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ANALYSIS OF MULTIVARIABLE REMOTE SENSING DATA: ARE WE READY FOR LANDSAT-D?

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INTRODUCTION

Landsat-D, the fourth in the series of earth resources technology satellites sponsored by the National Aeronautics and Space Administration (NASA), is presently scheduled to be orbited some time in 1981. Aboard will be a multispectral scanning instrument called Thematic Mapper which has the potential to significantly improve our capability to map and monitor phenomena at and near the surface of our planet. Are we prepared to capitalize on this potential for improvement?

Let us consider what the design specifications of Thematic Mapper (TM) have to offer the remote sensing community.

* Areal resolution: The instantaneous field-of-view of TM is to be 900 square meters (except in the far-IR spectral band), roughly seven times better than the resolution of the Multispectral Scanner (MSS) aboard the preceding Landsats.

* Spectral coverage and resolution: The TM will measure reflected electromagnetic radiation is seven bands, including three in the visible

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region (MSS has two), one in the near-IR (MSS has two), two in the middle-IR (MSS has none) and one in the far-IR or thermal region (MSS has none). The spectral bands have been narrowed and carefully placed to provide maximal information about the ground cover observed, especially with regard to vegetation mapping applications [1,2].

* Measurement precision: The dynamic range and signal-to-noise ratio of TM are sufficient to support digitization of the TM data to 8-bit precision (256 levels) compared to six or seven bit precision for MSS.

* Most other parameters are roughly comparable to those of the preceding Landsat scanners.

These specifications mean that it will be possible to obtain much more detailed data about the earth's surface from periodic satellite observation than ever before. They also mean, however, that roughly ten times more data will be collected for a given ground area (accounting at once for ground resolution, spectral coverage and measurement precision) than were collected by the previous Landsats. We shall survey a number of issues this raises and assess current prospects for resolving them satisfactorily.

ISSUES AND PROSPECTS

To begin with, the ground stations intended to receive data from Landsat-D will have to be capable of handling the high data volume. This means that facilities driven to capacity by the present Landsat satellites will have to be upgraded if they are to receive TM data. Without minimizing some political issues which have been raised in this regard, it may be observed that this investment in scientific and technological advancement is expected to pay ample returns in terms of earth resources survey capabilities. These expectations are well-supported by research results obtained from lower-altitude and laboratory investigation. Research issue: Lossless data compression techniques for transmission and storage of multivariable image data.

The high dimensionality of the TM data (seven bands as compared to four for MSS) raises numerous technological issues. It has been found that false-color imagery generated from three of the four MSS spectral bands is readily interpretable by manual techniques and apparently conveys much of the information contained in the 4-band data. The capability to manually interpret data from the seven TM bands will in all likelihood depend on some yet-to-be-specified and rather ingenious means for producing imagery. Research issue:

interpretable display of highly multivariate image data.

Or, looking at the dimensionality problem from another viewpoint, it is clear, that computer-aided analysis will be even more essential for TM data than has been the case for MSS data [3]. This raises two new issues: how to maintain or improve the speed of processing by the computer in the face of the greatly increased data volume; and how to improve the ability of the computer to utilize more general features of the data (e.g., spatial and temporal variation characteristics of the scene).

The speed-of-processing issue can be addressed by building faster, more complex and sophisticated computers for processing multivariable image data. Research issue: development of parallel processing and other multiprocessing implementations of image processing algorithms [4]. Another approach is to develop dimensionality-reducing transformations of the data, probably of an applications-specific nature, so that with minimal loss of real information relative to the analysis problem at hand, the heavy computing can be performed on data of lower dimensionality [5]. For example, it is widely known that two linear combinations of the four Landsat spectral bands (sometimes simply a 2-band subset) are often sufficient for discriminating important ground cover types [6]. Using data now available from field research and airborne instrumentation, it would be possible to assess in advance of Landsat-D the necessary dimensionality of the data needed for specific applications and to estimate transformations for achieving the reduced dimensionality [7]. Research issue: determine the "intrinsic dimensionality" of TM data and dimensionality-reducing transformations for specific applications.

Some interesting approaches have been developed for using simple types of spatial information in computer analysis of remote sensing data. One of these [8] exploits the fact that "objects" in the scene tend to appear as spectrally homogeneous collections of picture elements (pixels). First, the scene is automatically segmented into these homogeneous regions; then each region as a whole is classified as to cover type. Despite the computational load imposed by the segmentation algorithm, if the objects in the scene generally consist of several pixels, the overall process can be much faster than classifying each pixel individually. Furthermore, since more information is used in each classifying decision, the accuracy of the classification can be much improved. Obviously, the improved spatial resolution of TM makes this approach very attractive. Research issue: formulate more general ways of utilizing spatial context, shape, and structure in deriving earth resources information from remote sensing image data.

Some serious problems related to the spatial nature of the image remain to be dealt with, however. One example is the "mixed pixel" problem, which arises when pixels overlap boundaries of objects. The improved spatial resolution of TM does not solve this problem, since boundaries on the ground will simply occupy more pixels and the boundaries of interesting objects smaller than ever before resolvable by Landsat-borne scanners will now have to be dealt with. Research issue: determine tractable strategies for solving or otherwise satisfactorily dealing with the mixed-pixel problem.

There are other significant issues which could be listed, but the sample addressed above will suffice to support the theme of this discussion.

CONCLUSION

Answering the question which titles this paper, we may conclude that perhaps we are not as ready now for Landsat-D as we might like to be. But approaches for solving many of the important problems have been identified. Whether we will be prepared two years hence to use the TM data to good advantage depends equally on the diligence of the remote sensing research and engineering community in pursuing solutions to the outstanding problems and on the willingness of the potential user community to support the needed research and development.

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