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# Propagation of spatial imprecision in imprecise quantitative data in agronomy

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## Abstract

*One of the stakes of Observox, an observatory of agricultural practices, is to deal with imperfect spatial information and to always associate a quality evaluation to acquired or computed data. So, we introduce the notion of fuzzy geographical entities. Then, we consider both spatial and quantitative information in order to obtain fuzzy local quantitative information. This paper proposes a new operator which gives the fuzzy quantity of spatially disseminated chemical products for each location.*

**Keywords:** Imprecision, fuzziness, propagation, agriculture.

## 1 Introduction

In the past 30 years, the use of GIS has grown and today it is the standard for managing spatial – as located on Earth – and spatiotemporal data. Their use goes from archaeology (Conolly and Lake, 2006; De Runz and Desjardin, 2010) to agronomy (the context of this work).

The spatial feature of studied entities is often as imprecise (and/or uncertain) as its quantitative and descriptive features. According to literature (Klir and Yuan, 1995; Smets, 1995; Fisher *et al.*, 2006; De Runz *et al.*, 2008), fuzzy set theory and fuzzy logic are a good approach to deal with this kind of data imperfection. Then, one can build entities where both the spatial and the quantitative features are fuzzy.

The fuzzy set theory allows overlap between fuzzy shapes. The question is: what is the value of fuzzy quantitative attributes in a location where two or more fuzzy spatial shapes overlap? The answer to this question is the heart of this article.

Actually, in order to build an observatory on agricultural practice in the Vesle Basin, we have to deal with multiple sources of information that introduce imprecision in the object. From this situation, spatial and quantitative information may thus be imprecise.

Indeed, in the spatial context, there is two main ways for modelling imprecision (Bejaoui *et al.*, 2009). In the first hand, the crisp models extend or transform precise spatial concept in order to represent spatial imprecision as for instance the Egg-Yolk model (Cohn and Gotts, 1996). In the second hand, the models are based on uncertain mathematical theories as the ones, such as (Navratil, 2007), using fuzzy sets (Zadeh, 1965), either those, for example (Worboys, 1998), exploiting

rough sets, or those, as for instance (Pfoser *et al.*, 2005), using probabilities.. The fuzzy models give us a unique and soft framework that allows us to represent imprecision and to better conceptualize the reality (see Smets (1995)). As the aim of our system is to give interpretable information in each location of the monitored space, fuzzy data modeling data is used by us.

This paper exposes our opinion and choices in order to answer to these questions in the context of agronomical data exploitation. It introduces an operator for the propagation of spatial imprecision to imprecise quantitative information. It also presents a global structure for the management of fuzzy geo-entities. This structure is based on a fuzzy data storage impact analysis.

Section 2 is devoted to the imprecise geo-entity modelling in the framework of fuzzy set theory. Then, the propagation of imprecision in overlapping areas is studied (section 3). Finally, the conclusion is presented in section 4.

## 2 Fuzzy modeling of agronomical entities

In the sustainable development context, the AQUAL project (a State-Region Project in the Champagne-Ardenne, France) highlights the need of a monitoring environment for the study of agricultural practices and their pressure on the water resources in the Vesle basin. It is called Observox and it exploits data coming from heterogeneous sources: satellite images, land registry, statistical data, Corine Land Cover and other European data. The construction of a unique set of entities implies the combination of information coming from all the sources. The built entities thus induce some imprecision in the definition of spatial features and quantitative attributes (Shi, 2010).

On the other hand, Fisher in (Ficher, 1996) presents a comparative study between crisp sets and fuzzy sets in order to model landscape. The formers simplify the modeling but could amplify errors. The latters make the models and the treatments more complex. In (Fisher *et al.*, 2006), the authors present a taxonomy of uncertainty in spatial context where the vagueness is associated to the fuzzy set theory. According to (Duckham *et al.*, 2001), vagueness is a special type of imprecision. Vagueness and imprecision could be both represented by fuzzy sets (Bouchon-Meunier, 1995; Klir and Yuan, 1995; Smets, 1995) introduced in (Zadeh, 1965).

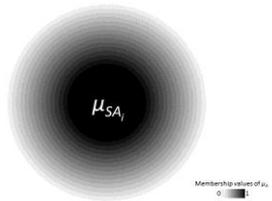
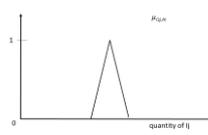
According to this, in agronomical studies as well as in geography, the geographical entities could be modeled as fuzzy geographical entities. Those entities have a label, a fuzzy spatial shape and a set of fuzzy quantities (each quantity corresponds to a specific attribute such as population or a specific chemical). The definition of a geographical entity may be defined as follows.

Let  $\Omega$  be the set of studied geographical entities  $\{A_1, \dots, A_n\}$ . Let be  $Q$  the set of monitoring quantitative information  $(Q_1, \dots, Q_m)$  if one supervises  $m$  different information  $(P_1, \dots, P_m)$  as for instance  $m$  different molecules or products . Let us define a fuzzy geographical entity  $A_i$  in  $\Omega$  as an object described by:

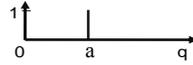
- A label or concept  $LA_i$  member of an ontology.
- A fuzzy set  $FSA_i$  describing its spatial representation. The membership function  $\mu_{SA_i}$  of  $FSA_i$  is defined on  $\mathbb{R}^2$ .
- A fuzzy quantity  $FQ_j A_i$  for each quantity  $Q_j$  (of  $P_j$ ) in  $Q$ . The membership function  $\mu_{Q_j A_i}$  of  $FQ_j A_i$  is defined on  $\mathbb{R}^+$ .

An example of an  $A_i$  is shown in Table 1.

**Table 1.** A fuzzy geographical entity  $A_i$  (only one quantitative information is shown)

Type of information	Attribute	Value example
Label/Function	$LA_i$	Vineyard
Spatial definition	$FSA_i$	
Quantity of $P_j$ (e.g. Isoproturon)	$FQ_jA_i$	

If  $Q_j$  is a precise quantity (with a value  $a$ ), it could be represented by a singleton in the fuzzy set theory as follows: if  $q=a$  then  $\mu_{Q_jA_i}(q)=1$  else  $\mu_{Q_jA_i}(q)=0$  such as  $q$  belongs to  $\mathbb{R}^+$ ). This principle is presented in figure 1.

**Figure 1.** Illustration of a precise quantity  $a$  represented in the fuzzy set theory.

In the context of OBSERVOX,  $Q$  is the set of studied chemical (or at a micro-scale, the set of phytosanitary molecules). It could be for example a fuzzy prescribed dose or an estimation of quantity which was actually spread.

The next section is devoted to the sensibility of quantity values in a space location.

### 3 Propagation of imprecision

Let us consider  $x$  a location. We consider that the confidence in  $FQ_jA_i$  should be put into perspective with the membership degree  $\mu_{SA_i}(x)$  in order to define  $FQ_jA_{i,x}$  with its membership function  $\mu_{Q_jA_{i,x}}$  as proposed in (1). In this definition, when a fuzzy geographical entity  $A_i$  does not participate to the definition of  $x$  ( $\mu_{SA_i}(x) = 0$ ), the quantity of product  $P_j$  diffused at  $x$  by  $A_i$  is certain and null.

$$\begin{aligned} & \text{if } \mu_{SA_i}(x) \neq 0 \text{ then } \mu_{Q_jA_{i,x}}(q) = T(\mu_{SA_i}(x), \mu_{Q_jA_i}(q)) \\ & \text{else if } q = 0 \text{ then } \mu_{Q_jA_{i,x}}(q) = 1 \\ & \text{else } \mu_{Q_jA_{i,x}}(q) = 0 \end{aligned} \quad (1)$$

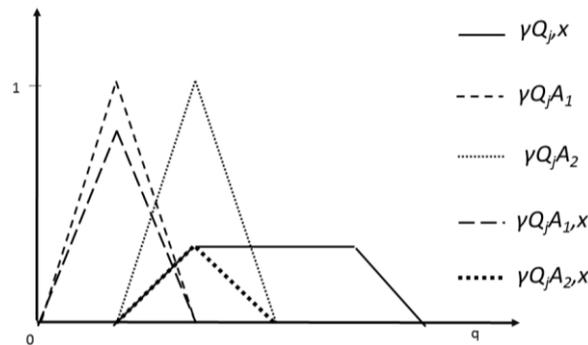
with  $q$  in  $\mathbb{R}^+$  and  $T$  an aggregation function, usually a  $t$ -norm such as the multiplication or the minimum.

The imprecision, conceptualized using a classical fuzzy number for quantities and by fuzzy area for spatial feature, is propagated in the consideration of fuzzy quantities at a specific location. As our goal is to consider all the quantities of a specific product at each location of the space, an aggregation operator is now needed for obtaining the combined information. Then, we use the Zadeh's extension

principle that allows to extend usual operation in the fuzzy set context such as in our context the sum (due to the additive aspect of product diffusion).

Thus if we deal with an additive information  $P_j$ , using this hypothesis and Zadeh's extension principle we define  $FQ_{j,x}$  the overall quantity at the position  $x$  by following the equation (2) for the definition of its membership function  $\mu_{Q_j,x}$ .

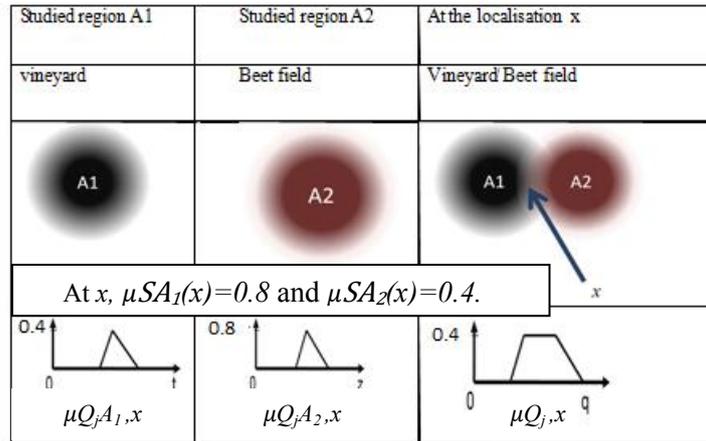
$$\mu_{Q_j,x}(q) = \sup_{q=z+t} (\min_{A_i, A_k \text{ in } \Omega^2, i \neq k} (\mu_{Q_j A_i, x}(z), \mu_{Q_j A_k, x}(t))) \quad (2)$$



**Figure 2.** Illustration of the imprecision propagation on quantitative value  $Q_j$  of  $P_j$  for a specific location  $x$ , with  $\Omega = \{A_1, A_2\}$ ,  $\mu_{SA_1}(x) = 0.8$  and  $\mu_{SA_2}(x) = 0.4$ .

In order to test the feasibility of our approach, we illustrate it using two overlapped fuzzy geographic entities ( $A_1$  and  $A_2$ ) at a specific location  $x$  (figures 2 and 3). The goal is in this example to determine the total quantity of a chemical  $P_j$  (corresponding to Bentazone) at  $x$ .

This principle allows us to compute the quantity of each monitored molecule in every location of the studied region. The confidence in the computed fuzzy quantity is lower (or equal) than the original confidence in each fuzzy geographical entities.



**Figure 3.** Illustration of the imprecision propagation: a spatial/quantity view.

## 4 Conclusion

In this paper, we propose a study of the imprecision propagation from spatial information to quantitative one. We firstly introduced our context and our approach of a fuzzy geographical entity. Next, we proposed a new operator of imprecision propagation.

This paper is a starter for the future construction of an agricultural practice observatory. In our future work, we will use conceptual approach that allows us to automatically obtain a fuzzy spatiotemporal data storage solution (Zoghalmi *et al.*, 2011), but we also want to study the propagation of quantitative imprecise information into other topological relations between fuzzy spatial objects.

This paper is a preliminary study before building the observatory. It presents our choice at the beginning of the project. In our future work, we will develop our approach by defining new fuzzy agronomical indices in the observatory.

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