# Fuzzy Controller for Spatial Objects Recognition

Mihaela GHINDEANU

Faculty of Mathematics and Computer Science,
Department of Computer Science,
University of Craiova, Romania
mghindeanu@yahoo.com

**Abstract.** One of the most important capabilities of Geographic Information System (GIS) is to interpret and solve spatial problems. In this paper we present a fuzzy controller designed for interpretation of a spatial photograph. Thus, using a proper database of fuzzy rules the system can diagnose the objects of the spatial image based on certain features.
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## 1 INTRODUCTION

Spatial analysis in GIS commonly has been performed with statistics packages as analysis tools. Other approaches have included the use of fuzzy logic, cellular automata, neural-networks, and artificial intelligence (AI) techniques, such as knowledge-based systems. This paper examines an application of AI techniques in GIS.

Although some AI techniques have been applied to spatial data, it is very difficult for non-experts in AI techniques to develop and use a hybrid system based on GIS and AI techniques because of computer programming skills required to apply expert's knowledge. However, a rule-based expert system uses a simple, easy rule structure, and hence has been the most common technique in knowledge-based AI for developing hybrid systems with GIS.

In this paper, a fuzzy rule-based expert system is presented. Using this system users can determine a solution to a specific problem easily from the constructed fuzzy rules through the interactive question and answer sequence. The questions and solutions will be generated by the inference engine using the existing rules.

There are some limitations in applying a rule-based system. First, if a complex task has to be executed, several hundred rules may be required. Second, a rule-based expert system cannot use the previous solutions that have been obtained. Thus, the users have to answer again to all the questions generated by the inference engine, even if the problem is the same or similar to an old one. Third, there are no exceptions in rules. This means that it is not allowed for users to make mistakes in answers.

## 2 THE INFERENCE ENGINE OF THE SYSTEM

This fuzzy controller was built using the programming environment MATLAB and can be used for recognize spatial objects from an (satellite) image. Based on the features introduced by the user for a certain detail of the photo the system establishes if the detail is entirely or is part of:

- a lake
- a river
- an arable field
- a park
- a residential district
- a street
- industrial buildings

In this system there are four basic elements for the interpretation of aerial photographs: texture, spectral value, area and contour. Thus:

- *texture* is a frequency of tone change within the photographs
- *spectral value* is the density of brightness. It is a record of light reflection from the land surface on the photo.
- *area* it is established with reference to a certain scale
- *contour* reflects in what measure the detail is regular or not

Based on these four elements the fuzzy rules of the system have been constructed. First, we use the *contour* and the *spectral value* in order to separate the urban uses from others such as lakes and lands. The *texture* is used for separate rivers from lands or industrial buildings from residential ones and based on *area* we establish how large the detail is.

## 3 THE FUZZY RULES BASE OF THE SYSTEM

As we said in the previous section, based on these four features of the structures that can appear in the spatial image the rules of the system were built.

1. If (*contour* is regular) and (*texture* is very unsmoothed) and (*spectral value* is medium) and (*area* is medium) then (**Structure** is Residential)

2. If (*contour* is regular) and (*texture* is very unsmoothed) and (*spectral value* is medium) and (*area* is large) then (**Structure** is Residential)

3. If (*contour* is regular) and (*texture* is unsmoothed) and (*spectral value* is deep) and (*area* is medium) then (**Structure** is Park)

4. If (*contour* is regular) and (*texture* is unsmoothed) and (*spectral value* is deep) and (*area* is small) then (**Structure** is Park)

5. If (*contour* is regular) and (*texture* is smooth) and (*spectral value* is light) and (*area* is medium) then (**Structure** is Industrial)

6. If (*contour* is regular) and (*texture* is smooth) and (*spectral value* is light) and (*area* is large) then (**Structure** is Industrial)

7. If (*contour* is very regular) and (*texture* is smooth) and (*spectral value* is deep) and (*area* is large) then (**Structure** is Arable Field)

8. If (*contour* is very regular) and (*texture* is smooth) and (*spectral value* is deep) and (*area* is very large) then (**Structure** is Arable Field)

9. If (*contour* is regular) and (*texture* is very smooth) and (*spectral value* is medium) and (*area* is large) then (**Structure** is Car Road)

10. If (*contour* is irregular) and (*texture* is very smooth) and (*spectral value* is deep) and (*area* is medium) then (**Structure** is River)

11. If (*contour* is very irregular) and (*texture* is very smooth) and (*spectral value* is deep) and (*area* is small) then (**Structure** is Lake)

As it can be seen, the *spectral value* is used to separate urban uses from the natural ones (parks, lands, rivers). The artificial structures such as industrial buildings or residential districts are distinguished ones from the others by the *texture* feature. Thus, the industrial buildings have the *texture* smooth, while the *texture* of residential districts is usually very unsmoothed. The linear structures such as rivers and streets are distinguished by their *contour*.

An example of a proper spatial figure for our base of spatial fuzzy rules is shown in Figure 1.

**Figure 1.** An example of a spatial image

## 4 THE USER-INTERFACE OF THE SYSTEM

As we have said, this fuzzy controller was entirely built using the MATLAB platform. The GUI interface contains dialogs for each of the four spatial features that are used in the reasoning module. Thus, the user chooses a detail within the spatial image and then it is prompted for the crisp values of the chosen detail with respect to these four features.

In our system, the premises of the fuzzy rules existed in the $R - base$ are defined as a conjunction of these four linguistic values: *area*, *texture*, *spectral value* and *contour*.

When the inference engine is started, the user is first prompted within the *area dialog* for the value of the *area* feature of the chosen detail (structure). The *area dialog* shows the membership functions for the four values of this linguistic variable: *small, medium, large, very large* (Figure 2). Thus, based on the crisp value selected by the user within the interval [1000, 110000] $m^2$ it is establish the area of the structure.

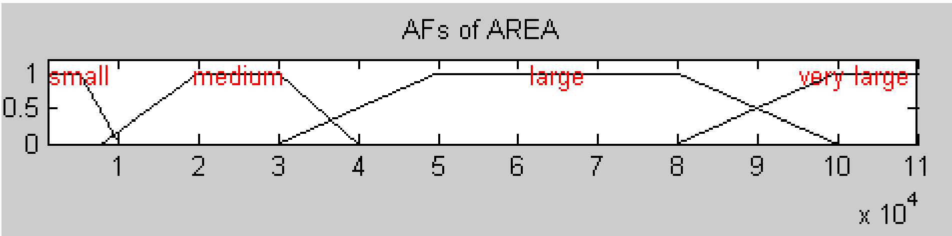


**Figure 2.** The values of the linguistic variable area

Also, it is shown the initial spatial image, but filtrate such that the user can easily determine the area of the structure. By this image transform (Figure 3) all the details are shown using tones of a unique colour and the possible irregularities are minimized.

**Figure 3.** The "area" transform

The following dialog corresponds to the linguistic variable *contour*. The values of this variable are: *very irregular, irregular, regular, very regular* (Figure 4).

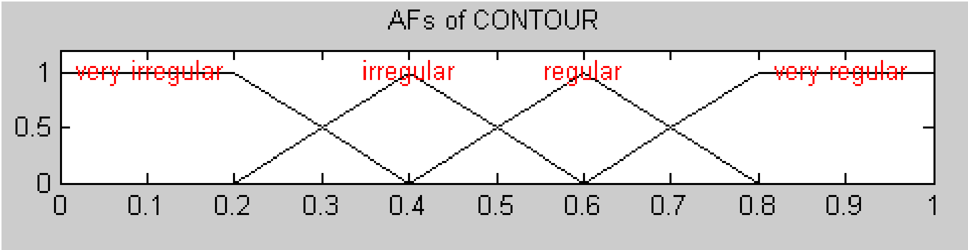


**Figure 4.** The values of the linguistic variable contour

As opposite to the *area dialog*, the *contour dialog* transforms the initial image such that all the possible irregularities of the image details are relieved (Figure 5).

**Figure 5.** The "contour" transform

The *texture dialog* also shows the membership functions of the four values of this variable: *very unsmoothed, unsmoothed, smooth, very smooth*. In the "texture" transformation all the 3-D irregularities, not only the 2-D irregularities are relieved as it can be seen in Figure 6.

**Figure 6.** The "texture" transform

Finally, the *spectral value* shows the membership functions corresponding to the values of this variable: *deep, medium, light* and the "spectral value" transform of the image.

**Figure 7.** The "spectral value" transform

For instance, let's consider the following detail in these four transformations of the considered spatial image (Figure 8).


**Figure 8.** A linear detail in all four transformation

Thus, if we choose for the *area* feature the crisp value 40000, for the *contour* feature the numerical value 0.9, for the *texture feature* the numerical value 1 and for the *spectral value* the numerical value 0.7 then the following rule will be fired:

IF AREA is large, CONTOUR is very regular, TEXTURE is very smooth, SPECTRAL VALUE is medium THEN STRUCTURE is car road

so, it is confirmed that the chosen detail is a street.

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