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Application of fuzzy logic-based approach to the remote sensing

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Abstract

Fuzzy logic as an approach of Artificial Intelligence is widely used in a number of fields, especially in control systems. As it allows to consider uncertain values and an opinion of experts it is successfully applied to the remote sensing field as well. However, despite high accuracy and performance of fuzzy logic based approaches, it is still not widely distributed among the remote sensing professionals.

This poster demonstrates some application cases of fuzzy logic to land-cover classification and urban facilities recognition. A particular example of using fuzzy logic for snow cover recognition on cloudy AVHRR imagery is illustrated in details.

Introduction

Fuzzy logic

Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) binary logic on which the modern computer is based. The idea of fuzzy logic was first propsed by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1965 in his "Fuzzy Sets" publication.

Fuzzy logic systems usually use linguistical variables, which are more suitable for human perception. For instance, for a system controlling the speed of vacuum cleaner engine the variables may be "slow", "medium", and "high". The user can put the handler in any position of the range.

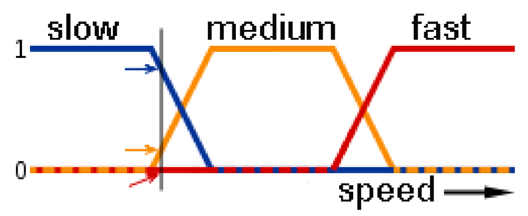

Figure 1: Membership function for vacuum cleaner speed controller

In order to perform operations under fuzzy sets IF-THEN rules (Fuzzy rules) are usualy used. Fuzzy Rules are usually expressed in the form:
IF *variable* IS *property* THEN *action*

Fuzzy logic is widely applied to very diverse fields. For instance, it was implemented in numerous applications such as facial pattern recognition, air conditioners, washing machines, vacuum cleaners, antiskid braking systems, transmission systems, control of subway systems and unmanned helicopters, knowledge-based systems for multiobjective optimization of power systems, weather forecasting systems, models for new product pricing or project risk assessment, medical diagnosis and treatment plans, and stock trading. Fuzzy logic has been successfully used in numerous fields such as control systems engineering, image processing, power engineering, industrial automation, robotics, consumer electronics, and optimization.

Thanks to the ability of fuzzy logic techniques to hold uncertainty and to include the experts opinion, it can be very useful for the satellite imagery classification and pattern recognition.

Related works

A lot of researchers already use fuzzy logic based technics in the field of the remote sensing. The advantages of method is proved by a number of distinguished publications. This section overviews some of the research related to urban landscape imagery recognition.

I. Lizarazo, J. Barros. Fuzzy Image Segmentation For Urban Land-Cover Classification

In this paper a Fuzzy Image-Regions Method (FIRME) is proposed. Traditional segmentation techniques focus on partitioning imagery into image-objects with well-defined boundaries. Instead, the proposed methodology aims to produce and analyze fuzzy image-regions expressing degrees of membership to different target classes. This approach is suitable to deal with the spectral and spatial complexity of urban landscapes.

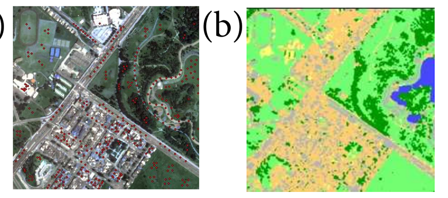

Figure 2: (a) Original QuickBird Image (True Color RGB321)
(b) Land-cover classification based on fuzzy sets

M. Fauvel et al. Decision Fusion for the Classification of Urban Remote Sensing Images

This paper proposes fusion approach in two steps. In a first step, data are processed by each classifier separately and the algorithms provide for each pixel membership degrees for the considered classes. Then, in a second step, a fuzzy decision rule is used to aggregate the results provided by the algorithms according to the classifiers' capabilities.

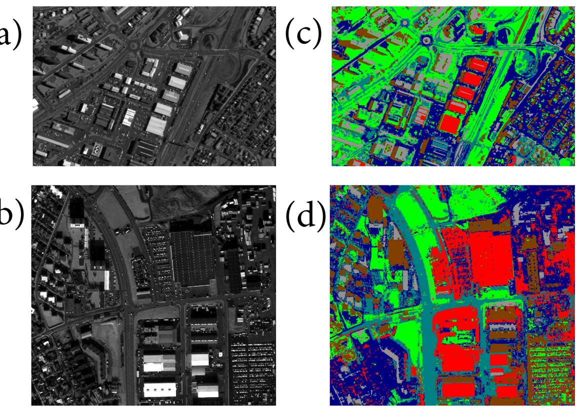

Figure 3:
(a) Original IKONOS image 1,
(b) Image 1 classification results,
(c) Original IKONOS image 2,
(d) Image 2 classification results.
Red = Large Buildings, Gray = Small Houses,
Dark Blue = Streets, Blue-Gray = Large Road,
Green = Open Areas and Brown = Shadows.

F. Prandi et al.Semi-Automatic Objects Recognition in Urban Areas Based on Fuzzy Logic

The proposed methodology semi-automates some geographic objects clustering operations, in order to perform the recognition process. The object recognition approach proposed integrates 3D structural descriptive components of objects, extracted from LiDAR DSM, into a fuzzy reasoning process in order to exploit more fully all available information, which can contribute to the extraction and recognition process and to handling the object's vagueness.

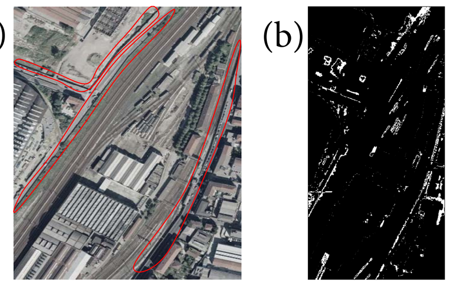

Figure 4: (a) Sample data-set, the more important partition walls are highlighted.
(b) Results of fuzzy walls recognition process using the weighted sum approach.

Snow Cover Recognition on Cloudy AVHRR Imagery

Definition of snow cover using remote sensing is widely used for the purposes of meteorology, climatology, and agriculture (weather prediction, climate change, global warming, yield of crops, etc). Nowadays the task of snow recognition is being performed manually in many cases because the snow and low level clouds have very similar spectral characteristics. Moreover, the same classes may look different in different parts of the image. The range of one class's spectrum is very large, thus machine can not differentiate one class from another. This paper describes an approach of snow cover definition on cloudy imagery using fuzzy logic.

For the purpose of defining snow cower using remote sensing satellite imagery with visible (red), infrared, and near-infrared spectral channels are being used. For monitoring large territories, such as the territory of Kazakhstan, the satellites with the large swath width are being used. The swath width of NOAA/AVHRR satellite is approximately 2500 kilometers.

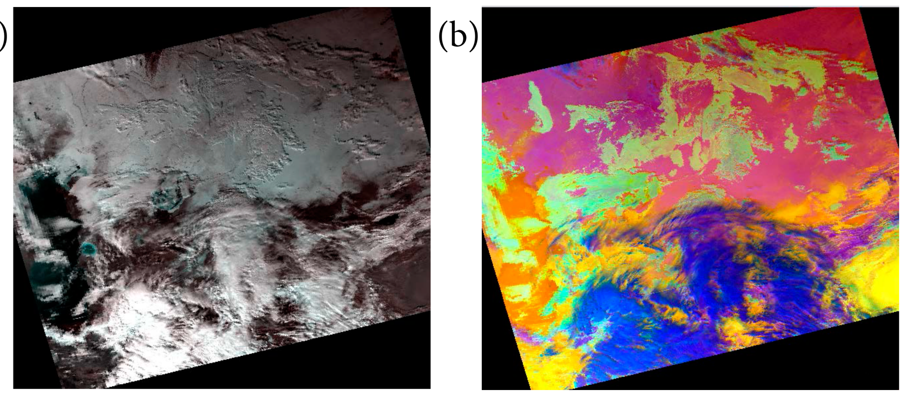

Figure 5: Original AVHRR image
(a) True colors (RGB322)
(b) False color (RGB532)

For clear interpretation of clear imagery (with less than approximately 20% of clouds) automatic classification (such as k-means or isodata) is commonly used. However, when the amount of clouds is high it is impossible. In this case supervised classification (such as parallelepiped, maximum likelihood, spectral angle mapper) or manual classification is used, but even supervised classification in most cases has accuracy not enough for this purposes. For manual classification either the composite of 5, 3, and 2 channels (Figure 5) or Normalized Difference Snow Index (NDSI) is used.

In order to develop new approach for the problem of automatic snow cover recognition on cloudy AVHRR imagery fuzzy logic toolbox of MATLAB software was used. 5, 3, and 2 spectral channels of AVHRR were chosen.

Considering input parameters (reflectance (%) for visible channel and temperature (K) for infrared and near-infrared channels) as fuzzy sets; and their standard deviations and mean values as membership functions (Gaussian distribution) (Figure 6), creating fuzzy rules. As each of the channels are represented as two-dimensional array 578x361 finally we have 3 inputs.

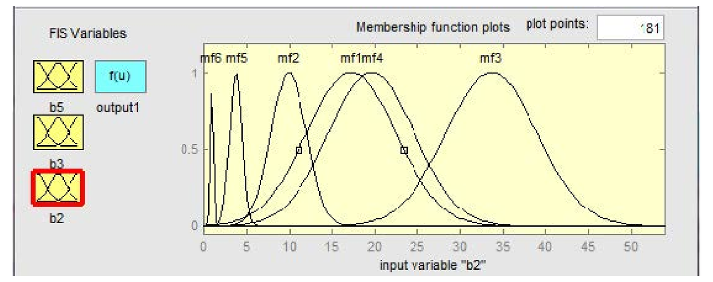

Figure 6: Membership function for channel 2

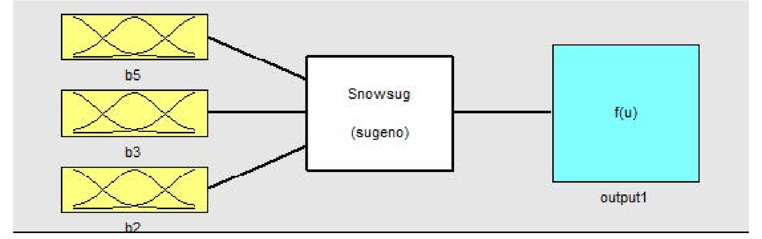

Figure 7: Fuzzy Inference Systeme

Results and future works

Classification of cloudy AVHRR imagery using fuzzy logic allows to achieve relatively precise results comparing to classical methods (Figure 8). Moreover, this approach makes image classification process time effective, comparing to manual techniques and supervised classification. Simple user-friendly interface was developed. The software may be easily modified and improved for the other tasks.

The future study includes further improvement of an existing algorithm in order to increase precision, probably with the use of the Adaptive Neuro-Fuzzy Inference System (ANFIS). Similar approach will be applied to similar remote sensing problems such as crops and pastures recognition.

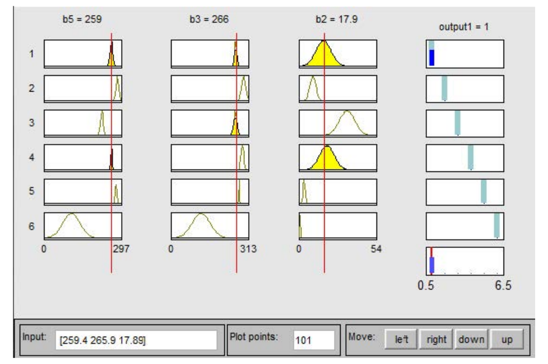

Figure 8: Fuzzy rules visualisation

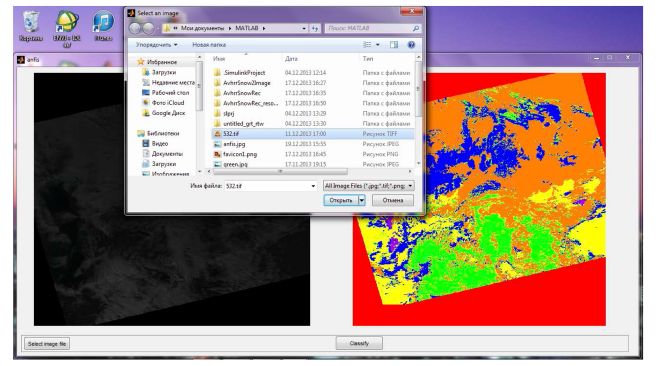

Figure 9: User interface

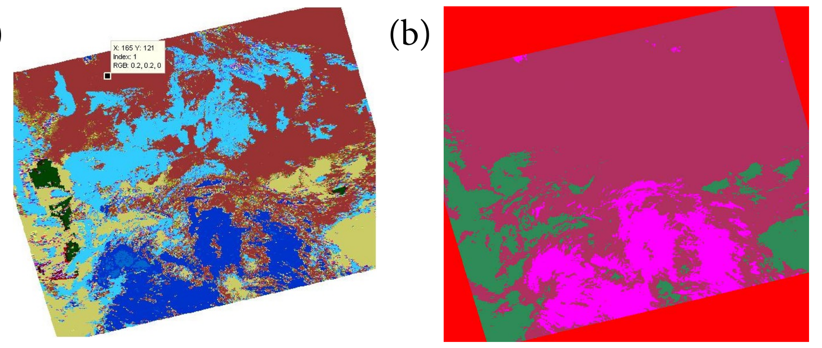

Figure 10:
(a) The result of classification using fuzzy logic

1. Snow	RED
2. Ground (not snow)	YELLOW
3. High level clouds	BLUE
4. Low level clouds	CYAN
5. Water	GREEN

(b) k-means classification

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