THE DESIGN AND IMPLEMENTATION OF AN URBAN DECISION SUPPORT SYSTEM BASED ON ARTIFICIAL INTELLIGENCE CONCEPTS

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ABSTRACT:

In this paper, fuzzy set theory was used to deal with the current issues in urban management and spatial decision making. Recently one of the common tools used in this field is Urban Information System (UIS) whose capability is obvious, but one of the considerable problems in this system is how to communicate with users, i.e., the citizens, in a suitable way due to inherent vagueness exists in definitions of needs and criteria with lingual statements. The method used in this study is based on the UIS, as an efficient tool and the fuzzy set theory as a best solution to cope with vagueness. The method was tested in a case study to find a suitable house according to user's criteria using a 1:2000 digital map of Rasht which consisted of several layers. The result shows superiority of our proposed method based on fuzzy set theory over the conventional systems.

1. INTRODUCTION

Structural complexities as well as the cultural and economical complications in cities have made the urban management and proper decisions making a real necessity. This means that powerful city planning and management's tools based on spatial decision support systems are real needs for the present situation of the world (Cardenas and Whitaker, 2000; Danahy, 1999). Decision making from land administration and property valuation to simple house transaction as well as transportation decision in a city needs spatial decision support systems based on *Urban Information System (UIS)*. An urban information system is now internationally acknowledged to be a suitable tool to improve the management and planning potentials for the people who live in urban areas (Haala, 1999). These systems' Achilles' heel is that they mainly provide users with simple spatial queries, which are far from real needs, so a partial solution to the problem may be obtained.

In order to increase the potentials of a UIS and make a proper *Spatial Decision Support System (SDSS)* to deal with these queries, it is necessary to incorporate the following concepts into the decision support system (Shyllon, 2000):

(a) Descriptive parameters should be expressed based on linguistic variables
(b) Uncertainty levels of the decisions should be modelled.

During recent years, a wide variety of related topics have been investigated by many researchers in GIS community (Smith, 1984; Fisher et. al. 1988; Altman, 1994; Hootsmans, 1996; Openshaw and Openshaw, 1997; Zheng and Kainz, 1999).

The method that is proposed in this paper takes advantage of the concept of the fuzzy logic to solve the above-mentioned complications. To verify the proposed idea, an *Urban Decision Support System (UDSS)* based on artificial intelligence concepts designed and implemented as a case study to select and purchase an appropriate house in the following steps.

2. FUZZY SET THEORY

L. Zadeh suggested the use of fuzzy sets as a framework for designing knowledge based systems. The main idea for introducing the idea of fuzzy sets was that in many applications the crisp membership degree 1 (complete membership) and 0 (set exclusion) seem to be insufficient to describe vague concepts naturally (Kruse et al., 1991).

If X is a collection of objects denoted generically by x, then a *fuzzy set* $\tilde{A}$ in X is a set of ordered pairs:

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) \mid x \in X\}$$

$\mu_{\tilde{A}}(x)$ is called the *membership function* or grade of membership of x in $\tilde{A}$ that maps X to membership space *M*. The range of the membership function is a subset of the negative real numbers whose supremum is finite (Zimmerman, 1996).

The membership function is obviously the crucial component of a fuzzy set. It is therefore not surprising that operations with fuzzy sets are defined via their membership functions. The usual set-theoretic operations can be extended in a straightforward way by fuzzy logic to fuzzy sets. We obtain for all $x \in X$ (Zimmerman, 1996):

- The membership function $\mu_{\tilde{C}}(x)$ of the *intersection* $\tilde{C} = \tilde{A} \cap \tilde{B}$ is defined by

$$\mu_{\tilde{C}}(x) = Min\{\mu_{\tilde{A}}(x), \mu_{\tilde{B}}(x)\}$$

- The membership function $\mu_{\tilde{D}}(x)$ of the *union* $\tilde{D} = \tilde{A} \cup \tilde{B}$ is defined by
$$\mu_{\tilde{D}}(x) = Max\{\mu_{\tilde{A}}(x), \mu_{\tilde{B}}(x)\}$$

- The membership function of the *complement* of a fuzzy set $\tilde{A}$ is defined by
$$\mu_{\sim\tilde{A}}(x) = 1 - \mu_{\tilde{A}}(x)$$

3. DESIGN AND IMPLEMENTATION

3.1 Design and Preparation

Preparation step consists of selecting an area and digital maps and extracting required information layers. The required information layers have been extracted from 1:2000 scale digital maps of the city of Rasht. These maps have been produced from 1:4000 aerial photographs by National Cartographic Centre (NCC) of Iran. Sample part of the maps is presented in *Figure (1)*.

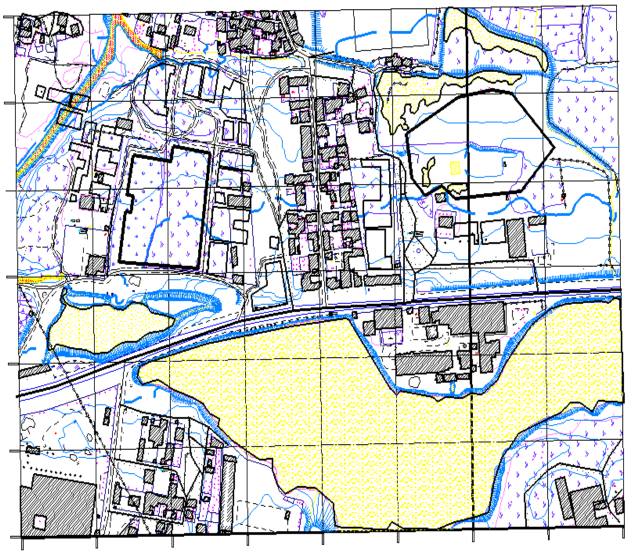

Figure 1. Sample of 1:2000 digital map of Rasht

After extracting information layers, these layers were classified to 5 different classes Structure, Way, Building, Area and Utility. Different layers of each class which were imported from MicroStation design files (IGDS) were converted to ARC/INFO coverages. After importing, the layers cleaned and edited for entering to an Urban Information System using ARC/INFO software.

Besides these layers, spot heights and 3D information of the map features were used to create digital elevation model (DEM) of the area which in turn were used to generate slope grid.

Attributes such as Ownership, Price and Usage were collected from field survey and linked to the attribute tables.

3.2 Implementation

To model this intelligent decision support system based on the fuzzy reasoning approach, in the first stage linguistic variables for decision making to buy a house is defined. These linguistic variables are Distance, Dimension, Cost and Slope. Linguistic variables and linguistic labels are presented in *Table (1)*.

In the next step the membership functions with respect to the linguistic rules to describe an ideal house are determined. These are then embedded into a fuzzy reasoning structure by ARC Macro Language (AML). The fuzzy reasoning structure is *Mamdani* type in which the dimensions and cost of a house and distance from special areas and slope of the area which the house is located are defined as the input variables and the user's definition for an appropriate house is defined as the output variables.

Linguistic Variable	Linguistic Labels
Cost	*Cheap, Common, Expensive, So Expensive*
Dimension	*So Small, Small, Medium, Large, Huge*
Distance	*So Far, Far, Near, Close*
Slop	*Steep, Moderate, Slight*
Candidate	*Not Fit, Probably Not Fit , Probably Fit, Fit*

Table 1. Linguistic variables and Labels of fuzzy reasoning system

4. RESULTS

To evaluate the capability of implemented methods, we wanted a citizen to use each two systems to find his suitable house. As it was predicted, the user had various problems in classic method. The output of this part depicted in figure 2.

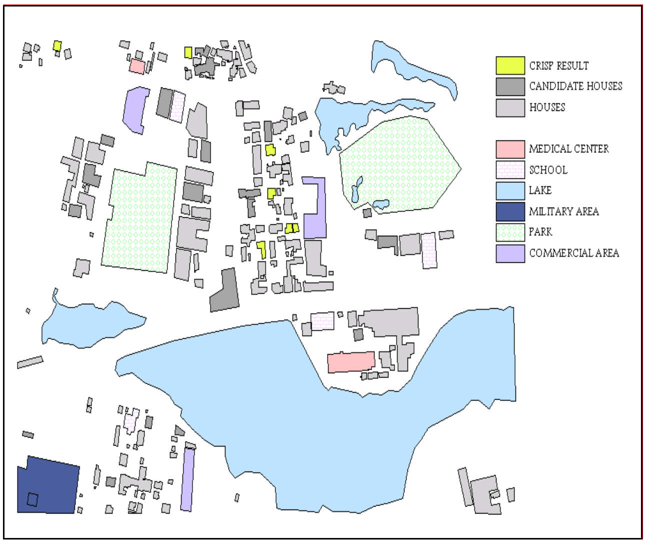

Figure 2. Output of crisp query

In fuzzy part, user submits his criteria about a suitable house in the form of the rules according to the linguistic variables and labels. Some of these rules are:

- ***If*** (Slope is Slight) ***and*** (Dimension is Medium) ***and*** (Cost is Cheap) ***and*** (MedicalDist is Near) ***and*** (SchoolDist is Near) ***and*** (MilitaryDist is not Near) ***and*** (LakeDist is not Near) ***and*** (parkDist is Near) ***and*** (CommerDist is Near) ***then*** (Fitness is Fit)

- ***If*** (Slope is Moderate) ***and*** (Dimension is Medium) ***and*** (Cost is Common) ***and*** (MedicalDist is Medium) ***and*** (SchoolDist is Medium) ***and*** (MilitaryDist is Far) ***and*** (LakeDist is Far) ***and*** (parkDist is Medium) ***and*** (CommerDist is Medium) ***then*** (Fitness is ProbabilyFit)
- ***If*** (Slope is Moderate) ***and*** (Dimension is Medium) ***and*** (Cost is Expensive) ***and*** (MedicalDist is not Near) ***and*** (SchoolDist is not Near) ***and*** (MilitaryDist is not Far) ***and*** (LakeDist is not Far) ***and*** (parkDist is Far) ***and*** (CommerDist is Far) ***then*** (Fitness is ProbabilyNotFit)

- ***If*** (Slope is Slight) ***and*** (Dimension is Huge) ***and*** (Cost is Expensive) ***and*** (MedicalDist is Medium) ***and*** (SchoolDist is Near) ***and*** (MilitaryDist is Medium) ***and*** (LakeDist Medium) ***and*** (parkDist is not Far) ***and*** (CommerDist is Near) ***then*** (Fitness is ProbabilyFit)

- ***If*** (Slope is Slight) ***and*** (Dimension is Large) ***and*** (Cost is Expensive) ***and*** (MedicalDist is Medium) ***and*** (SchoolDist is Medium) ***and*** (MilitaryDist is Near) ***and*** (LakeDist is Medium) ***and*** (parkDist is Far) ***and*** (CommerDist is Far) ***then*** (Fitness is ProbabilyNotFit)

After forming the rule-base, system was able to measure the amount of consistency between user's requests and candidate house. The output of this part depicted in figure 3.

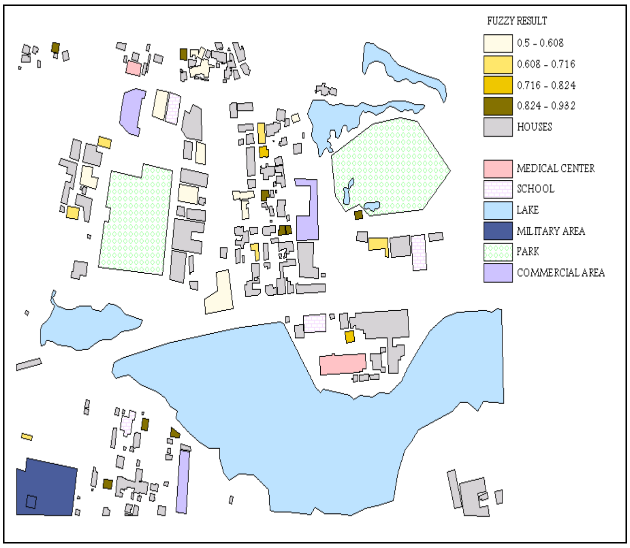

Figure 3. Output of fuzzy-based query

As well as mentioned capabilities of system, it also could recognize the candidate houses whose consistency degree was higher than a defined possible level (between 0 and 1).

5. CONCLUSION

In this paper, the 1:2000 scale digital map of a region of Rasht which included different layers like buildings, medical centres, schools used as a base, as well as attributes like cost, land use which linked to spatial data and tried to find the best and suitable house according to criteria mentioned by users, and was shown as a report or a view on screen. This process was done both in crisp and fuzzy forms. In crisp processing, the values were inputed to the system numerically and the results of analysis, i.e., the houses achieved user's criteria were reported. But in fuzzy part in spite of crisp, queries were sent to system using linguistic variables and the output of system was shown as the consistency of existing houses with user's criteria. The comparison of results of these two systems illustrates the high capability of fuzzy rather than the crisp.

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