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Digital Image Processing for Meteorogical Satellites Interact Aproach

Numerička obrada meteoroloških satelitskih slika projekt Interact

BOJAN LIPOVŠĆAK*, INTERACT, Hyderabad — India

Abstract: This article shows the approach to the digital immage processing of TIROS — N/NOAA satellite data which is developed under the INTERACT project. The theme of the discussion is the problem of automatic cloud classification from the high resolution AVHRR data. The algorythm for cloud classification based on multivarite normal density as decision function is proposed. Classifier learning phase is connected with use of training sample data from which the moments for normal density function are calculated. The decision area for the classification is defined by means of parameters (mean and covariances). The classification is performed using the Byes maximum likelyhood rule.

K e y w o r d s : cloud classification, meteorological satellites, patern recognition.

Sažetak: U radu je prikazan pristup obradi satelitskih meteoroloških podataka satelita TIROS — N/NOAA koji je razvijen okvirom projekta INTERACT u Hyderabadu, Indija. Diskutirana je problematika vezana uz klasifikaciju oblaka iz visoko rezolutnih AVHRR podataka. Predložen je algoritam za klasifikaciju oblaka baziran na višedimenzionalnoj normalnoj funkciji gustoće vjerojatnosti (jednadžbe (1). kao funkciji odluke. Učenje klasifikatora provodi se na skupu »trening« podataka iz kojih se računaju momenti funkcije gustoće. Na taj način određeni momenti (srednjaci i matrica kovarijanci) definiraju prostor donošenja odluke prilikom klasifikacije. Klasifikacija se vrši primjenom Baesova pravila principom maksimalne vjerojatnosti (jednadžbe (2) i (3).

K l j u č n e r i j e č i : Klasifikacija oblaka, meteorološki sateliti, raspoznavanje oblaka.

1. INTRODUCTION

The use of meteorological data for very short range weather forecasting (nowcasting) is connected with the need for a high number of classical meteorological information obtained from a network of manned and automatic meteorological stations, radar data and meteorological satellite data. Accuracy of information and analysis of meso scale systems is connected with well developed telecomunication network, e. g. telephones, telexes and radio conections.

The use of satellite platforms for remote sensing enables us to receive informations from the places which would not be accessible for us if using normal instruments in in-situ mode. Additionally, the satellite cloud images provide the information on cloud top temperature. The problem of reception and analysis of high resolution satellte data conditions the purchase of expensive receiving hardware and software. Non-developed countries have no possibility of receiving the raw digital satellite data, their fast processing and dissimination to the users. The processing software for the digital satellite data analysis is equally expensive as receiving station hardware.

With the INTERACT project which is developing in India under the sponsorship of UNFSST, UNDP and Govt. of India the processing software for the digital satellite data is getting developed and will be given free of charge to the countries participating in the project. The aim of the project is the development of the software package which will be able to anluze the high resolution satellite data, to reduce the amount of data taking care of the main meteoroogical features and disseminate the data to the users. In its basic conception the software is made for the digital image processing for TIROS — N/NOAA seres satellites AVHRR da-

* current affilation: Hydrometeorological institute Zagreb, Yugoslavia

ta (Gupta et all 1983).

2.1. **Review of cloud classification**

Since the appearance of first satellite picture there have been many attempts to classify the cloud pictures. The first classification attempts were based on the use of visible channel information [Conover (1962), Anderson (1966), Kondratjev (1966)]. The methods used were manual, based on difference in reflectance, shape and texture of cloud elements on the satellite picture. Use of infrared (IR) cloud imagery enables the more sophiticated methods for cloud classification. The first attempt for a computer based classification is found in Barens and Chang (1969). They found out that it was possible to make a cloud classifier on the basis of multichannel measurements. Graves and Chang (1970) used statistical method and classified five cloud categories on the basis of 0.2—0.4, 6.4—6.9, and 10.0—11.0 micrometer satellite data. Lo and Johnson (1971) used bivariate frequency distribution for classifying clouds from nimbus-2 MRIR 10.0—11.0, 6.4—6.9 micrometer data. Shenk's (1976) method is based on thresholding of satellite measurements and histogram seperation of data. Raynolds (1977) used bispectral method for dynamical classification of meso scale clouds based on the difference between time in a series of satellite pictures over one area. Raynolds et all (1978) developed a scheme for different cloud type seperation based on visible and IR data. Parikh and Rosenfeld (1978) proposed a cloud classification scheme which resolved the ambiguities in IR cloud imagery by a comparison of textural measures of known and unknown cloud segments. Parikh et all (1980) developed a scheme for cloud classification based on IR measurement data of SMS-1 satelilte data. Liljas (1981) employed a box like thresholding function based on three channel NOAA-imagery. Desbois et all (1982) used clustering method for classification of three channel METEOSAT data, they treated land and sea as one class and identified five types of clouds. The major problem of this method is identification of clusters corresponding to different cloud types.

Under the INTERACT project a statisticaly based cloud classifier is designed and developed, Lipovšćak (1983), Mehtre (1984), wich use the multivariate normal distribution function as discriminat function and supervised learning of training parameters.

2. SYSTEM DESIGN: INTERACT APPROACH

The NOAA 6, 7 and 8 data received by the NRSA (National Remote Sensing Agency) at Hyderabad India, are stored on magnetic tapes and delivered to the users. The use of tapes is connected with the use of software for interpretation and formation of data base which has been classified into three units:

— preprocessing software;
— system software;
— advanced software.

All the three units are linked together by the application programmer.

2.1. **The preprocessing software**

Stellite data on CCT-s (computer compatible tapes) are decoded and reformated for data base and then corrected. The tape formats are standard and hence the same programs can be used for future NOAA satellite data. With little modification the software could be used for data received in other earth stations.

The satellite dependent parameters are kept in a separate file and these can be changed / updated. Thus it is expected that the software will be flexible enough to be used for all polar orbiting satellites. The main parts of the preprocessing software are:

— calibration;
— geometric corrections;
— earth rotation corrections;
— earth location.

2.2. **System software**

The system software is divided in two parts:

— data base,
— man machine interface.

The structure of these programs depends on the system and contains all possible system oriented routines and functions.

2.3. **Advanced modules**

The advanced module programs are operated on the calibrated and corrected data. This part contains the programs for enhancement of the meteorological features seen in the picture, pattern recognition applications, cloud classification and temperature fields calculation.

3. CLOUD CLASSIFICATION

Cloud classification based on digital satellite data and pattern recognition is a computer oriented methodology, permitting rapid and repeatable analysis. The bases of pattern recognition methodology have been discussed by Mendel and Fu (1970), Meisel (1972), Fu (1978), Swain (1978), Deekshatulu (1982). The meteluological application in analysis of satellite cloud imagery and pattern recognition probem is connected with the determination of different cloud types according to remote sensing measurements in infrared (IR), near infrared (NIR), and in visible (VIS) spectral intervals.

The different type of clouds and other surface features have different albedos in visible and near infrared, and their thermodynamc temperature gets reflected in infrared data WMO (1979). It makes possible the construction of the automatic calssifiers using multispectral data. The main task of the classifier is the recognition of different cloud types and their display on the video or hard copy terminals.

The scheme of the model of a cloud classifier is shown in figure 1.

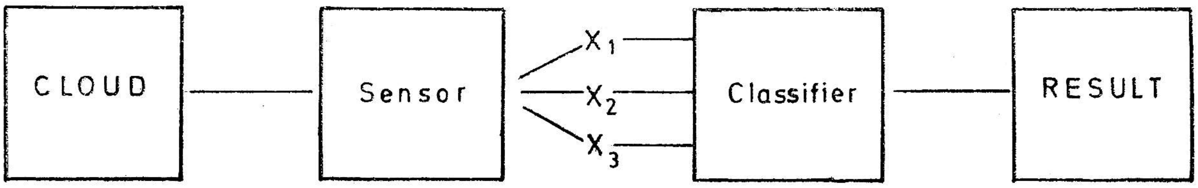


Figure 1' Model of a cloud classifier.

Slika 1. Model klasifikatora oblaka.

Sensor is the satellite VIS, IR, and NIR scanner, the values x1, x2 and x3 are the values of the three different channels (out of total 5 spectral channels) of the scanner. The values of x are different for different cloud types. Liljas (1981) suposes fixed boundaries between cloud classes and divides the measurment space into 8 decision regions. In this way the problem of overlapping the patterns belonging to the classes of interest is not solved.

The process of actual constructing the classifier is conceptually rather simple. Formally the following classification rule must be respected:

Suppose we can find a set of m functions of X, g (X) which we call discriminant functions, let ω_i denote the i-th class. Decide that X belongs to class ω_i if and only if discriminant function $g_i(X)$ is greater or equal to $g_j(X)$ for all classes J = 1 . . . . m.

The scheme of the classification rule is shown on figure 2.

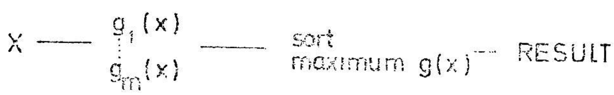


Figure 2. Scheme of a classifier:

Slika 2. Shema klasifikatora

Presume that the probability of appearance of one cloud type in one channel measurements can be approximated by the normal (Gaussian) probability density function. We have in disposition three channels and the three-dimensional normal density function can be used. The n-dimensional multivariate normal density function can be written as:

$$p(X/\omega_i) = \frac{1}{(2\Pi)^{n/2}\,|\Sigma_i|^{1/2}} \exp\left[-\tfrac{1}{2}(X-\mu_i)^T\Sigma_i^{-1}(X-\mu_i)\right] \quad (1)$$

where X is the data vector, μ_i mean vector for class i, Σ_i covariance matrix for class i, Π Ludolph's number. $|\Sigma_i|$ is the determinant of the covariance matrix and Σ_i^{-1} is the inverse of Σ_i, $(X-\mu_i)^T$ is the transponse of the vector $(X-\mu_i)$. According to the definition of classification rule and using the optimal decision rule which minimize the average loss (Byes rule) we define the discriminant function as:

$$g_i(X) = p(X/\omega_i) \cdot p(\omega_i) \quad (2)$$

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

Equation (1) with (2) becomes easy to use for the computer implementation in the form shown in equation (3):

$$g_i(X) = \log p(\omega_i) - \tfrac{1}{2}\log|\Sigma_i| - \tfrac{1}{2}(X-\mu_i)^T\Sigma_i^{-1}X - \eta_i) \quad (3)$$

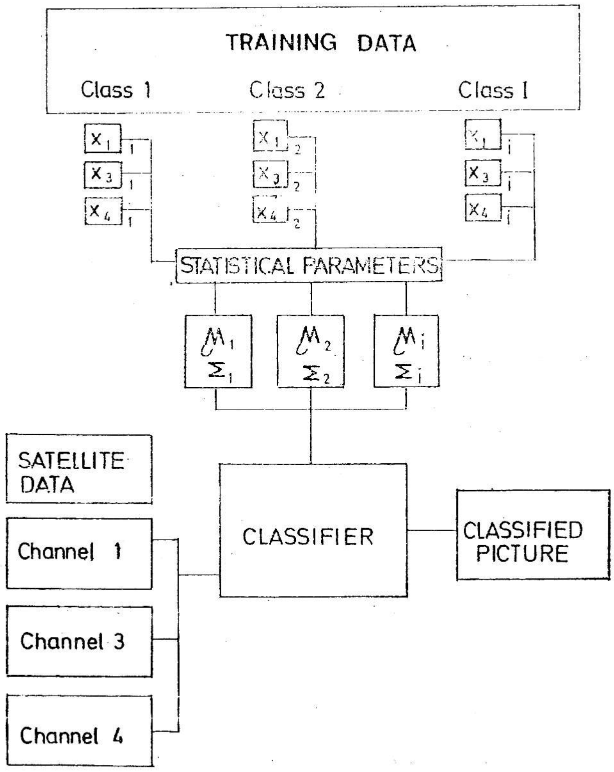
When the moments of distribution are computed (mean and covariance matrix), from the set of training data, only the rightmost term of equation (3) must be computed for every classification step. Apriori probability of class i appearance can be set equal to 1 for the first classification period performing to different seasons. After a certain period of time apriori probability is computed, set to the computed value and it presents the ponder of the classifier.

The use of the discriminant function (3) is connected to the learning of the classifier. This term means the determination of statistical moments of multivariate normal probability function for all possible classes of occurences which should be classified. From the set of training data which contains the known classes it is necessary to compute the mean and covariance matrix for every class and channel. Thus defined moments present the discriminant function for every event. The classification is made according to the classification rule in a way that the probability for every pixel is computed. The pixel is put in the class where the probability has the maximum value. The scheme of clasification procedure is shown in figure 3.

The basic components of the classification software are:

- programs for statistic parameters extraction from the training data set;

— program for the clouds and underlaying surface classification;
— programs for presentation of classified picture on video or hard copy terminals.



4. CONCLUSION & ACKNOWLEDGEMENTS

The presented cloud classifier and the used classification methode is applied in the INTERACT software. The classifier, as a separate set of programs can be applied on every multichannel satellite data.

I would like to use this opportunity to thank very much all the INTERACT staff who helped me in designing and application of the classifier.

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IZVADAK

Kratkoročna prognoza vremena (nowcasting) povezana je s potrebom za vrlo čestim meteorološkim osmatranjima s guste mreže meteoroloških stanica. Upotreba meteoroloških satelita omogućuje neprekidno praćenje vremena nad velikim prostranstvima Zemlje. Okvirom projekta INTERACT razvijena je programska podrška za prijem i obradu visoko rezolutnih AVHRR satelitskih podataka satelita serije TIROS — N/NOAA. Programska podrška za obradu podataka sastoji se od tri osnovna dijela:

— programi za preliminarnu obradu,
— sistemski programi,
— aplikacioni programi.

Predložena je upotreba višedimenzionalne normalne funkcije gustoće kao funkcije diskriminacije za klasifikaciju oblaka, (jednadžba 1). Upotrebom Byes-ovog pravila koje minimizira srednji gubitak pogrešne klasifikacije (jednadžba 2), funkcija diskriminacije među klasama poprima oblik prikazan jednadžbom 3.

Više dimenzionalna normlana funkcija gustoće definirana je vektorom srednjaka i matricom kovarijanci. Određivanjem momenata razdiobe određuju se funkcije diskriminacije za pojedine klase.

5. REFERENCES

Anderson, R. K., E. W. Ferguson, V. J. Oliver 1966: The use of satellite pictures in weather analysis and forecasting, WMO Tech No. 75, 183 pp.
Conover, J. H. 1962: Cloud interpretation from satellite altitudes, Air force Cambridge Res. Lab., AFORL — 62. 680.
Desbois, M., G. Seze, G. Szeywach 1982: Automatic classification of clouds on METEOSAT imagery. Application to high level clouds. Jou. of app. Met., Vol 21, 401—412.
Dekshatulu, B. L. 1982: Pattern recognition and applications, Short course in signal processing, IEEE, Hyderabad, 20 pp.
Fu K. S. 1978: Pattern recognition in remote sensing of the earth's reasurces, Digiatl image process. for rem. sens., IEEE Press, New York, 277—305.
Gupta, R. K., N. N. Murthy, A. Prakash, V. Sharma 1983: Digital image processing system for meteorological satellites, Hyderabad, CMC Techn. dig., Vol 5, No. 4, 11—16.
Kondratjev K. J., E. P. Borisenko, A. A. Marozkin 1966: Prakticeskoe ispolzovanije danih meteorologiceskih sputnikov, Gidrometeoizdat, Leningrad, 251—256.
Liljas, E. 1981: Automated techniques for satellite imagery analysis, Proceedings IAMP Symposium, Hamburg, 331—339.
Lipovšćak, B. 1983: Pattern recognition in meteorological satellite imagery, Hyderabad, CMC Techn. dig., Vol 5, No. 8, 17—19.
Lo, R. C., D. R. Johnson 1971: An investigation of cloud distribution from satellite infrared radiation data, Mon. Wea. Rev., Vol 99, 599—605.
Mehtre, B. M. 1984: Project report on automatic cloud classification, Hyderabad, CMC — INTERACT, internal report.
Meisel, W. S. 1972: Computer oriented approaches to pattern recognition, A P, New York, Matematics in science and inginering Vol 83.
Mendel, J. M., S. K. Fu 1970: Adaptive, learning and pattern recognition systems, A P, New York, Mathematics in science and inginering Vol 66.
Parikh, J. A., A. Rosenfeld 1978: Automatic segmentation and classification of infrared meteorological satellite data, IEEE, Man nad cyb., Vol SMC-8, No. 10, 736—743.
Parikh, J. A., J. T. Ball 1980: Satellite cloud analyses for a radiation model, Pattern recognition in practice, North- Holland pub. Co., Amsterdam, 201—212.
Raynolds, J. W., T. H. Vander Haar 1977: A bispectral method for cloud parameter determination, Mon. Wea. Rev., Vol 105, 446—457.
Raynolds, J. W., H. L. Brown, E. A. Smith, T. H. Vander Haar 1978: Cloud type separation by spectral differencing of image pairs, Mon. Wea. Rev., Vol 106, 1214—1218.
Shenek, W. E., R. J. Holub 1976: A multispectral cloud type identification method developed for tropical ocean areas with NIMBUS — 3 MRIR measurements, Mon. Wea. Rev., Vol 104, 284—291.
Swain, P. H. S. M. Davies 1978: Remote sensing the quantitative approach, Mc Graw-Hill.
WMO 1979: Quantitative meteorological data from satelliters, WMO Tech. No. 166.