------ Iraqi Jour. Earth Sci., Vol.5, No.2, pp.32-40, 2005 ------

Fuzzy Rule Base-Multispectral Images Classification

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(Received 9/1/2005 , Accepted 12/5/2005)

ABSTRACT

As it is the case in remote sensing images, one of the main problems in multi-spectral images is that land cover may be more frequent than sampling intervals between pixels in the image. Thus, the pixel representing mixture of land cover is called mixed pixels.

The classic algorithm of classification is based on two values: right or wrong. When there is overlapping areas of the future space, there will be mistake in the top of classification. Thus, in recent years, the application of the fuzzy logic in remote sensing images witnessed rapid developments. Fuzzy set theory provides useful concepts and methods to handle interlocked information, where fuzzy classification is used to put a distinction line between the types, and to take the information from mixed pixels. Fuzzy classification plays a major role in carrying out full classification.

What is done in this research is designing a complete program for supervised classification depending on fuzzy rule base and using trapezoidal membership function to represent prior knowledge.

Such a program was applied to remotely sensed data recorded by the TM-sensor (Thematic Mapper) of Landsat-5 satellites. The results were good comparing with the results obtained using the traditional ways such as Maximum Likelihood (ML), and neural network such as Probabilistic Neural Network (PNN). The outcome accuracy of classification is shown to be better than those produced by either the ML or PNN. This technique is implemented by using Visual C++ 6.0 programming language.

تصنيف صور متعّددة الأطياف باستخدام قانون القاعدة الضبابية

الملخص

تمثل إحدى المشاكل الرئيسية في صور متعدد الأطياف كما هو الحال في صور التحسس النـــائي، بأن غطاء الأرض قد يتفاوت كثيراً اكثر من فترة اخذ العينات بين نقاط الشاشة (Pixels) في الصورة. لذا قد تمثل نقاط الشاشة (Pixels) الواحد خليط من أصناف غطاء الأرض. تدعى مثل هذه نقـــاط الشاشـــة (Pixels) بنقاط الشاشة المُختَلَطة (Mixed Pixels).

في خوارزميات التصنيف الكلاسيكية القائم على اساس التمييز بين قيمتين فقط: الحقيقي او الخاطئ. في هذا النوع من التصنيف عندما يكون لدينا تداخل في مناطق فضاء العينة، سوف يكون هنالك خطأ في

دقة التصنيف. لهذا في السنوات القلية الماضية شهدت تطبيقات المنطق الضبابي في التحسس النائي نمواً سريعاً. حيث تزود المجموعات الضبابية مفاهيم وطرق مفيدة للتعامل مع معلومات متداخلة فيما بينها. حيث تم استخدام التصنيف الضبابي لاكتشاف الحيرة في حد بين الاصناف ولانتزاع معلومات نقاط الشاشة المُخْتَلَطة (Mixed Pixels)، وتلعب التصنيف الضبابي دوراً مهماً في اجراء التصنيف الكامل.

وما تم إنجازه في هذا البحث هو تصميم برنامج متكامل للتصنيف المشرف عليه يعتمد خوارزمية قانون القاعدة الضبابية والتي تستخدم دالة العضوية لشبه المنحرف (Trapezoidal membership function) لتمثيل المعرفة المسبقة. وقد تم تطبيق هذا البرنامج على صور متحسس الخرائط الموضعية (TM-Sensor) تمثل مناطق في الموصل. وقد كانت النتائج جيدة مقارنة مع النتائج التي تم الحصول عليها باستخدام الطرق التقليدية للتصنيف مثل خوارزمية الإمكانية القصوى، وطرق الشبكات العصبية الاصطناعية مثل الشبكة العصبية الاحتمالية. وتم برمجة هذا النظام باستخدام لغة فيجوال سي++ ذات رقم الإصدار السادس.

INTRODUCTION

The aim of multi-spectral image used in remote sensing images is to classify all the pixels automatically in image categorizes representing land cover, which means conversion of image data to information of a certain induction (Lillesand and Kiefer, 1994).

There are two types of image classification: the supervised and unsupervised, where the supervised classification is controlled by user more than the latter because supervised classification requires prior knowledge about the field and consequently leads to results better than of unsupervised classification (Tso and Mather, 2001). Therefore, in this research the supervised classification is used.

Many methods of classification were applied on remote sensing images such as the classical methods e.g. Abkar et al. (2000) who used maximum likelihood for the segmentation and classification of remotely sensed images.

With the development of artificial neural network technologies, this method was used in the classification of remotely sensed images (Atkinson and Tatnoll, 1997) where the two researchers, Mohanty and Majumdar, (1999) used multi-layer Perceptron network to classify the images and with all the development in computer technologies related to image processing, software programs were made to classify remote sensing images. Al-Shumam, (2001) built an Integrate software to classify the data of remote sensing which included all classical and neural network methods.

The development of the neural network algorithms, the stable need for classical methods of classification and not being able to prefer one method above the other, came the possibility of integration between neural network and statistical approaches to classify remotely sensed images classified (Wikinson et al., 1995). However Al-Nuaimy, (2002) classified the data of remote sensing by using integration between neural networks and classical methods, and with the rise of mixed pixel in horizon and the lost boundaries among these methods the attention now is directed to use fuzzy set theory to solve this overlapping problem. Where in the previous methods all kinds of pixels were generated and exactly assigned to all kinds, but the need for solving integration problem and the need to find a way varying proportions, thus the fuzzy classification is used.

Chen (1999) made a study to develop fuzzy supervised to train the selected data and classify the image The basic step in this method is to guess fuzzy mean and fuzzy covariance to choose the training area and to use them in maximum likelihood to classify the image. The researchers Bardossy and Samaniego, (2002) made a fuzzy rule base modeling to classify LADSAT TM sensor from 1984 for region south Germany. They used land cover map with four different categories with an image showing degree of ambiguity of classification for each expected pixel.

Ghosh, et at., (2003) suggested fuzzy rule base cloud classification scheme to produce cloud cover using MeteoSat 5 visible image of the Indian subcontinent and Indian ocean to classify each pixel into one of the following three categories: clear sky, cloudy sky and partially cloudy sky.

The present study differs from all previous works are totally different form this study. It uses a complete program using algorithm of fuzzy rule base to classify multi-spectral images (i.e. more than one band being dealt with in more than one mathematical process Petron, (1999). In addition to that, the study uses trapezoidal fuzzy membership function instead of triangular fuzzy membership function applied in all previous studies, due to its easiness. After that, this program is used to classify multi-spectral image of Mosul and the results are good compared with the results when using maximum likelihood and the results of probabilistic neural network.

MULTI-SPECTRAL CLASSIFICATION USING FUZZY RULE

A fuzzy rule base is used (fuzzy system) for classification which generally comprises of three principal steps, as shown in Figure (1). The first step, fuzzification, involves the division of the input feature space into fuzzy subspace, each specified by a fuzzy membership function. Fuzzy rules are then generated from each fuzzy subspace. The second step, inference, requires the calculation of the strength of each rule being triggered. The final step, defuzzification, combines all triggered rules and generates a non-fuzzy outcome (Tso and Mather, 2001).

FUZZY MEMBERSHIP FUNCTIONS

There are many membership functions that can be used for land cover classification using a fuzzy approach. Examples of fuzzy membership function shapes are: Monotonic, Triangular, Trapezoidal, Bell-Shaped etc (Klir et al., 1997).

A monotonic function will result in a crisp classification without any fuzziness. The classification training set contains a range of pixels. A triangular function is not suitable to describe the data in the training set. It has only peak value, at which membership equals 1. The bell-shaped function gives rise to a similar problem, where only one peak value is there a long with many values nearer to the peak. So this does not hold good for supervised classification (Hegde, 2003).

A trapezoidal function or a function that results in a fuzzy set with a central region and upper and lower transition zones with different widths can be successfully used for fuzzy supervised classification. Figure (2), shows an example using a trapezoidal membership function to divide the feature space into fuzzy partitions. The diagram shows two partitions with an overlapping area. Within each partition, the membership value depends on the pixel values. Once the input feature space has been divided in a fuzzy fashion, the rule set is then generated. The general form of fuzzy rule is as follows "If the pixel is in fuzzy partition *A* then the pixel belongs to class *j* with certainty *w*".

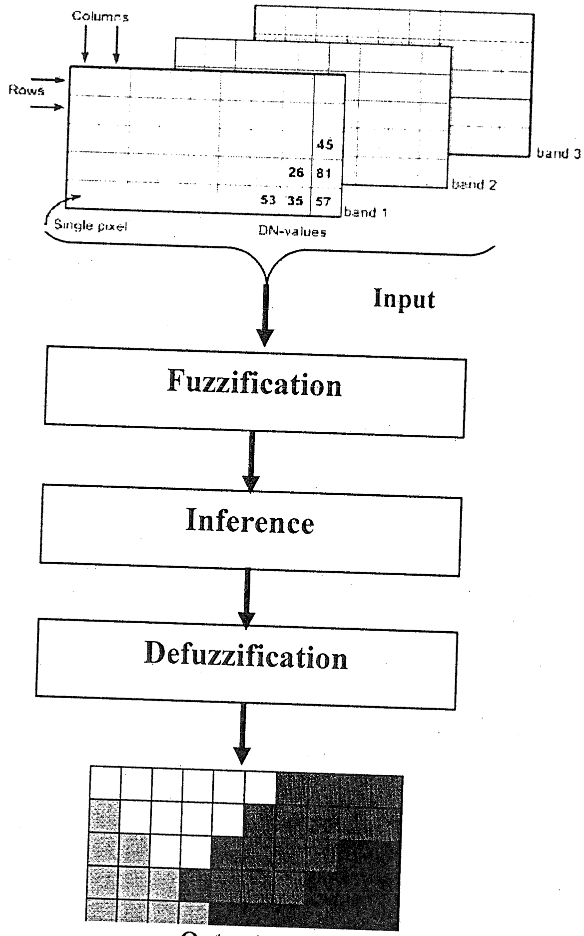

Fig. 1: Basic architecture of fuzzy system.

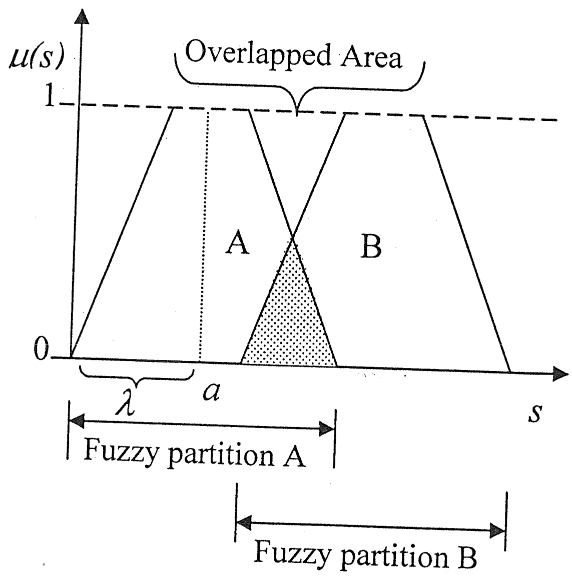

Fig. 2: Example of two partitions based on a trapezoidal fuzzy membership function

The creation of rules and certainty parameters w (which is a function of membership value) is performed automatically. The user has only to define the membership function and to select training samples (Tso and Mather, 2001).

METHOD AND ALGORITHM

The fuzzy supervised classification used in this research consists of two major steps: (1) the estimate of the fuzzy parameters from training data, and (2) the fuzzy classification of the images.

For simplicity, a two dimensional input case is used:

1- The input features are normalized onto the range [0,1].

2- Each dimension in the input space is the partitioned into *k-fuzzy* subspace denoted by $\{ a_1 , a_2 ,..., a_k \}$, where a_i indicates the *ith* fuzzy subspace.

A trapezoidal membership function is adopted, and the fuzzy subspace for a_i is then defined by:

$$\left.\begin{array}{l} \mu_i(s) = \min\left\{2 - \dfrac{2|s-a_i|}{\lambda}, 1\right\}, \quad for \ \ a_i - \lambda \le |s - a_i| \le a_i + \lambda \\ \mu_i(s) = 0 \qquad otherwise \end{array}\right\} \qquad \text{.............(1)}$$

where s is the normalized input pixel value, $\mu(s)$ is the member grade, a_i is the trapezoidal center for fuzzy subspace i and λ is the membership function width. Both a_i and λ are defined as:

$$a_i = \frac{i-1}{k-1} \qquad \text{.......................(2)}$$

$$\lambda = \frac{1}{k-1} \qquad \text{.......................(3)}$$

where k is the maximum number of partitions for the corresponding input dimension, and i runs from 1 to k.

1-Algorithm for the construction of fuzzy rule for each fuzzy subspace ij Begin:

Let l denotes the number of information classes, and n_x denotes the number of training patterns for class x currently falling within the fuzzy subspace ij, (Λ) operator is the minimum operator.

1- Calculate weighting β_x for each class x as:

$$\beta_x = \sum_{S=1}^{n_x} \mu_i(s_1) \wedge \mu_j(s_2) \quad , for \ x = 1 \ to \ l \qquad \text{.......................(4)}$$

2- Choose class c_{ij} such that

$$\beta_{c_{ij}} = Max\{\beta_1, \beta_2, ..., \beta_l\} \qquad \text{.......................(5)}$$

3- Calculate rule strength w_{ij} as:

$$w_{ij} = \frac{(\beta_{c_{ij}} - \beta)}{\sum_{x=1}^{l} \beta_x} \qquad \text{.......................(6)}$$

where $\beta = \frac{1}{l-1} \sum_{x=1, x \neq c_{ij}}^{l} \beta_x$ ....(7)

End

2-Algorithm for classifying the image:

Begin

For each pixel

1-Calculate α_x for each class, as :

$$\alpha_x = Max\{[\mu_i(s_1) \wedge \mu_j(s_2)] \cdot w_{ij} \mid c_{ij} = x \forall i, j\}$$ ....(8)

2- Classify the pixel as class c such that

$$\alpha_c = Max\{\alpha_1, \alpha_2, ..., \alpha_l\}$$ ....(9)

End

RESULTS AND DISCUSSION

In this study, complete software was designed to classify multi-spectral images using algorithm of fuzzy rule base. This system was programmed using Microsoft Visual C++ ver 6.0 in windows. This program comprises many choices to be benefited in multi-spectral image classification as shown in Plate (1), and one of these choices is False Color Composite image which is used in the test of training area to be used later in supervised classification.

The main benefit of this program is its generality in classification of any kind of image with any number of bands. The researchers applied this program on a sense in Mosul area taken by the TM on the satellite Landsat 5 with resolution 30m. Three bands were used of the Landsat 5 they are: TM3 (0.63-0.69)µm, TM5 (1.55-1.75)µm, TM7(2.08-2.35)µm, six integrated type, were known using the visional analysis of false color composite image made of three bands RGB(3,5,7) as shown in Plate (2).

The classification adopted these three bands only for the impossibility of using the other bands. These were Water area, Grasses, Agricultural fields, Barren area, Urban area and Hill area. In order to make a study showing the importance of using fuzzy supervised to eliminate integration and to solve the problem of mixed pixels. Fuzzy rule base algorithm was used which uses trapezoidal membership function. In order to make comparison with the traditional methods and neural networks, the same training area was used where maximum likelihood algorithm was used as one of the traditional methods and probabilistic neural network as one of the algorithms used in classification of images associated with artificial neural networks and the results are shown in Plate (3).

If a comparison was made between the three images, the result will be for fuzzy rule classifier rather than PNN classifier and ML classifier where small areas are shown in fuzzy rule classification within the range of river, indicating that there are small islands with grasses which is similar to field and it is a fact river in this part of Mosul contains many small islands, not to forget to mention, grasses and urban areas very clearly, and what enforces these results are accuracy calculations for each type in all algorithm as shown in Table (1) where we find the accuracy overall for the algorithm is (95.45%) higher than the accuracy overall for the algorithm of PNN which is (91.63%) and accuracy overall for algorithm of ML which is (91.58%).

Form this comparison, we conclude that fuzzy rule base algorithm is better in fuzzy supervised rather than the traditional method of maximum likelihood and probabilistic neural network.

The second part of the research concentrates on using trapezoidal membership function rather than triangular membership function in fuzzy base rule algorithm. We can see in plate (3) that the image resulting from the first case is better than the one resulting from the second case, asserted by accuracy, as shown in Table (1) where we find that accuracy overall when using trapezoidal membership function in fuzzy rule algorithm reading (95.45%), is better than accuracy overall when using triangular membership function in fuzzy rule function reading (92.10%). The reason as stated earlier that triangular function comprises a single pick whereas in trapezoidal function there is more than one value depending on the type of function.

Table 1: The accuracy of individual classes, overall accuracy using four types of classification algorithm (ML, PNN, Fuzzy rule base using triangular membership function, and Fuzzy rule base using trapezoidal membership function).

Individual / Class Accuracy	ML	PNN	Fuzzy rule base using Triangular membership function	Fuzzy rule base using Trapezoidal membership function
River ,Lake, Channel	98.64%	96.62%	97.29%	97.29%
Grasses	97.72%	98.63%	97.27%	96.36%
Agricultural Fields	100.0%	100.0%	97.14%	97.95%
Barren Area	87.33%	72.92%	72.92%	97.81%
Urban Area	94.88%	94.88%	100.0%	99.18%
Hill Area	70.88%	86.70%	87.97%	84.08%
Overall accuracy(%)	91.58%	91.63%	92.10%	95.45%

CONCLUSIONS

The research shows the significance of using fuzzy supervised for multi-spectral images containing integrated areas. The use of fuzzy rule base gives better results than using the traditional ways like maximum likelihood and probabilistic neural network.

The second conclusion is that using trapezoidal membership function in fuzzy rule base algorithm is better than other membership functions especially triangular membership function which is used for its simplicity by other researchers.

Finally, these conclusions were used to design complete software to classify multi-spectral images using fuzzy rule base.

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Plate 1: program of multi-spectral image classification by using fuzzy rule base

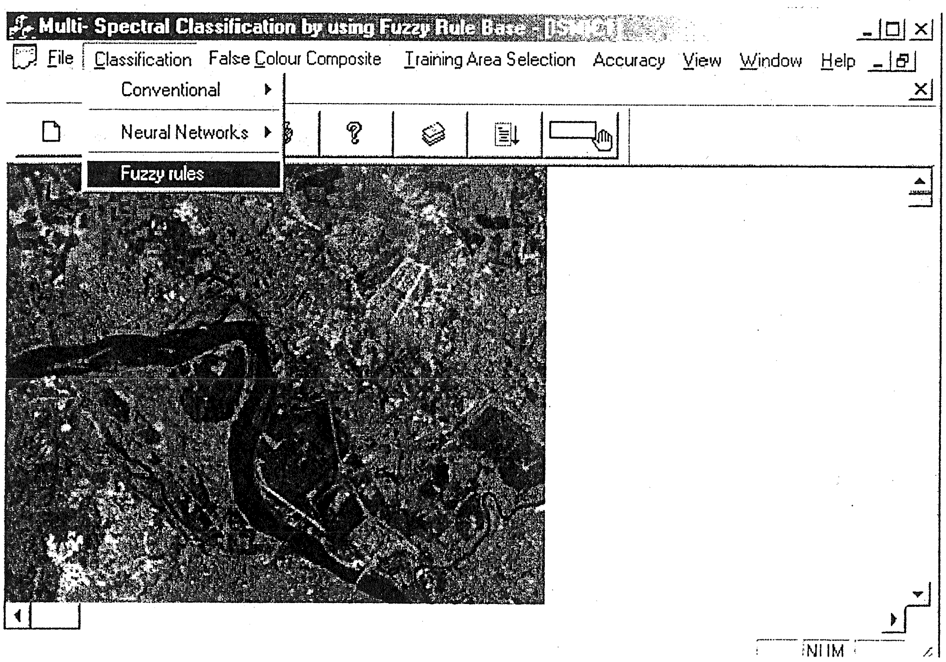
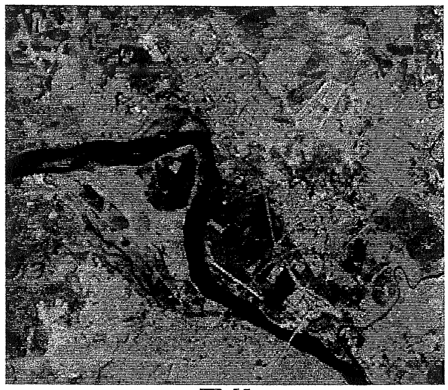
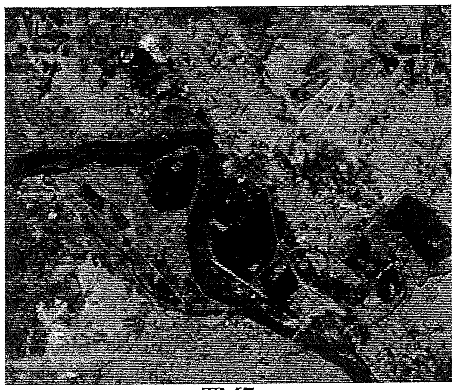


Plate 2: TM-Sensor Raw Images of Mosul Area, and FCC's of Original Band


TM3


TM5


TM7

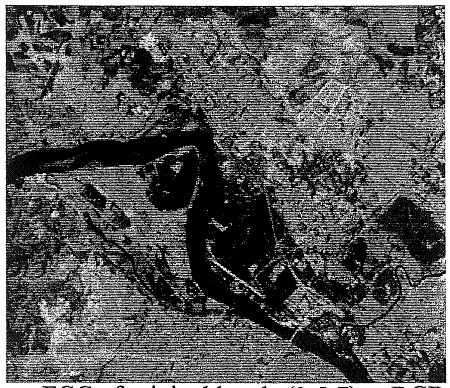
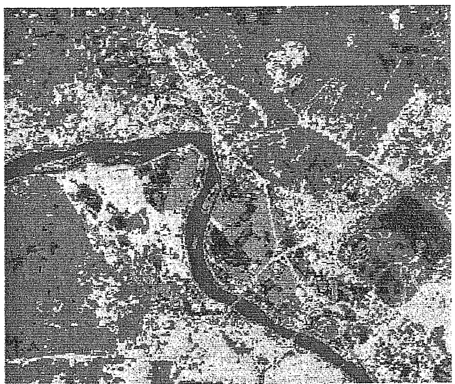
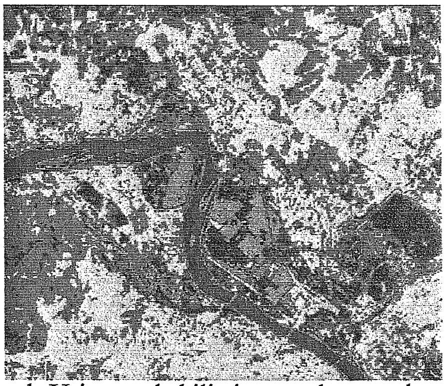
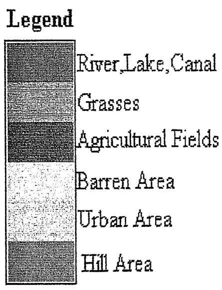
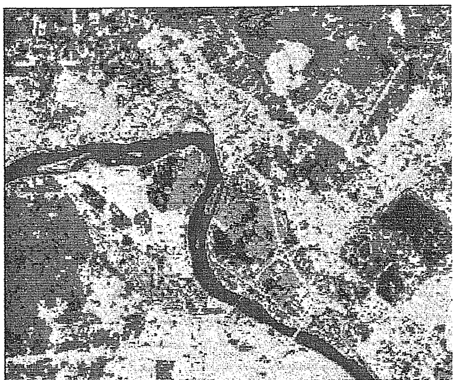

FCC of original bands (3,5,7) as RGB

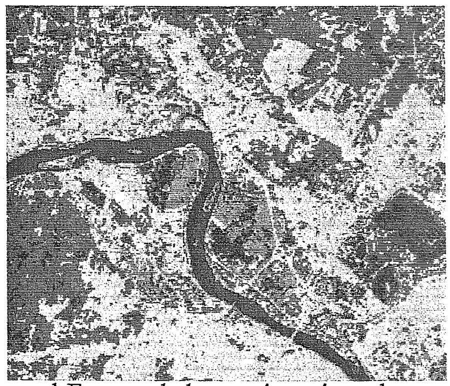
Plate 3: Supervised Classification Results.


a-Using Maximum likelihood classifier


b-Using probabilistic neural network classifier




c-Fuzzy rule base using trapezoidal membership function


d-Fuzzy rule base using triangular membership function