IGARSS '90

THE EFFECTS OF THE APPLICATION OF SMOOTHING AND ORTHOGONAL TRANSFORMS TO SPOT AND TM DATA ON REGRESSION BASED CROP ACREAGE ESTIMATES

Sherman B. Winings, Martin Ozga
National Agricultural Statistics Service
United States Department of Agriculture
Washington D.C. 20250

Jacques Stakenborg
Commission of the European Communities
Joint Research Center
Ispra Establishment
21020 Ispra
Italy

ABSTRACT

1990

Two types of smoothing algorithms, edge preserving and classified spatial, were studied using multitemporal Landsat Thematic Mapper and multitemporal SPOT data over an area of Arkansas. The goal was to see the effect of smoothing on crop acreage estimation using regression estimation. Both types of smoothing were found to improve results with edge preserving smoothing being the best. Data reduction using the principal components transform was also tested, but found to significantly degrade results.

INTRODUCTION

The National Agricultural Statistics Service (NASS) of the United States Department of Agriculture has an ongoing project using remotely sensed data to improve crop acreage estimation [1]. NASS has produced crop acreage estimates for many years. The primary method currently used is to randomly select segments or areas of land in various land use strata. Then, enumerators are sent to those segments to collect information from the farmers. Finally, the total estimates are calculated from the segment data based on a direct expansion estimator. Remotely sensed data gives additional information about the entire area, including the segments, allowing use of a regression estimator to more precisely calculate the crop acreage estimate. The segments provide training input for clustering the remotely sensed data. Entire scenes are classified and aggregated by land use strata. These values are input to the regression estimator to produce the final estimate.

Previous work has been performed largely with Landsat Multi-Spectral Scanner (MSS) data, sometimes multitemporal. However, the introduction of Landsat Thematic Mapper (TM) and SPOT data, with their higher resolution, indicate that some form of smoothing would be useful. This is particularly true for agriculture since crops are typically grown in rather regular fields. Two methods of smoothing were investigated, edge preserving smoothing (EPS) which is applied to the raw data before any clustering or classification, and classified spatial smoothing (CSS) which is applied as a post-processing step after classification. These methods of smoothing were compared to raw, unsmoothed data (RAW). Since data reduction might be desirable, particularly for multi-temporal TM data, reduction in the dimensionality of the data using principal components (orthogonal transforms) was also studied.

METHODS OF EVALUATION

Three measures of the quality of the results were used, percent correct, commission error, and regression quality. Percent correct is the percentage of pixels for a ground cover correctly classified into that cover and is based on the cover reported for various fields in the segments. Commission error is a percentage measure of pixels classified into a cover that actually belong to some other cover and is also based on the segment data. Regression quality is measured by R-squared also called the coefficient of determination [2]. As R-squared increases to a maximum of 1.0, confidence increases that the independent variable, in this case classified pixels, is accurately predicting the dependent variable, crop acreage.

All processing for the evaluation was done using the PEDITOR system [3,4] on the NASS MicroVAX and IBM-compatible PCs. New programs were added to PEDITOR to handle edge preserving smoothing, classified spatial smoothing, and principal components.

TEST AREA

The test area chosen is in Lonoke and Jefferson counties in Arkansas. In this area, multitemporal data were available for both TM and SPOT. The principal crops are soybeans, rice, and cotton. Two subareas were used based on available SPOT and TM scenes. In the first subarea, there were only two segments, insufficient for regression, so that only the percent correct and commission error could be computed. In the second subarea, there were ten segments so that regression estimation could be performed and R-squared computed. The tables of results show the percent correct and commission error combined for both subareas and R-squared only for the second subarea.

If edge preserving smoothing was being used, it was applied first to the data. Then, in any case, the data was clustered using a modified version of the ISODATA method [5,6]. Clusters were obtained for soybeans, cotton, rice, woods, waste, and other. Waste is a miscellaneous category of non-agricultural use. Other includes everything not included in the preceding categories. The data were classified using the maximum likelihood classifier. If classified smoothing was used it was then applied to obtain the final classified output.

EDGE PRESERVING SMOOTHING

Edge preserving smoothing has been described very well in [7] so only a brief description will be given here. Smoothing takes place in a moving window of five by five pixels, with the pixel to be processed in the center. Inside this window nine different sub-windows are defined which all contain the center pixel. The sub-windows are positioned like a rotation bar around the center. For every image pixel the neighboring sub-window with the least variance is chosen with the new value of the pixel being the mean of the pixels in the chosen sub-window. This technique assumes that variance is a measure of homogeneity. Thus smoothing is relative to the sub-window with the fewest edges, leading to the name edge preserving. A variety of methods are available for multi-channel images. Although none of these methods have proven better than the others, we have chosen to use the sub-window which has the least total variance summed over all channels since this gives the best visual output [8]. Edge preserving smoothing may be iterated repeatedly on the same data set, but in practice two iterations seems to give the best results. Areas smaller than two by two pixels tend to disappear after smoothing. These areas are considered to be mixed so that even if they were preserved they would not be a good radiometric representation of the cover of interest. The segmentation properties of this filter are very good making it well-suited for use in agricultural areas. Further descriptions of somewhat modified versions of edge preserving smoothing and their use may be found in [9,10]. The algorithm requires only a moderate amount of computer time and can be executed on a PC.

Applying edge preserving smoothing to the SPOT data raised the overall percent correct from 89 to 95 percent on one scene and from 74 to 76 percent on the other. For TM data there was a similar gain from 94 to 98 percent on one scene and from 88 to 90 percent on the other. Percent correct improved in 9 out of 14 instances. Commission error was reduced in 12 out of 14 instances. Regression R-squares did not show much improvement, but R-squares were already large and there was limited room for improvement. Visual displays of the data, both classified and raw, were perceptively more pleasing as clutter was reduced. The results obtained with edge preserving smoothing are shown in the tables under the heading EPS.

CLASSIFIED SPATIAL SMOOTHING

Classified spatial smoothing is a method that considers a neighborhood of nine pixels centered on the pixel to be processed. Weights are chosen such that the center pixel is changed to the dominant cover and assigned to the the dominant class within that cover in the nine pixel region. Within a solid field for a particular cover, areas of one or two pixels different than that cover tend to be eliminated. Areas of three pixels are reduced to one pixel. Effects on larger areas and areas with several covers are more complex. The algorithm does, however, always reduce the complexity of the data. The algorithm requires only a moderate amount of computer time and can be executed on a PC.

Applying classified spatial smoothing to the SPOT data raised the overall percent correct from 89 to 93 percent on one scene and from 74 to 77 percent on the other. For TM data there was a similar gain from 94 to 97 percent on one scene and 88 to 90 percent on the other. Percent correct improved in all 14 cases. Commission error improved in 12 out of 14 instances. Regression R-squares behaved similarly to the edge preserving smoothed data. Visual displays of the classified data were perceptively more pleasing as clutter was reduced. The results obtained with classified spatial smoothing are shown in the tables under the heading CSS. In addition, tests were made using classified spatial smoothing on data sets to which edge preserving smoothing had been applied. These results are shown in the tables under the heading EPS+CSS.

PRINCIPAL COMPONENTS

Each pixel is converted to a principal component pixel with the first n principal components being saved, where n is less than or equal to the dimensionality of the data. For multitemporal TM (14-channel) data, the first four principal components contain about 95 percent of the variation and the first six about 98.5 percent. The principal components then become the channels of a new data set. These channel values are scaled, shifted and rounded such that all transformed channel values are in the range 0 to 255. This manipulation results in a pseudo orthogonal data set with small values reappearing in the off diagonal elements. Classification results were disappointing as the R-squares dropped more than expected and were about the same as would be obtained by simply eliminating channels. Apparently the orthogonal transforms lose some of the separability information available in the individual channels. Full rank orthogonal data sets, those with the same dimensionality as the original data, also lost some of the separability. Due to these disappointing results, dimensionality reduction using principal components was not pursued further and results are not shown in the tables.

Nevertheless, a positive benefit did come from use of principal components. Generally, the training data for a cover contains some pixels, called outliers or bad pixels, which are obviously not related to the other pixels for that cover. This situation is usually due to minor errors in registering the segments to the remotely sensed data. Previously, these pixels were detected and then eliminated by looking at scattergram plots of various combinations of the channels. However, by using full rank principal components, all channels are considered simultaneously allowing immediate automatic deletion of all outliers. A pixel is retained if each principal component value is within x standard deviations. Choosing x anywhere between 3.0 and 4.0 gives approximately the same results. However, values of 2.5 and 4.5 showed the usual effects of over and under editing respectively.

TABLES OF RESULTS

The following tables summarize the results achieved for the various types of smoothing. First, the tables are shown for TM and then for SPOT. RAW means data on which no smoothing of any type was performed. CSS indicates classified spatial smoothing. EPS indicates edge preserving smoothing. EPS+CSS indicates both edge preserving and classified spatial smoothing.

R-squared (TM)

COVER	RAW	CSS	EPS	EPS+CSS
Soybeans	.92	.93	.98	.98
Cotton	.98	.98	.98	.98
Rice	.98	.98	.95	.95
Idle Crop	.96	.95	.95	.95
Woods	.92	.91	.99	.99
Waste	1.00	1.00	1.00	1.00
Other	.50	.52	.26	.27

Percent Correct (TM)

COVER	RAW	CSS	EPS	EPS+CSS
Soybeans	82	84	88	89
Cotton	87	90	87	88
Rice	90	92	95	96
IdleCrop	86	87	86	87
Waste	96	97	95	95
Woods	95	97	95	96
Other	91	92	91	91

Percent Commission Error (TM)

COVER	RAW	CSS	EPS	EPS+CSS
Soybeans	14	12	12	12
Cotton	5	5	5	5
Rice	9	8	10	10
IdleCrop	13	9	9	8
Waste	3	1	1	1
Woods	19	18	11	11
Other	34	21	40	37

R-squared (SPOT)

COVER	RAW	CSS	EPS	EPS+CSS
Soybeans	.83	.83	.88	.88
Cotton	.98	.98	.95	.95
Rice	.95	.95	.94	.94
IdleCrop	.85	.82	.91	.91
Waste	.97	.98	.99	.99
Woods	.92	.93	.96	.96
Other	.22	.26	.10	.11

Percent Correct (SPOT)

COVER	RAW	CSS	EPS	EPS+CSS
Soybeans	64	67	74	75
Cotton	78	81	67	69
Rice	88	91	92	93
IdleCrop	63	65	70	70
Waste	88	93	89	90
Woods	84	87	85	86
Other	80	84	86	87

Percent Commission Error (SPOT)

COVER	RAW	CSS	EPS	EPS+CSS
Soybeans	22	18	20	20
Cotton	9	9	8	8
Rice	20	17	16	15
IdleCrop	26	22	21	20
Waste	53	48	42	40
Wood	29	27	28	27
Other	69	64	71	70

CONCLUSIONS

Smoothing should be applied to TM and Spot data. Edge preserving smoothing is preferred over classified spatial smoothing because it gives better overall percent correct. If visual products are important, classified spatial smoothing should be applied in addition to edge preserving smoothing. Two iterations of edge preserving smoothing and one iteration of classified spatial smoothing is optimum in most cases.

Reduction of dimensionality through use of principal components was found to be undesirable. However, use of the principal component transform to delete outlying pixels was found to give approximately the same results as manual editing with considerably less work required and is recommended.

REFERENCES

[1] J.D. Allen and G.A. Hanuschak, The Remote Sensing Applications Program: 1980-1987, SRB Staff Report Number SRB-88-08, United States Department of Agriculture, Washington, DC, 1988.

[2] W.G. Cochran, Sampling Techniques, third edition, John WIley & Sons, New York, 1977.

[3] M. Ozga, "USDA/SRS Software for Landsat MSS-based Crop-Acreage Estimation", Proceedings of the IGARSS '85 Symposium, Amherst, Massachusetts, 1985, pp. 762-772.

[4] G. Angelici, R. Slye, and M. Ozga, "PEDITOR - A Portable Image Processing System", Proceedings of the IGARSS '86 Symposium, Zurich, Switzerland, 1986, pp. 265-269.

[5] G.H. Ball and D.J. Hall, "A Clustering Technique for Summarizing Multivariate Data", Behavioral Science, vol. 12, pp. 153-155, March, 1967.

[6] P.H. Swain, "Pattern Recognition: A Basis for Remote Sensing Data Analysis", Information Note 111572, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana, 1973.

[7] M. Nagao and T. Matsuyama, A Structural Analysis of Complex Aerial Photographs, Plenum Press, New York, 1980.

[8] J. Stakenborg, "Adaptive Filtering Using Spatial Features" Memoria Della Societa Astronomica Italiana, Report on the workshop on Advanced Image Processing for Astronomical and Planetological Applications, Vulcano, Italy. Istituto Di Astrofisica Spaziale, Frascati, Italy, 1985.

[9] J. Stakenborg, "Exploring the Spatial Domain", Proceedings of the IGARSS '87 Symposium, Ann Arbor, Michigan, 1987, pp. 125-130.

[10] J. Hill and J. Megier, 1987. "Cluster Based Segmentation of Multi-Temporal Thematic Mapper Data As Preparation Of Region-Based Agricultural Land-Cover Analysis", Proceedings of the IGARSS '87 Symposium, Ann Arbor, Michigan, 1987, pp. 91-96.