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Satellite Image Classification by Fuzzy Neural Network

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Abstract

Implementation of Fuzzy Reasoning by structure of Neural Network method is used in this work, weights of Neural Network is Fuzzy Reasoning. The FNN can automatically identify the Fuzzy Rules and tune the membership function by modifying the connection weights of Network using the back-propagation algorithm. Post-classification rules is used to reduce the number of isolated mis-classified pixels occur after the pixel-by-pixel classification principle.

الخلاصة

تم استخدام في هذا العمل طريقة تنفيذ ال Fuzzy Reasoning باستخدام هيكلية الشبكات العصبية المضببة، و تمثل ال Fuzzy Reasoning الأوزان للشبكات العصبية. تستطيع الشبكات العصبية المضببة تلقائياً أن تعرف القواعد المضببة و تناغم وظائف ال membership بتعديل الأوزان للشبكة باستخدام خوارزمية ال Back-Propagation. استخدمت قواعد لما بعد التصنيف لتقليل عدد ال Pixels المعزولة و غير المصنفة التي حدثت بعد استخدام التصنيف بمبدأ Pixel-by-Pixel.

1. Introduction

An advantage of using multisource spatial data is that additional features and spatial attributes can be incorporated in the classification. Ideally, each of the data sources will have unique information contributing to the classification process. A substantial difficulty for comprehensive analysis of multisource spatial data, however, arises from the conflicts and incompatibilities among the differences in measurement scales and feature distributions from the various data types. Therefore, a distribution-free and measurement scale-free classification technique is desirable for processing multisource spatial data.[4]

Neural network and fuzzy systems estimate input-output functions. Both are trainable dynamical systems. Unlike statistical estimators, they estimate a function without a mathematical model of how outputs depend on inputs. They are model-free estimators. They "learn from experience" with numerical and, sometimes, linguistic sample data.

Neural network and fuzzy systems encode sampled information in a parallel-distributed framework. Like brain, neural networks recognize patterns we cannot even define. We called this property recognition without definition.

Recognition without definition characterizes much intelligent behavior. It enables systems to generalize [2].

The aim of this work is to adopt and design a Fuzzy Neural Network technique for remote sensing image classification. So the needs for an accurate, quick, and flexible method for image classification have led to the development of this work. Furthermore, post classification rules, which we have suggested have been used to reduce the mis-classified pixels for certain, classes, increase the accurate of classification.

In short, the specification, design, and implementation of this work are presented in a software package.

2. What Fuzzy is Logic?

Fuzzy theory holds that all things are matters of degree. It mechanizes must of our "folk psychology". Fuzzy theory also reduces black-white logic and mathematics to special limiting cases of gray relationships. [2]

Fuzzy logic and neural networks have been combined in a variety of ways. In general, hybrid systems of fuzzy logic and neural networks are

often referred to as fuzzy neural networks.
Fuzzy neural networks in the first category are basically fuzzy rule-based systems where fuzzy if-then rules are adjusted by iterative learning algorithm [3].

3. Implementation of Fuzzy Neural Network

Supervised-learning networks represent the main stream of the development in neural networks. Tow phases are involved in a supervised learning network: learning phase and retrieving phase. [7]
Classifying multisource remote sensing and spatial data requires the ability to match large volumes of input pattern data simultaneously to generate categorical information as output [5]. So the fuzzified features extracted from data implicitly in the network via its layers as describe below.

3.1 Network Architecture

Figure (1) shows the architecture of four layers; they are describe here:
Layer 1: (INPUT) the nodes in this layer just transmit input values to the next layer directly.
Layer 2: (FUZZIFICATION) if we use a single node to perform a simple membership function, then the output function of this node is this membership function. (e.g. bell shaped function like Gaussian Distribution Function); the weights here are the mean values, and standard deviation [6].
Layer 3: (INFERENCE RULE) this layer performs precondition matching of fuzzy logic rules. Hence, the rule nodes should perform the fuzzy AND operation (mean the antecedent matching will be determine here).
Layer 4: (DEFUZZIFICATION) nodes here in down-up transmission mode, the link at layer four should perform the fuzzy OR operation (mean select the maximum value).
Referring to figure (1) there is n inputs, with n neurons (nodes) in the input layer, and c rules, with c neurons (nodes) in the inference and defuzzification layers. And there are n*c neurons(nodes) in the fuzzification layer .So the number of inputs n and number of classes c are determined the layout structure of the network[5].

3.1.1 Back-Propagation Algorithm:

The goal of Back-propagation algorithm is to minimize the error function.

$$E(W) = \frac{1}{2}\sum_{j,r}(T_{j,r} - O_{j,r}(W))^2 \qquad \ldots(1)$$

Where
$O_{j,c}(w)$: Output of the jth node in input-output case c.
$T_{j,c}$: Target of the jth node specified by the teacher.
There are 2-passes in learning forward pass (we describe it above), and backward pass is used to compute $\partial E / \partial y$ for all hidden nodes. Assuming that W is the adjustable parameter in a node (center of the membership function)[6]. The general learning rule is:

$$\Delta W \propto -\frac{\partial E}{\partial W}$$

$$W(t+1) = W(t) + \eta\left(-\frac{\partial E}{\partial W}\right) \qquad \ldots(2)$$

where η is the learning rate, and
Layer 4: only error signals need to compute and propagate, no parameters adjust

$$\delta_j^4 = (t_j - O_j) \quad \text{where } j = 1,2,\ldots\ldots,c \quad \ldots(3)$$

Layer 3: again only error signals need to compute and propagate, no parameters adjust

$$\delta_j^3 = -\delta_j^4\left(\frac{\left(\sum_{i=1}^{c} O_i\right) - O_j}{\left(\sum_{i=1}^{c} O_i\right)^2}\right) \qquad \ldots(4)$$

Layer 2: the adjusted parameters here are mean and standard deviation of membership function by:

$$m_{ij}(t+1) = m_{ij}(t) - \eta\delta_i^3 \exp(net_{ij}) * 2\frac{(X_i - m_{ij})}{\sigma_{ij}^2} \quad (5)$$

$$s_{ij}(t+1) = s_{ij}(t) - \eta\delta_i^3 \exp(net_{ij}) * 2\frac{(X_i - m_{ij})^2}{\sigma_{ij}^3} \quad \ldots(6)$$

3.2 Post Classification:

After classification based on the principle of "pixel by pixel", the resulted image may contain some isolated mis-classified pixels; so we may suggest some rules to eliminate these mis-classified pixels; the classified image is stored, then we apply the rule to the classified image. These rules is specified for the chosen area and area has the same nature of this chosen area, example on these rules[5]:

- If X_{ij} is Tree AND ($X_{i-1,j}$ is deep water OR $X_{i,j-1}$ is deep water) Then X_{ij} is shallow water.

4. Implementation and Results

The work is tested using a LANDSAT-TM image of Ramadi area recorded in 1989 of size (512*512) pixels window of (8-bit) format for bands (2-3-4). So the intensity of pixel is the characeristical feature used.

The software is Graphical User Interface GUI implementation for the theory described in this work, it contain three main parts:

1. Feature extraction
2. Training
3. Testing (classification)

These steps run in sequence to get the required output of this work (classified image), if the user has an enough required information input for any stage of the software, user can skip the previous stage(s).

Feature extraction is the first subroutine concerned with identifying the main input parameters to the system, the parameters that used to train the net, to classify the certain image(s) there after in the program. Selection of class will be visually by the mouse pointer, and the output data file name will be chosen by the user with the extension (.dat). The training sets intensity range(0-255) should be normalized between (0-1). This is necessary for neural networks.

The software is also provided with the ability to examine the displayed image (helping to determine the number of classes) by clipping (crop) part of it and viewing it's histogram, changing it's brightness, shrinking and stretching it's histogram, quantizing it's gray levels to another gray levels, and visually subdividing the image by a grid. In this stage the user must determine the names of selected classes, that is considered an important information in later part of the system (post-classification).

We extract the characteristical features that identify classes and name each class and save the training sets in file with extension (.dat). Then the training sets used to train the net, and feed the net with the required input variables, for this example they are:

Learning rate = 0.001
Momentum term = 0.95
Number of bands = 3
Number of classes = 7

The system reaches high accuracy about 95.238% in about 183 iteration, this is high-speed classification time, and good accuracy classification. Although, another mechanism of interest used here to reduce the classification time, by skipping the phase of updating network weight (fuzzy reasoning) for the corrected classified vectors (training set)[5].

Learning rate represents updating steps toward solution. Therefore, as the learning rate becomes smaller the error updating is improved but in small values. However, when the learning rate is large, fluctuations in error could be seen for the reason mentioned above. The criterion is to use the total error of the network to change the learning rate. When the total error decreases relative to the total error of the cycle before, the learning rate was kept constant. Otherwise, the learning rate was decreased by a proper amount defined by the user [1]. After training is finished the weights of the net (mean and standard deviation) is stored in a file with extension (.trn); these information is used later to classify image(s). Classified image for this example is shown in figure (2), it is also shows the information of each class obtained from the classification. Post-classification rules are applied to enhance the result of classification (reduce the number of isolated misclassified pixels). For this part, we store the classified image with some information in a file with extension (.cfp), and use this file to apply post-classification rules to the classified image latter [5].

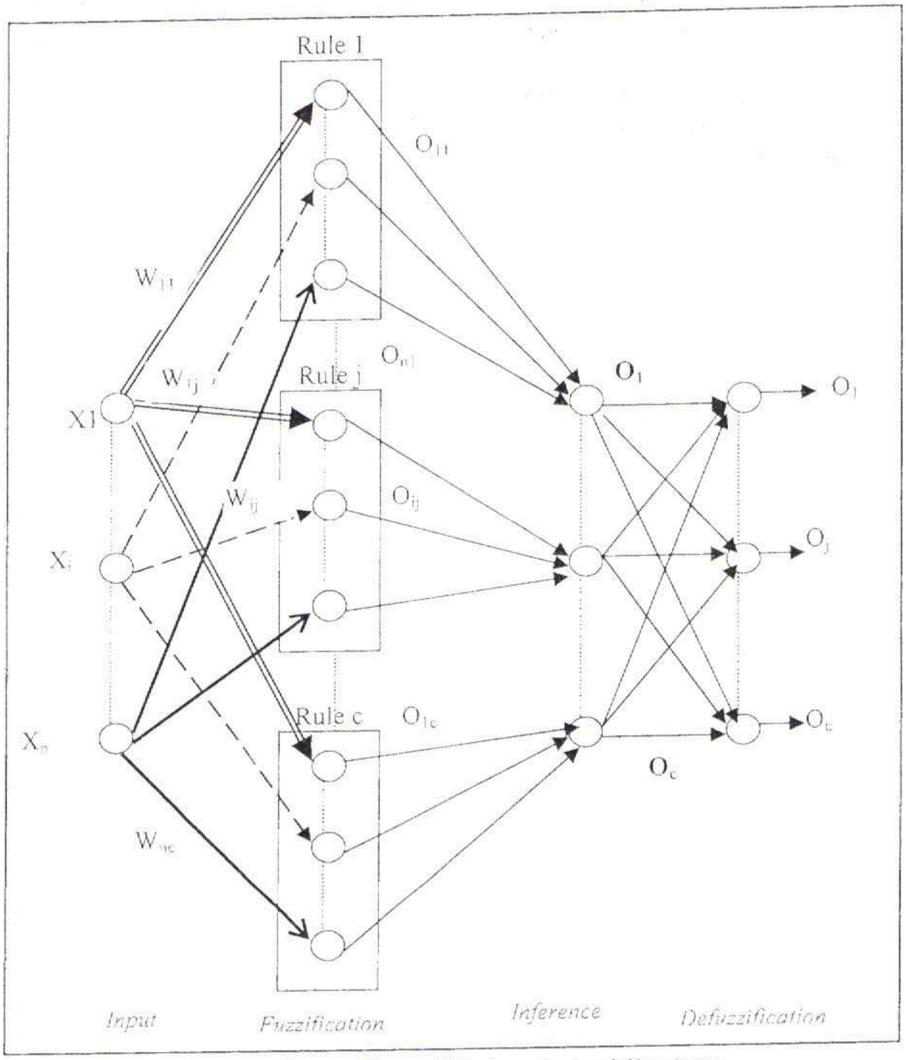

Figure (1) Fuzzy Neural Network Architecture

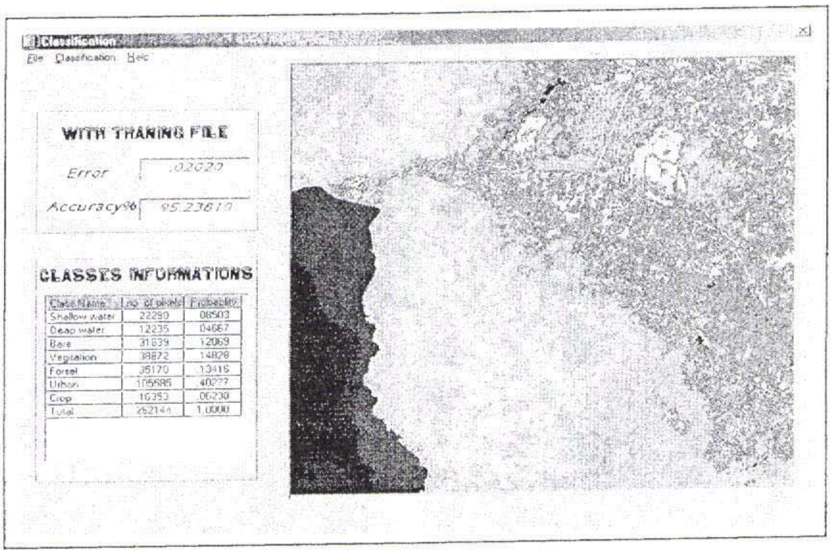

Figure (2) Classification

5. Conclusions

1. Using combination of fuzzy system and neural network which they are trainable dynamic systems that estimate input/output functions; i.e. estimate a function without any mathematical model and learn from experience with sample data, make the system flexible.
2. Also, the system is modular architecture with high flexibility, so it is able to change the number of bands and number of output classes without distributing the over all structure of the system.
3. Gaussian distribution function used is an efficient general distribution model; it is simple and optimal extraction of the data.
4. The system provide a user friendly interface software package, guiding the user step by step to examine the system, providing with help and error massage if the user make any mistake.

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