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Urban Design Logical Scheming Based on Semantic Network Information

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Abstract: Urban design logical scheming is a research based on the semantic network method, supplementing and perfecting the semantic network method. After the introduction of the semantic network logical scheming method, some experimental studies had been done from the aspects of logical judgment, logical screening and logical solving to text the validity and feasibility of semantic network scheming method applied in urban designing. Thereinto, logical judgment was mainly used to evaluate the accuracy of the urban design scheming reasoning. Logical screening was mainly used to select the effective scheming plans which applied the semantic network scheming method and the logical solving was mainly used to resolve contradictory problems in urban design scheming. These experimental studies could provide a basis for computer-aided urban design scheming.

Key words: Urban design, logical scheming, semantic network information

INTRODUCTION

Urban design scheming is a complex and difficult game process (Shan, 2008).There is a phenomenon that the human's emotion or subjectivity will often interfere with the rational thinking in urban design scheming. That is because the urban design scheming has characteristics of multi-staff and multi-specialty. In dealing with the urban design issues, people involved always "look ahead into the future but forget the past" and that make it difficult to ensure whether the restrictions would remain binding after discussion and reflection. It is not reliable to reason relying heavily on the experience of human. According to the characteristics of the logical structure of semantic network, it is significant to integrate this kind of logical tool into urban design scheming. In this paper, the application of this classical logic method will be discussed.

BASIC CONCEPT

Urban semantic network scheming method: Semantic network method was proposed in ICTAS2011 in allusion to urban design scheming (Dong and Zou, 2011). It aimed at building a formal expression and analysis to adapt to the human's thinking mood and the feathers of urban designing. And this method would assist the urban design scheming. It was consistent with the advancement "knowledge based design" proposed by Thomas Herzog, scilicet, against with the traditional "experiences or consciousness in design" (Wang and Zhang, 2009). It was also a response of the view which regarded urban design as pseudo-scientific (Marshall, 2012).

Logic in the urban semantic network: One of the implications of building an urban semantic network is that as long as the urban design scheming issue forms a propositional semantic network, it would be expressed by the predicate logic axiom system. So it will be possible to solve the logical problems in the urban design scheming process by means of the computer such as Prolog. Through the logical proposition, various dimensions of urban design scheming elements will be associated and applied in logic operations. This is particularly important for complex problems. Because the veracity of scheming conclusion could be assured as well as the planners will be freed from the complex calculations and focus on the judgment of the key issues.

Logical scheming process based on SN method: In the SN method of urban design scheming process, this logical tool will be applied to achieve "Evidence Based Design (EBD)". In this paper, the principles and the applications of logical judgment, logical screening and logical solving in logical scheming process will be introduced through some experiments. The basic procedures are: urban semantic network, predicate logic expression, programming in logic and computer implementation (Fig. 1).

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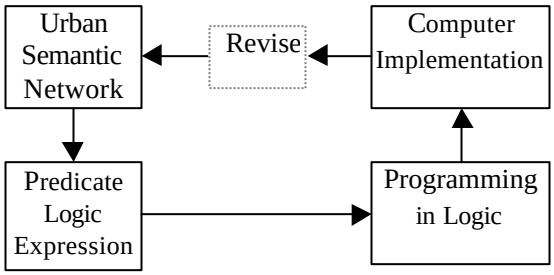

Fig.1: Procedure of urban design logical scheming

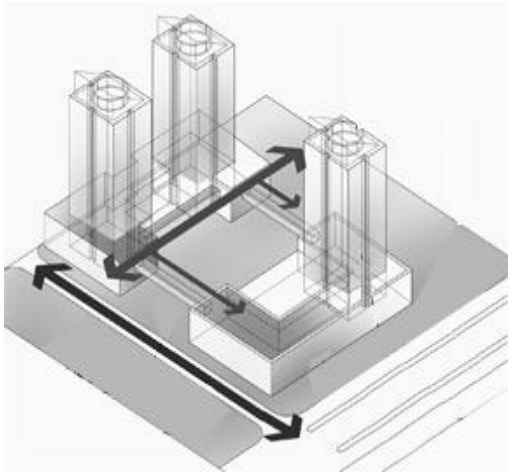

Fig. 2: A District in CBD

LOGICAL JUDGMENT IN URBAN DESIGN SCHEMING BY SEMANTIC NETWORK

Axiom of corresponding function: The problems of reasoning and judging were often encountered in the process of building the urban semantic network model especially building the propositional semantic network. When a designer conceived in the scheming phase, his logical judgment was occasionally disturbed by the empirical or emotional thinking. Especially in multi-specialty discussion, there would be a simple logical error. The purpose of logical method applied in SN method is to inspect and modify the validity and accuracy of urban network chain through the logical reasoning and programming. Then the subjective and judgmental error will be correct in constructing the complex models and the efficiency will be improved.

There will be a large number of propositional logic and predicate logic in the building the urban semantic network and sometimes there will be a logical contradiction. In order to verify whether the form of

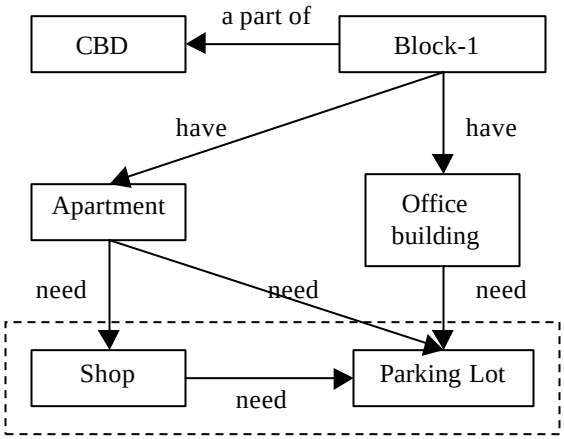

Fig.3: Part of Semantic Network of Case 1

reasoning was established or not in the semantic network, three kinds of inference methods were used generally. They are truth table, direct demonstration and indirect demonstration (Cai *et al*., 2008). In this paper, the indirect demonstration will be chosen to illustrate the specific implementation of the logical judgment of urban design scheming based on semantic network.

Case study: In urban design scheming process, regulatory detailed planning will be partly adjusted. For example, when a designer devises an urban plot using scheme, he sometimes will implement the actual function according to the needs of the urban landscape control. In Fig. 2, this plot should mainly be built point high-rise buildings on the basis of the comprehensive urban design.

But after the discussion and analysis, it is possible to build the ancillary facilities with several functions such as office building or apartments. While the sky-bridge system create good condition for setting a surface parking lot. Taking the region convenience into account, a mini-mall could be built in the podiums. It is common to encounter the logical judgment such as whether there should be a parking lot in front of a shop when constructing an urban semantic network. And this judgment is the grey-colored area in the propositional semantic network in Fig. 3.

After the discussion, the following propositions in semantic network must be met in Fig. 3:

- If built the office buildings or apartments on this plot, there must be the parking lot
- No shopping malls or office buildings
- Build apartments

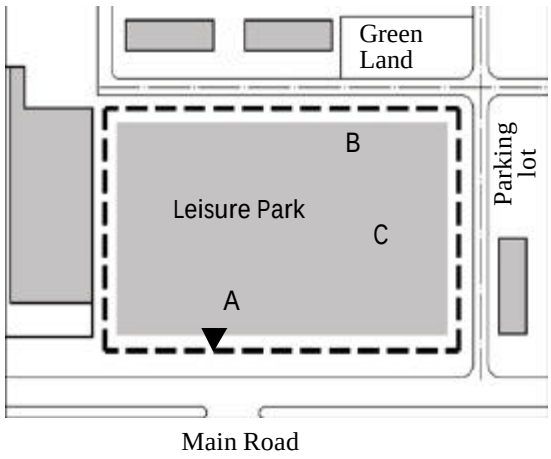

Fig. 4: Leisure Park in a District

If the three preconditions are met at the same time, it can be judged by the CP rules that whether the NE proposition in grey-colored area is true.

Logical judgment: First, semantic nodes or NEs can be proposed like this.
where, P is built office buildings, Q is built apartments, S is setting parking lots, R is building shopping malls:

- **Premise:** $(P \wedge Q) \rightarrow S, \neg R \vee P, Q$
- **Conclusion:** $R \rightarrow S$

Proving the validity of the conclusions by inference rules:

- R P(additional)
- $\neg R \vee P$ P
- P T, I, (1), (2)
- Q P
- $P \wedge Q$ T, I, (3), (4)
- $(P \wedge Q) \rightarrow S$ P
- R T, I, (5), (6)
- $R \rightarrow S$ CP Rules

Consequently, the reasoning process is correct and the NE proposition in gray area is true.

LOGICAL SIFTING IN URBAN DESIGN SCHEMING BY SEMANTIC NETWORK

Axiom of corresponding function: The conclusion can be reached by the use of the conjunctive normal form and the disjunctive normal form to determine whether a formula is a tautology or a contradiction in the proposition of urban semantic network. However, the various representations of the conjunctive normal form and the disjunctive normal form of the propositional formula in urban scheming would cause difficulties to judge the equivalent propositional formula. And that is not necessary for the practicability of urban design scheming. So the uniqueness of the principal normal form can be used to express the propositional formula. The purpose of logical screening in urban design scheming based on semantic network is to screen a feasible scheme and to provide the basis for the optimaldesign. So what will be discussed in this paper is not the principal conjunctive normal form but the principal disjunctive normal form.

If the amount of the propositional variables were N, there should be 2n minimum terms. Each minimum term has only one true assignment, so the logical scheme would be obtained by the minimum terms in urban design scheming process. In this way, not only the accuracy and the efficiency of urban design scheming would be improved, but also the possible options were not easy to be ignored. In order to verify the effectiveness of the logical screening, the case below is used to explain how to obtain possible schemes through the minimum terms of the principaldisjunctivenormalform.

Case study: After the demolition of the original building, a leisure park which primarily serves the nearby residents is needed on the site of this district. Location A is able to highlight the image of the entrance to the park. Location B and C are more convenient for the nearby residents. However, in order to facilitate management, at most two locations from A, B, C could be select as the entrances. After the study of urban design scheming, where to set the entrances must meet the following three conditions:

- If one entrance was set in Location A, the other should be set in Location C as a convenient entrance
- If one entrance was set in Location B, the other should not be set in Location C by the reason of the close distance between B and C
- If any entrance could not be set in Location C, there must be an entrance set in Location A or B (or set in Location A and B)

The following propositions were obtained as the figure below:
where, P is setting entrance in Location A, Q is setting entrance in Location B, R is setting entrance in Location C.

The corresponding propositional semantic network is expressed like Fig. 5.

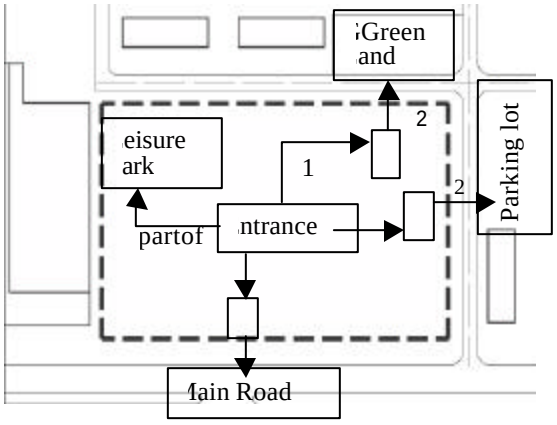

Fig. 5: Semantic network of Case 2

Logical sifting: In this case, several schemes fulfilled the conditions above could be obtained by means of the logical calculus.

A formula can be obtained according to the known conditions:

$$(P\rightarrow R)\wedge(Q\rightarrow\neg R)\wedge(\neg R\rightarrow(P\vee Q))$$

After calculation, the formulas can be obtained like this:

$$(P\rightarrow R)\wedge(Q\rightarrow\neg R)\wedge(\neg R\rightarrow(P\vee Q))\Leftrightarrow$$
$$(\neg P\vee R)\wedge(\neg Q\vee R)\wedge(R\vee(P\vee Q))\Leftrightarrow$$
$$(\neg P\wedge\neg Q\wedge R)\vee(\neg P\wedge Q\wedge\neg R)\vee(P\wedge\neg Q\wedge R)$$

This principal disjunctive normal form contains three minimum terms. It means there are three alternatives:

- To set the entrance in Location C. Neither Location A nor B set the entrance
- To set the entrance in Location B. Neither Location A nor C set the entrance
- To set the entrances in both Location A and C. There is no entrance set in Location B

The condition ③ can be used as the forth alternative because it is also an eligible condition. Consequently, the feasible scheme can be obtained explicitly by means of logical operation and then the feasible semantic network of that scheme can be determined. The case above is just a simple example. But it would be inevitably to lead to the error in judgment if there were too many constraints. The application of SN method would help the designers to get rid of the mental problems and paid more attention to the thinking of key issues.

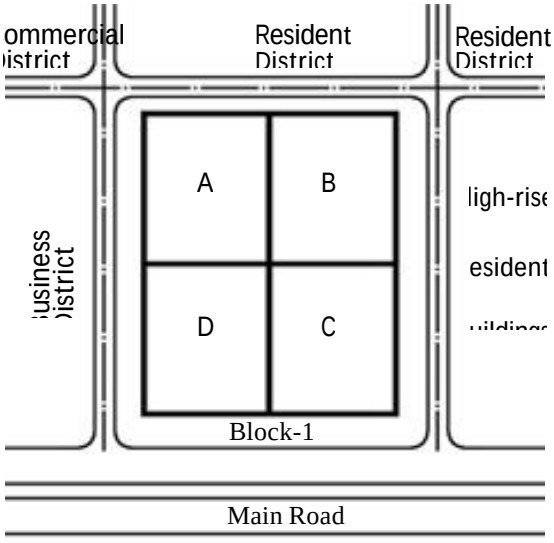

Fig. 6: Open space in a district

LOGICAL SOLVING IN URBAN DESIGN SCHEMING BY SEMANTIC NETWORK

AXIOM OF CORRESPONDING FUNCTION: In logic, if there was a known equivalence, several corresponding equivalences could be deduced. This process is called Equivalent Calculation. As an important section of mathematical logic, Equivalent Calculation can both demonstrate the equivalence of a formula and judge the propositional formula. An equivalent calculation combined with substitution theorem and replacement theorem will be took for example to solve the problem of the logical solution in urban design scheming.

This research is in allusion to the urban design scheming in the model of urban semantic network. In the process of the operation of urban semantic network, a great many of implication propositions constituted by the semantic network elements have to be confronted. So it is important to transform the implication forms into disjunctive forms and conjunctive forms when solving the problem of urban design scheming. Take the following two laws of proposition for example:

- **Implication equivalent:** $\alpha>\beta\Leftrightarrow\neg\alpha\vee\beta$
- **Hypothetical translocation:** $\alpha\rightarrow\beta\Leftrightarrow\neg\beta\vee\neg\alpha$

Case study: There was a block with four parts of A, B, C, D. Assuming that it required the functions of parking lot, commercial, office and green land (Fig. 6).

The designer I considered from the situational analysis view and he setting the parking lot on C and the commercial on B.

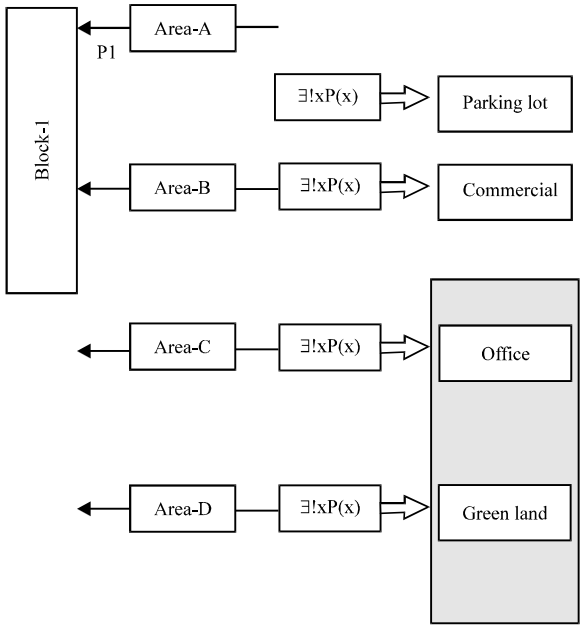

Fig. 7: Semantic Network of Case 3, P(x):x have function of P1: a quarter of

Resident Representative II and developers III considered from their own needs and interests and presented their ideas about the functional distribution:

Resident Representative II required that C should be the commercial and D should be the office.

Developer III required that the A should be the commercial and D should be the green land.

This was a typical game of urban design scheming. There were a number of contradictions in the requirements of the expectations and interests from the different crowd.

If there was no power factor, this problem could be solved by means of logical solving on condition of a general satisfaction which reached half of the desired level from designers, community residents and developers. The semantic network is shown in Fig. 7.

Logical solving: Pi, Qi, Ri, Si represented the functions which were accommodated by plot A, B, C, D and the order of the function item could be recorded as i (i = 1, 2, 3, 4). If only the half desired level could be reached lead to the following three equivalents:

- $(R1\wedge\neg Q2)\vee(\neg R1\wedge Q2)\Leftrightarrow 1$
- $(R2\wedge\neg S3)\vee(\neg R2\wedge S3)\Leftrightarrow 1$
- $(P2\wedge\neg S4)\vee(\neg P2\wedge S4)\Leftrightarrow 1$

The conjunctions of the tautologies were still tautologies, so it could be deduced that ①∧②⇔1. That was to say:

$$1\Leftrightarrow((R1\wedge\neg Q2)\vee(\neg R1\wedge Q2))\vee((R2\wedge\neg S3)\vee(\neg R2\wedge S3))\Leftrightarrow (R1\wedge\neg Q2\wedge R2\wedge\neg S3)\vee(R1\wedge\neg Q2\wedge\neg R2\wedge S3)\vee (\neg R1\wedge Q2\wedge R2\wedge\neg S3)\vee(\neg R1\wedge Q2\wedge\neg R2\wedge S3)$$

Parking lot and commercial were incompatible on plot C. Plot B and C could not be office simultaneously. So it could be deduced that:

$$R1\wedge\neg Q2\wedge R2\wedge\neg S3\Leftrightarrow 0$$
$$\neg R1\wedge Q2\wedge R2\wedge\neg S3\Leftrightarrow 0$$

And:

- $(R1\wedge\neg Q2\wedge\neg R2\wedge S3)\vee(\neg R1\wedge Q2\wedge\neg R2\wedge S3)\Leftrightarrow 1$

The conjunction of ③ and ④ was recorded as ③∧④⇔1.That was to say:

$$1\Leftrightarrow((P2\wedge\neg S4)\vee(\neg P2\wedge S4))\vee((R1\wedge Q2\wedge\neg R2?S3)\vee(\neg R1\wedge Q2\wedge\neg R2\wedge S3))\Leftrightarrow (P2\wedge\neg S4\wedge R1\wedge\neg Q2\wedge\neg R2\wedge S3)\vee(P2\wedge\neg S4\wedge\neg R1\wedge Q2\wedge\neg R2\wedge S3)\vee(\neg P2\wedge S4\wedge R1\wedge\neg Q2\wedge\neg R2\wedge S3)\vee(\neg P2\wedge S4\wedge\neg R1\wedge Q2\wedge\neg R2\wedge S3)$$

Plot A and B could not be commercial simultaneously. Office and green land were incompatible on plot D. So it could be deduced that:

$$P2\wedge\neg S4\wedge\neg R1\wedge Q2\wedge\neg R2\wedge S3\Leftrightarrow 0$$
$$\neg P2\wedge S4\wedge R1\wedge\neg Q2\wedge\neg R2\wedge S3\Leftrightarrow 0$$
$$\neg P2\wedge S4\wedge\neg R1\wedge Q2\wedge\neg R2\wedge S3\Leftrightarrow 0$$

It would be obtained that:

- $P2\wedge\neg S4\wedge R1\wedge\neg Q2\wedge\neg R2\wedge S3\Leftrightarrow 1$

Consequently, what could be deduced was that plot C should be the parking lot, A should be the commercial, D should be the office and B should be the green land. Thus, all aspects of the expectations and interests were partly satisfied.

Sometimes the logical solving could deduce only one certain semantic network but sometimes it would deduce several relatively satisfying results. To the second case, a balance of scheming satisfactory was needed according to the actual conditions.

CONCLUSIONS

What is indispensable are logical thinking and experience judgment of the scheming participants no matter in the construction of the urban semantic network or the determination of the NE proposition. The purpose is not pursuing the absolute right in a specific link, but to ensure the accuracy and logicality of the scheming process through this method as far as possible. Therefore, this method is essentially not excluding the experience factors, subjective factors or even personal bias when defines the variables (Alexander, 2010):

- Logical tools are necessary in urban design scheming to ensure the accuracy of scheming process and get rid of the dependence on empirical or inertia thinking. In urban design scheming process, logic is practical at least in three aspects, namely logical judgment, logical screening and logical solving
- Logical method is mechanical and rigid which leads to some limitations and it can not replace the human's experience-based judgment. Subjective thinking in urban design scheming process excludes the logical thinking sometimes. However, it is necessary for logical method to assist scheming on some links of urban design scheming. That is the guaranteejavascript:void (0); of obtaining a correct scheming conclusion
- The construction of urban semantic network could transform the scheming problem into a logical proposition. It provides the basis of a formal language for computer-aided scheming. It makes computer and artificial intelligence system play an important role in the urban design scheming based on semantic network

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