FUZZY SPATIAL RELATIONS FOR HIGH RESOLUTION REMOTE SENSING IMAGE ANALYSIS: THE CASE OF "TO GO ACROSS"

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1. INTRODUCTION

Due to the increase of the sensors diversity and resolution, image analysis techniques need to evolve toward a higher level of abstraction: low-level processing relying on textures or edges can only partially describe an object of interest which is represented by a whole image portion, and mixed up with background or neighboring objects. In this context, we propose to use spatial reasoning techniques to describe a scene and the complex objects it contains. The main novelty of this work is the use of fuzzy set theory together with spatial relationships. In this paper, we concentrate on the "to go across" relationship.

2. SPATIAL REASONING IN SATELLITE IMAGING

Spatial reasoning can be defined as the domain of spatial knowledge representation, in particular spatial relations between spatial entities, and of reasoning on these entities and relations [1]. Among the possible applications of spatial reasoning are scene recognition, description and interpretation.

This work is motivated by the importance of the relations between linear objects and regions when creating natural language descriptions of spatial scenes of satellite images. These types of relations are frequently observed between linear structures such as rivers or roads and spatial regions such as cities, agricultural fields, water surfaces, etc. Some examples of these relations are "to go across", "to go through", "to bypass", "to intersect", "to go along", "to enter", "to go into", "to surround", etc. These natural language expressions depend on the shape of the region and their definition can be sometimes vague or imprecise. For instance the relation "to go across" can have the following meaning: a line goes across a region if it goes from one side of the region to the opposite side. When the region has a complex shape, the notion of opposite side becomes vague. The fuzzy sets framework is appropriate for modeling these kinds of relations since it captures the imprecision inherent to the spatial information and to the semantics of the relations.

Spatial relations between lines and regions were studied in [2]. They focused on a topological model, that was then enhanced using metric concepts. In this work we propose three models that seize the semantics of the spatial relation "to go across". These models can be easily extended to fuzzy objects.

3. LINE REGION RELATIONS

In order to understand the usual perception of the considered relation, 8 line-region configurations were proposed to 32 persons. Their answers on whether the line goes across the region or not were then analyzed. A first meaning derived from this analysis is very permissive and only considers the fact that a line enters or starts at the border of the region and leaves or ends at the border of the region. Two more restrictive meanings are then also considered:

(i) the line goes from one side of the region to the opposite one,
(ii) the line goes deeply inside the region and passes close to its middle point.

Taking into account the remarks of [3, 2] the relation "to go through" and "to go across" are very similar, and in some dictionaries can be used as synonymous. But "go through" relies on topological aspects, since it refers to entering and leaving a medium [3], while "go across" has a more geometrical aspect: there is a specification regarding the way it should enter or leave

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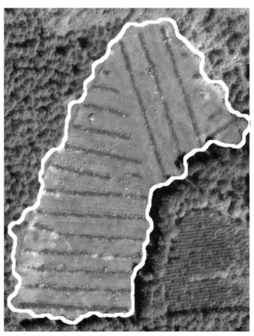
the interior of the region . Therefore we are going to call the first model “to go through”. The other two meanings will be called “to go across (i)” and “to go across (ii)”, which are specific meanings of the “to go through” relation.

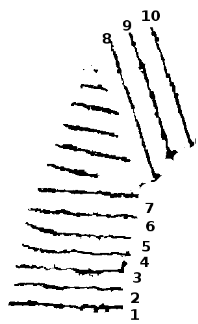
For the “to go across (i)” relation it is necessary that the linear object “goes through” the region and that it goes from one side to the opposite one. To determine the second condition a fuzzy measure was constructed to evaluate when two points are located on opposite sides. This measure is based on the spatial cognition studies of Williams cited in [4]. An adult considers that a linear object goes across a region, if it goes through two different segments of the boundary region. These two segments can be the consecutive sides of a rectangle or two segments of the boundary of a circle. In the case of convex objects we check if the angle formed by the intersection of the tangent lines to the region at those points is approximately π. In the case of a non-convex object, we compute the measure with the closest points on the boundary of the convex hull.

We now move to the model of “to go across (ii)” relation. The degree of satisfaction depends on the degree of satisfaction of the relation “to pass through”and the degree of satisfaction of the relation “to go into”. The relation “to go into” measures to what extent the linear object penetrates the region. In the proposed definition, the degree to which a linear object “goes into” a region is inversely proportional to the distance between the linear object and the ultimate erosion of the region normalized by the maximum distance.

4. RESULTS



(a) Original image and region



(b)Ten quasi-linear paths

Path	Degree *to go through*	Degree *to go into*	Degree *to go across(i)*	Degree *to go across(ii)*
1	1.00	0.14	0.92	0.14
2	1.00	0.53	1.00	0.53
3	1.00	0.96	1.00	0.96
4	0.00	1.00	0.00	0.00
5	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00
9	1.00	0.97	0.97	0.97
10	1.00	0.50	0.97	0.50

(c) Table showing the degree of satisfaction of the relations

Fig. 1. Results for the two interpretations of the “to go across” relation and the relations involved in their definition.

The above presented relations were evaluated for ten different paths and a region, and the results are presented in Fig.1. We can observe that the obtained results agree with the perception of the relations. The relation “to pass through” verifies the intersection with the interior and the boundaries, and the greater degrees were obtained for the paths that started and ended at the border of the region. Higher values were obtained for the degree of satisfaction of the relation “to go into” as the paths went deeply into the region (paths $4-8$). The notion of opposite sides fits with the intuition. For points situated on almost parallel edges high values were obtained. The results reflect the need of using two different definitions for the relation “to go across” since in ambiguous cases (for example paths 1 and 10) it is not possible to reach a consensus.

The full paper will include the mathematical model for the fuzzy relations described above as well as additional test cases for validation.

5. REFERENCES

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