Landmark Extraction Based on Location
Check-in Data [J]. Chinese Journal of Computer Science, 39(2): 405-413.

[7] Deng W B, Xu C L, Fan Z F.(2014) Multi-criteria Fuzzy Decision Making Method Based on Vague Set Similarmetric [J]. Systems Engineering Theory & Practice, 34(4): 981-990.

[8] Gau W L, Buehrer D J. (1993) Vague sets[J].IEEE Transactions on Systems, Man and Cybernetics, 23(2): 610-614.

[9] Xu W, Ma J, Wang S Y, et al.(2010) Vague soft sets and their properties[J]. Computer and Mathematics with Applications, 59(2): 787-794.

[10] Molodtsov D.(1999) Soft set theory—First results[J]. Computer and Mathematics with Applications, 37(4-5) :19-31.

[11] Meng Y Y, Wei B, Zou Y.(2017) Landmark Decision-making Based on Fuzzy Entropy _TOPSIS of New Vague Soft Set [J]. Journal of Guangxi Normal University (Natural Science Edition), 35(4): 39-48.

[12] Herrera F,Herrera A,Viedma E.(2000) Linguistic decision analysis: steps for solving decision problems under linguistic information[J].Fuzzy Sets and Systems, 115(1): 67-82.

[13] Zhao F, Wang Q S, Hao W L.(2015) Improvement of Constraint Condition of Intuitionistic Fuzzy Entropy and Construction of New Fuzzy Entropy [J]. Computer Applications, 35(12): 3461-3464.

[14] Wang J, Liu S Y, Zhang J.(2005) Fuzzy Multi-objective Decision Making Method Based on Vague Set [J]. Systems Engineering Theory & Practice, 25(2): 119-122.

[15] Bigand A, Colot O.(2010) Fuzzy filter based on interval-valued fuzzy sets for image filtering[J]. Fuzzy Sets and Systems, 161: 96-117.

[16] Wang Y L, Ren L F, Chen L W, Sun Z Q.(2013) A new and improved TOPSIS method and its medical application[J]. Journal of Central South University (Medical Science Edition), 38(2): 196-201.