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PATTERN RECOGNITION IN METEOROLOGICAL SATELLITE IMAGERY

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INTRODUCTION

A pattern is commonly thought of as a set of measurements which describe some object. The measurement can be of different nature; for example albedo, pressure, temperature, height, space coordinate etc. Recognition is a method which classifies a set of patterns into different categories.

Pattern recognition is a computer-oriented methodology that permits rapid and repeatable analysis. The basics of pattern recognition methodology are presented for example by Swain (1978), Deekshatulu (1982), Fu (1978), Mendel and Fu (1970), Meisel (1972). In meteorological application like analysis of satellite cloud imagery the pattern recognition problem is connected with determination of different cloud types according to remote sensing measurements in infrared (IR), near infra red (NIR) and visible (VIS) spectral intervals.

These measurements make it possible to classify different cloud types. The main task of pattern recognition procedure is to automatically classify cloud types and prepare classified data for presenting cloud image on color video display. Figure 1 shows a schematic of the model of a pattern recognition system.

CLOUD - - - - SENSOR - - - [X1 / X2 / X3] - - - CLASSIFIER - - - RESULT

Fig. 1. A model of pattern recognition system.

X1, X2, X3 are the values of different channels of the scaner. The values of Xi are different for different cloud types.

2. DISCRIMINANT FUNCTIONS

The job of designing the pattern classifier consist of two steps:

a) dividing the measurement space into decision regions each region corresponding to a specific discriminable cloud class.

b) Constructing the classifier so that it will identify any measured cloud as belonging to the class corresponding to the decision region in which it falls.

The first step is much more difficult and requires statistical approach. The next section describes the statistical approach to determine the decision regions and discriminant functions.

The process of actually constructing the classifier is conceptually rather simple. The following classification rule must be followed:

Suppose there is a set of m functions of x, $g_m(x)$ is discriminant function. Let Qi denote the i-th class. X belongs to class Qi if and only if discriminant function gi(x) is greater or equal to gj(x) for all classes j = I......m.

Schematically a simple example of a classifier is shown in figure 2.

X —— gi (x) … gm (x) ——SORT MAXIMUM g (x)————RESULT

Fig 2. Scheme of a classifier.

3. STATISTICAL APPROACH

Statistical methods for pattern recognition are appropriate for meteorological analysis of remote sensing data because:

1. Due to the inherent randomness of the nature, remote sensing data exhibit many incidental variations which tend to obscure the characteristic differences among cloud classes. Statistical analysis helps to account for these variations and to reduce their potentially adverse effects on classification accuracy.

2. There is often uncertainity in identifying the training patterns used to determine the discriminant functions. Statistical methods are appropriate for such errors as long as their frequency of occurence is relatively low.

3. Different patterns belonging to the classes of interest may actually overlap in the measurement space. Statistical methods will allow for classifications which are 'most often' or 'most probably' correct.

The probability of appearance of one cloud type according to one chanel measurements can be approximated by a normal (or Gaussian) probability density function. If there are three channels (day time measuments) and two channels (night time measurements), then 3/2 dimensional multivariate normal density function can be written as (Swain, 1978):

$$p(X/Q_i) = \frac{1}{(2\pi)^{n/2} |S_i|^{1/2}} \exp\left[-\frac{1}{2}(X-U_i)^T S_i^{-1} (X-U_i)\right] \quad \text{------- (1)}$$

Where X is data vector, Ui is mean vector for class i, and Si is coveriance matrix for class i.

| Si | is the determinant of the coveriance matrix Si and Si^{-1} is the inverse of Si, (X - Ui) T is the transpose of the vector (X - Ui).

The mean vector and the covariance matrix for class can be estimated from training patterns by :

$$(U_i)_j = \frac{1}{q_i} \sum_{l=1}^{q_i} (X)_{jl} \qquad j = 1, 2, \ldots n \quad \text{------------ (2)}$$

$$(S_i)_{jk} = \frac{1}{(q_i - 1)} \sum_{l=1}^{q_i} ((X)_{jl} - (U_i)_j)((X)_{kl} - (U_i)_k) \quad \text{----- (3)}$$

$$j = 1, 2, \ldots n; \; k = 1, 2, \ldots n$$

where qi is the number of training patterns in class i; j and k denote number of channels.

According to definition of classification rule and using the optimal decision rule which minimizes the average loss (Bayes' rule) we define the discriminant functions as :

$$g_i(X) = P(X/Q_i)\, P(Q_i) \quad \text{-------------- (4)}$$

where p (Qi) is the apriori probability of class i and p (X/Qi) the probability density function associated with the measurement vector X.

Using (1), the descriminant function becomes -

$$g_i(X) = \frac{P(Q_i)}{(2\pi)^{n/2} |S_i|^{1/2}} \exp\left[-\frac{1}{2}(X-U_i)^T S_i^{-1} (X-U_i)\right] \quad \text{------ (5)}$$

or in a simplified form for implementation on computers

$$\log[g_i(X)] = \log P(Q_i) - \frac{1}{2}\log|S_i| - \frac{1}{2}(X-U_i)^T S_i^{-1}(X-U_i) \quad \text{------ (6)}$$

Once the clouds classification has been specified and the statistical parameters estimated from training data, only the rightmost term of equation (6) varies during the classification process and must be calculated for each classification. The classification strategy based on eqn (6) is :

X is an element of Qi if and only if gi(X) is greater than or equal to gj(X) for all classes j = 1 ... m.

The apriori probability of cloud class appearance can be set 1 for the first period of cloud measurements. After statistical analysis of cloud class appearance it can be determined and introduced in equation (6).

4. POSSIBLE METHODS OF DESIGNING THE CLASSIFIER

Depending on available data there are three ways to solve the problem.

1. On the basis of already taken cloud measurements by satellite, pick out fixed boundaries between the classes and design the classifier. (The overlaping problem is not solved).
2. On the basis of already taken cloud measurements use statistical parameters : mean and coveriance and design the classifier based on multivariate normal density function.
3. Select meteorological situations, analyse them, fix cloud classes and compare data with satellite measurements. Make statistical analysis of three chanel measurements for every cloud type, pick out statistical parameters mean and coveriance and design the classifier based on multivariate normal density function.

The different cloud types can be classified in classes as shown in thble 1.

TABLE 1. Different cloud types

CLASS	CLOUD TYPE
1	Cumulonimbus, Cb
2	Cumulus Congestus, Cucong
3	Nimbostratus, Ns
4	Altocumulus, Ac
5	Altostratus, As
6	Cirostratus, Cirus, Cirocumulus, Cs, Ci, Cc
7	Stratocumulus, Cumulushummilie, Sc, Cu
8	Stratus, Fog, St
9	Snow
10	Land and Water

The separation of Cs, Cc and Sc, Cu can be made from the texture by the image interpreter.

Problems connected with pattern recognition :

The main problem is the absence of VIS data during the night pass of the satellite over area of interest. It is necessary to investigate the possibility of simple classification of cloud types on the basis of IR and NIR measurements. The two dimensional multivariate density function can be used for determining the discriminant functions.

During the day pass of the satellite the problem with VIS data is connected with different sun elevations and albedo values. One way to solve this problem is to use different multivariate density functions (only mean and convariance must be changed for each sun elevation).

The three cases can be shown as :

CASE 1.

SATELLITE DATA---FIX. BOUND. BTW. CLAS.---DECISSION--RESULT

CASE 2.

SATELLITE DATA--APRIORI DETERM. PARAMET.---P(X/QI)---RESULT

CASE 3.

TRAINING DATA -- DETERMINATION OF PARAMETERS

SATELLITE DATA——————————P(X/Qi)–RESULT

For obtaining the discriminent functions eqn (4) or (6) it is necessary to make statistical analysis of satellite data which have to lay down the apriori probability of different cloud type appearance. This apriori probability will be an important factor for the discriminent functions.

Feature extraction is a simplification in the process in pattern recognition. It can be done by using thresholding i. e. separation of cloud, land and water data. The pixel without clouds can be assigned to land or sea and shown in specific colour on the screen. This data is then not required to be passed on to the clarrifier.

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