A Fuzzy Approach Using Euclidean Geometrical Formulation for Classifying SAR Images

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ABSTRACT

Synthetic Aperture Radar (SAR) is a good tool to investigate problems in many geophysical application as classification of ground terrain types and coastal protection. In scientific literature, many analytical and/or numerical techniques have been taken into account to solve the classification problem at hand, especially in all of applications in which it is necessary to classify portion of images with uncertainty and imprecision. In fact, according to the conventional classification approaches, the assignment of a class to each portion of an image could be particularly inadequate for all those portions that span more than a class (for example the coastal areas of the shoreline). This article is devoted to present a fuzzy-geometric approach based on fuzzy subsethood operator to classify SAR images for coastal protection applications. The obtained results were compared, in terms of accuracy, with standard techniques of classification.

Keywords: Fuzzy-Geometric Approach, Fuzzy Subsethood Operator, Geophysical Application, Standard Techniques of Classification, Synthetic Aperture Radar (SAR)

INTRODUCTION TO THE PROBLEM

The classification problem of very extensive areas using Synthetic Aperture Radar (SAR) is nowadays an important application development of microwave remote sensing. In particular, recent advances in technology have provided a significant improvement in the measures of capacity, allowing the synthesis of coherent systems is a multi-frequency polarization. In addition, the ability to make measurements in harsh environment, it has allowed to SAR imaging to be a useful investigative tool in many
geophysical problems and coastal protection applications. In any case, to take advantage from measurements made at the same time reducing the necessary instrumentation for measurement and photographic image processing, we need a classification procedure that manipulates data potentially affected by uncertainty and/or imprecision with a low computational load very useful for real-time applications in coastal protection.

In this context, scientific research has produced significant technological advances especially in the areas of conventional classification in which the principle is based on the concept of “all or nothing” but it turns out to be inadequate for all areas of transition in which the uncertainty and imprecision takes over. For those particular areas, such as coastal areas, the classification is an open issue on which many researchers are actively engaged. For example, G. Moser, V. Krylov, S.B. Serpico and J. Zerubia (2010), combine the Markov random field model to Bayesian image classification and a finite mixture technique for probability density function estimation while L. Bruzzone, M. Marconcini, R. Wemuller and A. Wiesmann (2004), classify automatically by means of a hybrid soft computing system. However, both approaches need of a conspicuous computational load. So, classification of coastal areas can be thought in terms of membership to several classes and, from this point of view, fuzzy logic is an excellent candidate to treat problems in which uncertainty and/or imprecision manifest their presence (G. Angiulli, V. Barrile & M. Versaci, 2002). In particular, each selected area has a sort of membership value to a specific class quantified by a membership function defined in the set of possible values (so called “universe of discourse”) ranging on [0, 1] where 0 indicates that the chosen area certainly not belongs to class while unity sanctions its total membership. Moreover, the continuity of values between 0 and 1 representing all possible partial memberships of that area to the class.

The authors, in this paper, direct their attention to a classification tool formulated in fuzzy n-dimensional euclidean geometry. Specifically, using euclidean representation of fuzzy sets by points into unit hyper-cube, it translate classes of coastal areas in the hyper-rectangles inside unit hypercube for which the classification of particular areas is translated into an equivalent problem of distances among points and hyper-rectangles in Euclidean geometry.

The paper is structured as follows. Next two sessions provide a brief overview of SAR acquisition system and geometric representation of fuzzy sets by defining the algebraic operators of interest. In the following, the proposed algorithm is detailed in the explanatory steps to understand the details of the analytical/algebraic processing. Finally, numerical results and some conclusions take rightful place.

SYNTHETIC APERTURE RADAR (SAR): AN OVERVIEW

Synthetic Aperture Radar (SAR) has been developed since 1951 in response to the comments made by Carl Wiley of Goodyear Aircraft Corporation. He noted that he could have obtained a high resolution angular analyzing the spectrum of the received signal from a radar system of the type consistent. Wiley’s ideas were later detailed at the University of Michigan and led to the development of an airborne SAR system (AN/UPD-1) for the U.S. Army. The huge development technological occurred in the following years led to the creation of a SAR system by satellite platform which was launched in 1978 on board the satellite SEASAT. After this first experiment, Earth Observation eighties saw the birth of the SAR systems carried aboard the shuttle. Following from the early nineties almost all the space agencies have included among their programs launching platforms bringing on board sensors SAR. Among these include: the ESA program ERS 1/2, the NASDA JERS of the Canadian RADARSAT.

In order to tackle the study of the principle on which SAR is necessary to introduce the basic geometry of the acquisition system. However, this geometry is common to several radar types (for example, Real Aperture Radar (RAR)),

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