Fuzzy comprehensive evaluation model for mobility model

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Abstract

Evaluation of mobility model is an important means to ensure the quality and design level. At present, many mobility models are proposed for opportunistic networks. But, there is no practical quantitative evaluation system to evaluate the mobility models. Firstly, this paper put forward a comprehensive evaluation index system of mobility model based on the analysis of the main factors affecting the quality of mobility model and the relationship between them. Secondly, based on the theory of fuzzy comprehensive evaluation, this paper put forward a fuzzy comprehensive evaluation model for mobility model (FCEM). In this model, the membership function of fuzzy mathematics is used to deal with the fuzzy evaluation of each index of the mobility model. The model realizes the quantitative evaluation of mobility model. This model not only provides new ideas and methods for mobility model evaluation, but also provides help and guarantee for mobile node modelling. Finally, the application of the model is demonstrated through the evaluation of the random waypoint (RWP) model.

Keywords:

mobility model,
evaluating indicator,
membership function,
fuzzy comprehensive evaluation

1 Introduction

Opportunistic network is a mobile ad hoc network that does not require a complete link between the source node and the target node, and uses the opportunity of the meeting to communicate [1]. Mobility model is the basis of network protocol, network topology and network security. Different mobility models have different effects on network performance. The rationality of model plays an important role in the design of protocol parameters. Model evaluation is an important means to evaluate the rationality of a model. Therefore, more and more researchers pay attention to the evaluation methods of mobility model. The evaluation of mobility model can provide objective index and evaluation method for the construction and analysis of mobility model. The evaluation of mobility model can also guide the application of the model. The application of mobility model is diverse, and different scenes have different requirements for mobility model. Therefore, it is very difficult to evaluate the quality of mobility model. Many factors need to be considered in the design and evaluation of mobility models. At present, many mobility models are proposed for opportunistic networks. Most of the models are evaluated by comparative analysis. On the one hand, this evaluation method is only a single index evaluation and it is not comprehensive. On the other hand, this kind of evaluation method is very fuzzy. There is no practical quantitative evaluation system to evaluate the mobility models.

The rest of the paper is organized as follows: In Section 2, recent work on evaluation of mobility model is reviewed. The evaluation index of mobility model is introduced in detail in Section 3. In Section 4, the applicability of the evaluation model is proved through an application example. We conclude the paper and point out future work in Section 5.

2 Related work

At present, there are few researches on evaluation of mobility model. There is not a comprehensive and complete evaluation model to evaluate the mobility model. In the analysis of routing algorithm in the paper [2], evaluation system of the mobility model is proposed based on the physical characteristics, topological characteristics and network performance. However, the system did not present the evaluation indicators and did not do a detailed analysis. In the study of the group mobility model, the group mobility model is evaluated from the physical characteristics of the nodes in the paper [3]. In the literature [4], the calculation model of link duration is introduced in detail. It evaluates the model based on network link duration. In the literature [5], the mobility model is evaluated from the aspects of node velocity distribution, node distribution, node connectivity, and node motion trajectory. The evaluation model is based on the meeting time, the time interval of the meeting and the controllability of the parameters in the paper [6]. These methods are not universal and comprehensive.

At the same time, fuzzy comprehensive evaluation has a very sound theoretical system and has been successfully applied to many fields. Such as: the quality of software [7], quality of the paper [8], information systems [9, 10] and so on. However, there is no application of fuzzy comprehensive evaluation in mobility model.

In this paper, based on the theory of fuzzy comprehensive evaluation and combined with the characteristics of mobile nodes, the evaluation index system of mobility model is proposed. A practical evaluation model of mobility model is designed based on the membership function of fuzzy mathematics theory. This model not only provides new ideas and methods for evaluation of mobility model, but also provides help and guarantee for mobile node modelling.

3 Evaluation indexes

In order to provide an effective evaluation on mobility model, the main factors affecting the mobility model must be determined first. Then, it is necessary to establish a systematic, comprehensive index system according to the divided layers of these factors. As you know, mobility model can be evaluated from many factors or main indexes, which are further composed of some sub-indexes. After balancing seriously among all factors affecting mobility model, a general comprehensive evaluation index system with two-layer indexes is illustrated in figure 1.

Some notations are introduced: the evaluation objective, mobility model, is denoted by M; the index set U = (authentic (u_1), space-time (u_2), connectivity (u_3), routing (u_4)); in the first layer, and in the second layer, u_1 = (similarity (u_{11}), parameter controllability (u_{12})), u_2 = (node distribution (u_{21}), spatial dependence (u_{22}), velocity distribution (u_{23}), velocity dependence (u_{24}), temporal dependence (u_{25})), u_3 = (average number of link changes (u_{31}), connection duration (u_{32}), time interval (u_{33})), u_4 = (successful delivery ratio (u_{41}), average latency (u_{42})).

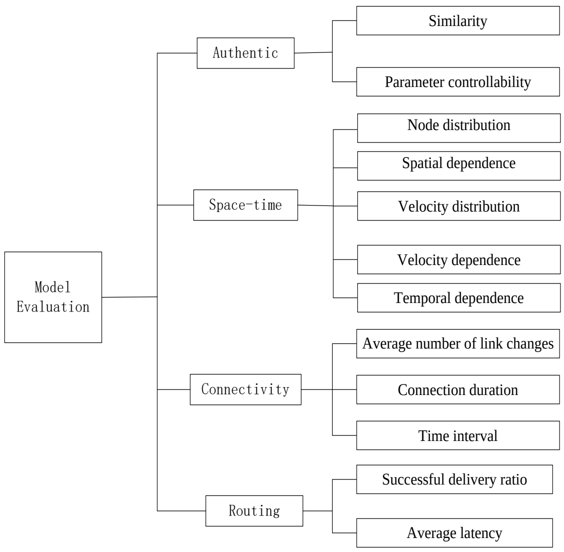

FIGURE 1 Evaluation indexes of mobility model

Obviously, the two-layer comprehensive evaluation index system in figure 1 is characterized by the multi-granular space. The higher layer is, the coarser granularity is. As the evaluation process moves from high layer to low layer, the information granularity to the comprehensive evaluation becomes finer. Therefore, the two-level evaluation index is comprehensive and complete.

4 FCEM

Due to the diversity and complexity of mobility models, there are many uncertain influencing factors. At the same time, these factors may be related to each other, so that we can not accurately determine the quality of the mobility model. So, there is no practical quantitative evaluation system. Fuzzy mathematics is usually used to study fuzzy problems. Fuzzy comprehensive evaluation method is a comprehensive evaluation method based on Fuzzy Mathematics. This method is to make a comprehensive evaluation of various evaluation factors. It can transform the qualitative evaluation into quantitative evaluation based on the theory of membership degree. This method has the following advantages: 1) the evaluation result is clear. 2) The system is strong. 3) It can solve the problem of fuzzy and difficult to quantify.

4.1 GENERAL PROCESS

Generally, the fuzzy comprehensive evaluation model includes the following factors: factor set, evaluation set, weight assignment set, evaluation matrix. In order to describe, according to the basic concept of fuzzy mathematics, the terms are defined as follows.

1) **Factor set (U)**. Factor set is a collection of various factors that influence the evaluation object.

$$U = \{u_1, u_2, ..., u_m\},$$

Where u_i (i =1, 2,…, m) is the factor affecting the mobility model.

2) **Evaluation set (V).**The evaluation set is a collection of evaluation results.

$$V = \{v_1, v_2, ..., v_n\},$$

where v_j (j =1, 2,…, n) is the result of evaluation.

Based on the existing Fuzzy comprehensive evaluation research, the mobility model grade is divided into grades of A, B, C, D, E respectively, corresponding to the mobility model grade is best, better, general and worse, worst the rank score is set to 100 points, the grade of mobility model as shown in the table below.

TABLE 1The grade of mobility model

Grade	A	B	C	D	E
Rank	Best	better	General	Worse	Worst
Point	100~90	90~80	80~70	70~60	60~0

3) **Weight assignment set (A).**The weight assignment set is the collection of the proportion of each factor in the evaluation.

$$A = \{a_1, a_2, ..., a_m\},$$

where a_i (i =1,2,… m) is the proportion of i factors in model evaluation. $\sum_{i=1}^{m} a_i = 1, 0 < a_i < 1$.

We determine the weights using the analytic hierarchy process (AHP) uses qualitative and quantitative systematically analysis methods. At present, it has been widely used in many fields [11, 12]. Its key steps are as follows. The judgment matrix (A') is given by expert or decision maker according to the scale of judgment, and then construct comparison judgment matrix to calculate the weights. In judgment matrix the eigenvector of the maximum eigenvalue is the weight vector of the system.

4) **First level fuzzy evaluation (R).** The evaluation of each factor set is a fuzzy mapping. Different factors will have different evaluation results. The evaluation matrix is constructed from the mapping of the factor set to the evaluation set.

$$R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

5) **Multilevel fuzzy evaluation**. Multi level fuzzy comprehensive evaluation means that fuzzy evaluation can be divided into several grades. The results of the fuzzy evaluation of the upper level fuzzy evaluation vector are normalized to synthesize the evaluation matrix. As shown in the following figure 2.

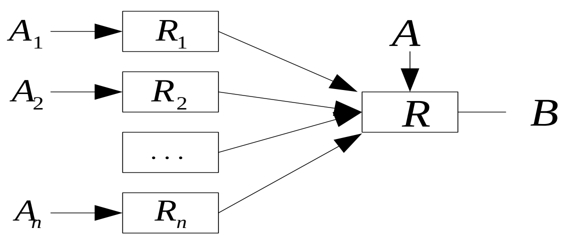

FIGURE 2 Sketch map of two-level fuzzy comprehensive evaluation model

6) **Evaluation results (** B **)**.Based on the above analysis, we can get the final vector of the multilevel fuzzy evaluation. There are two kinds of methods to judge the evaluation results, the maximum membership principle and the weighted average principle. In this paper, the maximum membership principle is used to evaluate the results.

$$B=A\circ R=[a_1,a_2,...,a_m]\circ\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}=[b_1,b_2,...b_n]\cdot(1)$$

Sign ($\circ$) is a fuzzy synthesis operator. We take the matrix multiplication.

4.2 ANALYSIS OF APPLIED EXAMPLES

Based on the above research results, this paper takes the random waypoint mobility model as an example to illustrate the effectiveness of the proposed method. The secondary indicators in mobility model evaluation index conclude both quantitative indicators and qualitative indicators, so need to combine expert consultation method and fuzzy membership function to calculate the membership. The results are shown in the following table.

TABLE 2 weights and evaluation indexes

Index	Weight	Index	Weight	Evaluation set				
				A	*B*	*C*	*D*	*E*
u_1	0.5	u_{11}	0.7	0.1	0.5	0.2	0.1	0.1
		u_{12}	0.3	0.3	0.3	0.2	0.1	0.1
u_2	0.2	u_{21}	0.3	0.1	0.4	0.3	0.2	0
		u_{22}	0.2	0	0.1	0.2	0.5	0.2
		u_{23}	0.1	0	0.2	0.4	0.2	0.2
		u_{24}	0.1	0	0.1	0.2	0.4	0.3
		u_{25}	0.3	0	0.2	0.3	0.3	0.2
u_3	0.2	u_{31}	0.5	0.1	0.3	0.3	0.2	0.1
		u_{32}	0.2	0	0.2	0.5	0.2	0.1
		u_{33}	0.3	0	0.3	0.5	0.1	0.1
u_4	0.5	u_{41}	0.6	0.2	0.4	0.2	0.1	0.1
		u_{42}	0.4	0.3	0.3	0.2	0.1	0.1

Based on the above indexes information, the weight and evaluation vector is constructed. First level weight matrix is as follow. The weight vector of u_1 is $A_1=(0.7,0.3)$. From u_2 to u_4, the weight vectors are $A_2=(0.3,0.2,0.1,0.1,0.3)$, $A_3=(0.5,0.2,0.3)$, $A_4=(0.6,0.4)$. The weight of U Is $A=(0.5,0.2,0.2,0.1)$. The evaluation matrix is as follows from u_{ij} to V.

$$R_1=\begin{bmatrix} 0.1 & 0.5 & 0.2 & 0.1 & 0.1 \\ 0.3 & 0.3 & 0.2 & 0.1 & 0.1 \end{bmatrix}$$

$$R_2=\begin{bmatrix} 0.1 & 0.4 & 0.3 & 0.2 & 0 \\ 0 & 0.1 & 0.2 & 0.5 & 0.2 \\ 0 & 0.2 & 0.4 & 0.2 & 0.2 \\ 0 & 0.1 & 0.2 & 0.4 & 0.3 \\ 0 & 0.2 & 0.3 & 0.3 & 0.2 \end{bmatrix}$$

$$R_3=\begin{bmatrix} 0.1 & 0.3 & 0.3 & 0.2 & 0.1 \\ 0 & 0.2 & 0.5 & 0.2 & 0.1 \\ 0 & 0.3 & 0.5 & 0.1 & 0.1 \end{bmatrix}$$

$$R_4=\begin{bmatrix} 0.2 & 0.4 & 0.2 & 0.1 & 0.1 \\ 0.3 & 0.3 & 0.2 & 0.1 & 0.1 \end{bmatrix}$$

Because all of the evaluation matrixes of u_{ij} are obtained, rank the evaluation matrixes corresponding to each index in u_{ij}. According to the formula (1), we can get the results of the first level fuzzy evaluation.

$$B_1=A_1*R_1=(0.37 \quad 0.44 \quad 0.2 \quad 0.1 \quad 0.1), \qquad (2)$$

$$B_2=A_2*R_2=(0.03 \quad 0.23 \quad 0.28 \quad 0.31 \quad 0.15), \qquad (3)$$

$$B_3 = A_3 * R_3 = \begin{pmatrix} 0.05 & 0.28 & 0.4 & 0.17 & 0.1 \end{pmatrix}, \quad (4)$$

$$B_4 = A_4 * R_4 = \begin{pmatrix} 0.24 & 0.36 & 0.2 & 0.1 & 0.1 \end{pmatrix}, \quad (5)$$

Based on the above results, we can get the second level evaluation matrix.

$$R = \begin{pmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{pmatrix} = \begin{bmatrix} 0.37 & 0.44 & 0.2 & 0.1 & 0.1 \\ 0.03 & 0.23 & 0.28 & 0.31 & 0.15 \\ 0.05 & 0.28 & 0.4 & 0.17 & 0.1 \\ 0.24 & 0.36 & 0.2 & 0.1 & 0.1 \end{bmatrix}$$

According to the formula (1), the fuzzy comprehensive evaluation result for evaluation objective M .

$$B = A * R = \begin{pmatrix} 0.225 & 0.358 & 0.256 & 0.156 & 0.11 \end{pmatrix}. \quad (6)$$

Finally, we use the weighted sum method to transform (B) into a concrete numerical value. That is an average score set $S = (95, 85, 75, 65, 30)$ is assigned for V , then the weighted sum of scores is as follows.

$$P = B \circ S^T = 840445. \quad (7)$$

From the above comprehensive evaluation value, we can draw a conclusion that the RWP model is better.

More examples about fuzzy comprehensive evaluation are not listed here because of limitations of paper length. However, all the results show that the FCEM can be effectively used to the comprehensive evaluation mobility model.

5 Conclusions

Mobility model evaluation is an important issue in mobility model research. Firstly, this paper studies the characteristics of mobility model and the characteristics of model evaluation. In this paper, we propose the mobility model evaluation system, which is based on the temporal and spatial characteristics of mobility model nodes, the network topology, the authenticity of the model and the influence of the model on the network performance. The model evaluation structure is introduced in detail, and the detailed definition and calculation method of each index are given. Secondly, on the basis of this, the paper puts forward a fuzzy comprehensive evaluation model by using the fuzzy evaluation theory of fuzzy mathematics. This model not only provides new ideas and methods for mobility model evaluation, but also provides help and guarantee for mobile node modelling. Finally, the application of the model is demonstrated through the evaluation of the random waypoint (RWP) model.

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