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An Experiment on Automated Statistical Recognition of Clouds

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Abstract — Results of the recognition of multi-spectral satellite data by means of a statistical automated classification algorithm (SACA) are presented. The algorithm is based on the approximation of an unknown probability density function for a given set of observations by a mixture of multi-dimensional normal distributions. For a given number of mixture components, optimal estimates for unknown parameters are found by the Day — Shlezinger algorithm as one of the solutions of the set of likelihood equations that maximize the likelihood function. Optimal number of classes is determined by the step-by-step checking of two complex statistical hypotheses. The classification of a given set of observations is performed by applying the bayesian rule. To reduce the computational cost of the SACA, a preliminary analysis of the structure of the set under investigation is carried out, which provides rough estimates for the number of classes and their basic characteristics. Results of automatic classification of the main types of clouds and underlying surface are described.

INTRODUCTION

The data on clouds and thermal characteristics of the Earth's atmosphere and surface are widely used both in synoptical practice and in models employed in weather forecast and analysis. Therefore, the development of automated methods for recognition of various types of clouds is a

topical problem. Data obtained from measurements by high-resolution radiometers aboard geostationary satellites is one of the most promising information sources. The large amounts of information received from satellites and the need for fast processing make it necessary to apply mathematical methods of pattern recognition to satellite data most promising.

The first experiments on automated recognition of satellite images based on previousli acquired data on various types of clouds under different geographic conditions and attempts to use them as reference data have shown that methods of data processing need further refinement (see [1 — 3]). The approach based on studies of multispectral data on radiative transfer in clouds with different properties and on the threshold classification of clouds did not lead to the development of highly efficient automated recognition techniques [4, 5]. Application of statistical automated classification algorithms to this problem has a number of advantages and improves the efficiency of recognition to 75 — 80% (see [6, 7]). For this reason, this approach was chosen for deciphering the parts of images containing relatively small areas occupied by frontal clouds. We tested the statistical algorithm of automated classification based on the approximation of an unknown probability density function for a given set of observations by a mixture of multidimensional normal distributions with different vectors of mean values and equal covariance matrices.

1. RECOGNITION ALGORITHM

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2. RECOGNITION OF OBJECTS BASED ON MEMEOROLOGICAL SATELLITE DATA

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REFERENCES

1. Solov'eva, I.S., Sonechkin, D.M., and Kharitonov, V.F, Computerized Processing and Analysis of Television Images of Clouds, Tr. Gidrometeorol. Nauchno-Issled. Tsentra, 1971, no. 73, pp. 64-74.
2. Bakst, L.A. and Fedorova, N.N., A Study of Clouds for Synoptic Analysis Based on Multispectral AVHRR Data from a NOAA Satellite, Issl. Zemli iz Kosmosa, 1994, no. 4, pp. 3-8.
3. Tokuno, M. and Tsuchija, K., Classification of Cloud Types Based on Data of Multiple Satellite Sensors, Adv. Space Res., 1994, vol. 14, no. 3, pp. 199-206.
4. Peak, J.E. and Tag, P.M., Segmentation of Satellite Imagery Using Hierarchical Thresholding and Neural Networks, J. Appl. Meteorol., 1994, vol. 33, no. 5, pp. 605-616.
5. Strabala, K.I., Ackerman, S.A., and Menzel, W.P., Cloud Properties Inferred from 8-12 μm Data, J. Appl. Meteorol., 1994, vol. 33, no. 2, pp. 212-219.
6. Bakst, L. and Fedorova, N., On Some Methods of Synoptic Analysis Based on the Study of the Multispectral Satellite Data Variation, Proc. 9th Meteorological Satellite Data Users' Conf., Locarno, Switzerland, Darmstadt: EUMETSAT, 1992, pp. 25-32.
7. Bankertt, R.L., Cloud Classification of AVHRR Imagery in Maritime Regions Using a Probabilistic Neural Network, J. Appl. Meteorol., 1994, vol. 33, no. 8, pp. 1023-1039.
8. Voloshin, G.Ya., Burlakov, I.A., and Kosenkova, S.T., Statisticheskie metody resheniya zadach raspoznavaniya, osnovannye na approksimatsionnom podkhode (Statistical Methods for Recognition Problems Based on the Approximation Approach), Vladivostok, 1992, ch. 1.
9. Anderson, T.W., An Introduction to Multivariate Statistical Analysis, New York: Wiley, 1958. Translated under the title Vvedenie v mnogomernyi statisticheskii analiz, Moscow: Fizmatgiz, 1963.
10. Day, N.E., Estimating the Components of a Mixture of Normal Distributions, Biometrika, 1969, vol. 56, no. 3, pp.463-474.
11. Shlezinger, M.I., Interrelation of Learning and Self-Learning in Pattern Recognition, Kibernetika (Kiev), 1968, no.2, pp.81-88.
12. Aprausheva, N.N., Splitting Algorithm for a Mixture of Normal Classes, Programmy i algoritmy (Programs and Algorithms), Frenkina, I.P., Ed., Moscow: TsEMI AN SSSR, 1976, no. 68.
13. Aprausheva, N.N., Analysis of a Splitting Algorithm for the Mixture of Normally Distributed Classes, Mnogomernyi statisticheskii analiz v sotsial'no-

ekonomicheskikh issledovaniyakh (Multidimensional Analysis in Social and Economic Studies), Aivazyan. S.A., Ed., Moscow: Nauka, 1974, pp. 135-150.
14. Aprausheva, N.N., Transformation of Features in the Statistical Solution of an Automated Classification Problem, Izv. Akad. Nauk SSSR, Ser. Tekhn. Kibern., 1985, no. 2, pp. 167-174.
15. Aprausheva, N.N., Novyi podkhod k obnaruzheniyu klasterov (A New Approach in Cluster Detection). Moscow: Vychisl. Tsentr Ross. Akad. Nauk, 1993.
16. Duran. B.S. and Odell, P.L., Cluster Analysis: A Survey, Berlin: Springer, 1974. Translated under the title Klasternyi analiz, Moscow: Statistika. 1975.
17. Aprausheva, N.N., Determination of the Number of Classes in Classification Problems, Izv. Akad. Nauk SSSR, Ser. Tekhn. Kibern., 1981, no. 3, pp. 71-77.
18. Wilkes, S.S., Mathematical Statistics, New York: Wiley, 1962. Translated under the title Matematicheskaya statistika, Moscow: Nauka, 1973.
19. Aprausheva, N.N., Determination of the Number of Classes in Classification Problems, Izv. Akad. Nauk SSSR, Ser. Tekhn. Kibern., 1981, no. 5, pp. 153-160.
20. Aprausheva, N.N., Bakst, L.A., Gorlach, I.A., et al., On the Recognition of Types of Frontal Clouds Based on Satellite Data, Moscow: Vychisl. Tsentr Ross. Akad. Nauk, 1996.
21. Cramér, H., Mathematical Methods of Statistics, Princeton (New Jersey): Princeton Univ. Press, 1946. Translated under the title Matematicheskie metody statistiki, Moscow: Mir, 1976.
22. Feller, W., An Introduction to Probability Theory and Its Applications, New York: Wiley, 1968.