ARTICLE IN PRESS

Information Sciences xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

Type-2 interval fuzzy rule-based systems in spatial analysis

Ferdinando Di Martino [a], Salvatore Sessa [a,b,*]

[a] Università degli Studi di Napoli Federico II, Dipartimento di Architettura, Via Toledo 402, 80134 Napoli, Italy

[b] Università degli Studi di Napoli Federico II, Centro Interdipartimentale di Ricerca per l'Analisi e la Progettazione Urbana Luigi Pisciotti, Via Toledo 402, 80134 Napoli, Italy

ARTICLE INFO

Article history:
Received 26 December 2012
Received in revised form 23 February 2014
Accepted 22 March 2014
Available online xxxx

Keywords:
Interval type-2 fuzzy set
IT2-FS rule-based system
GIS
Spatial analysis

ABSTRACT

In this paper we present a rule-based system by using interval type-2 fuzzy sets (IT2-FS) for solving problems of spatial analysis. This system is encapsulated in a Geographical Information System (GIS) by performing numerous tests for evaluating their reliability.

1. Introduction

A problem of spatial analysis [6,7,10] lacks reliability in its final results because of the uncertainty introduced via the decision process which concerns that problem. In many cases the expert's decisions can be modeled by using fuzzy rule-based systems. Many authors (see, e. g., [1,5–12,29–32,40]) present spatial analysis frameworks in which a fuzzy rule-based system is encapsulated in a Geographical Information System (GIS). Generally speaking, in a fuzzy rule-based system (see, e.g., [13–20,24–28,33–39,41,42]) a fuzzy implication can be expressed as an IF-THEN statement, where the IF (resp., THEN) term in the rules forms the antecedent (resp., consequent). The terms in the rules are linguistic labels represented from fuzzy sets like, for instance, in the following:

IF "max_temperature = Very high" AND "humidity = Very high" THEN "chance_of_rain = High"

The terms "max_temperature = Very high", "humidity = Very high" and "chance_of_rain = High" are type-1 (that is, classical) fuzzy sets. The knowledge of the domain expert is encoded in a fuzzy rule set which is used for making decision, starting by crisp input data. The expert creates a fuzzy partition of the input and output domains by assigning a linguistic label to each fuzzy set. The AND implication in each rule is modeled using a triangular norm, usually the operator min. Indeed, if the antecedent of a rule is "IF ($x_1 = A_h$) AND ($x_2 = A_k$)", the degree of the input matching $\mathbf{x} = (x_1, x_2)$ in the rule is given as $\mu_R = \min(\mu_{A_h}(x_\backslash), \mu_{A_k}(x_2))$. This value is called *the firing level* of the rule *R*. The components of a type-1 fuzzy rule-based system are shown in Fig. 1.

* Corresponding author at: Università degli Studi di Napoli Federico II, Dipartimento di Architettura, Via Toledo 402, 80134 Napoli, Italy. Tel.: +39 0812538907; fax: +39 0812538909.

E-mail address: sessa@unina.it (S. Sessa).

http://dx.doi.org/10.1016/j.ins.2014.03.114

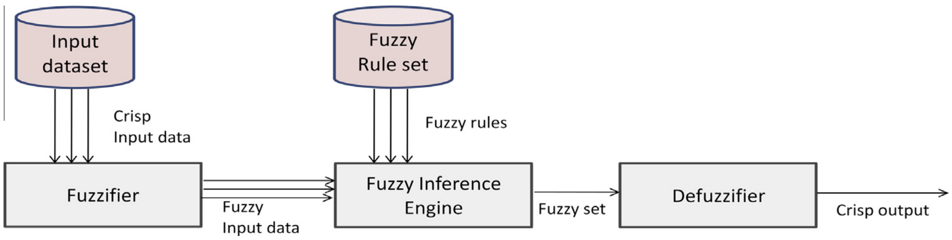

Fig. 1. Components of a type-1 fuzzy rule-based system.

The component, called *fuzzifier*, performs the fuzzification of the input crisp data; this component uses the fuzzy partitions of the domain of the input variable determining the membership value of a crisp data to each fuzzy set. Generally, this component verifies also the presence of noise in the input data.

The *fuzzy inference engine* performs the inference process; the most used inference models are due to Mamdani [23] and Sugeno [35]. In Fig. 2 an example of Mamdani inference model is applied on a fuzzy rule-based system formed from the two rules. By applying the max–min composition operator, we obtain the output fuzzy set B'.

The component, called de*fuzzifier*, performs the defuzzification process, i.e. the reconversion of the output fuzzy set B' in a crisp form. The most used defuzzification tools are the centroid and the center average methods.

In order to create the fuzzy rules, the expert creates a fuzzy partition of the variable domains. Each fuzzy set is defined via a linguistic label and the related membership function: generally, the expert uses triangular or semi-trapezoidal type-1 fuzzy sets. The membership function of a triangular type-1 fuzzy set is characterized from the lower L, central M and upper R values defined on the x-axis (L, M, R are distinct between them). The membership function of a left (resp., right) semi-trapezoidal type-1 fuzzy set have $L = M < R$ (resp., $L < M = R$) on the x-axis. Formulae (1)–(3) give the membership functions for triangular, left and right semi-trapezoidal type-1 fuzzy sets, respectively. The above type-1 fuzzy sets can be represented by a triple (L, M, R). For example, we consider a fuzzy partition of the domain "Max Temperature" in Fig. 3.

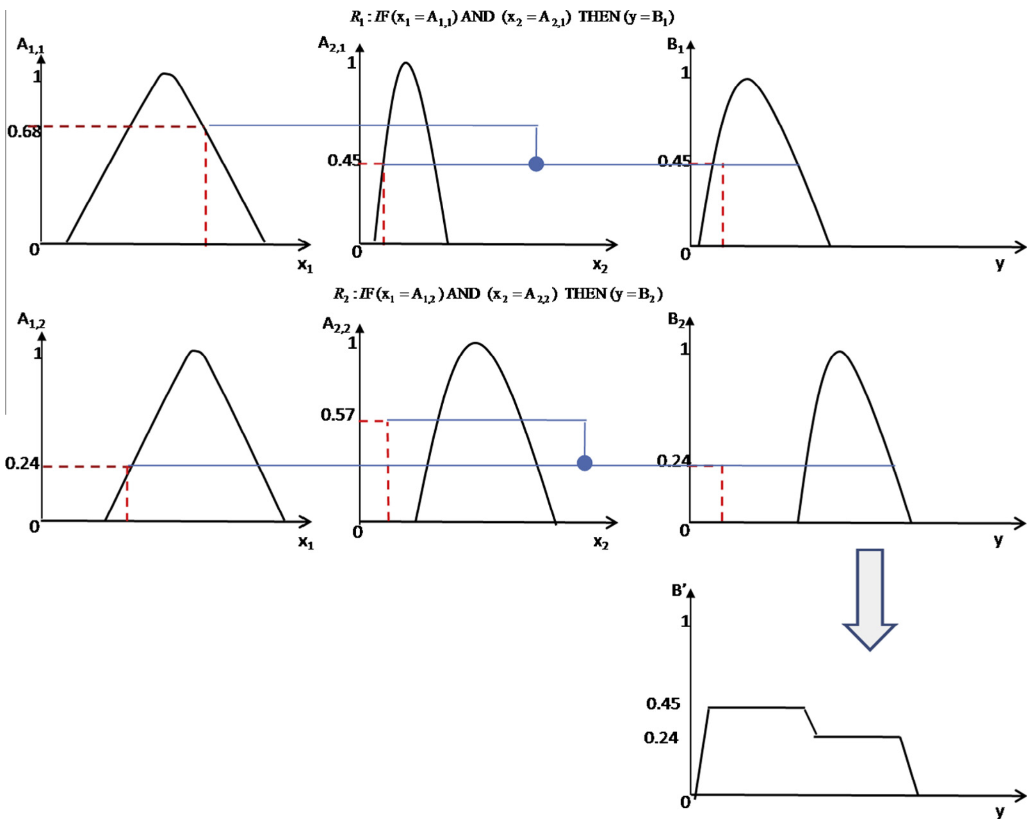

Fig. 2. Example of Mamdani model applied to type-1 fuzzy rules.

Please cite this article in press as: F.D. Martino, S. Sessa, Type-2 interval fuzzy rule-based systems in spatial analysis, Inform. Sci. (2014), http://dx.doi.org/10.1016/j.ins.2014.03.114