WARREN R. PHILIPSON
Cornell University
Ithaca, NY 14853

Problem-Solving with Remote Sensing

A framework of questions and significant points is outlined to assist those who must decide if and how a particular problem should be approached with remote sensing.

ABSTRACT: *The "Remote Sensing Task" is to collect, analyze, and convert remotely sensed data to information, for problem-solving or decision-making. Approaches to completing this task are numerous, especially in the data analysis stage. In this discussion, a framework of questions and significant points is outlined to assist those who must decide if and how a particular problem should be approached with remote sensing.*

INTRODUCTION

At times over the past decade, with the increased use of aircraft and, especially, satellite scanners, there has been an oversell—or, at least, overuse—of digital image analysis. This is expected and even healthy, given a new technology. On the other hand, whether due to their lack of equipment or expertise, or because of their realization of the limitations of digital image analysis, many in the remote sensing community have overemphasized non-digital, or manual, analysis techniques. At this time, when the dust should have settled and an understanding of the appropriateness of computer versus non-computer approaches might be expected, it is still too common to find that the "wrong" approach has been taken. A related but more fundamental problem is the widespread lack of appreciation regarding what the different approaches can accomplish.

The intent of this discussion is to review problem-solving with remote sensing and to suggest a framework for weighing the alternatives *before* deciding *if* and *how* a particular problem should be approached with remote sensing.

THE APPROPRIATENESS OF REMOTE SENSING

Remote sensing generally involves data collection, analysis, and interpretation; i.e., collecting data (e.g., images) with sensors from airborne or satellite platforms, processing and analyzing the data, and converting the data to information. The "Remote Sensing Task" is to complete these steps. As with any task, its completion can be approached in an efficient, cost-effective manner or in an inefficient, cost-ineffective manner.

The aim of remote sensing is to learn more or to learn more efficiently; to produce information which can be applied in decision-making or problem-solving. In other words, the remote sensing task is seldom the actual or ultimate problem in need of a solution. Completing the remote sensing task produces information for solving one or more other problems. For example, completing a land-use inventory with remotely sensed data produces land-use information for decision-making, it does not produce decisions. This being the case, three questions should be addressed before delving too deeply into the application of remote sensing to a given problem.

(1) Is there some legal or other reason why information derived through remote sensing would be invalid for this problem? This seemingly obvious point is occasionally overlooked.

(2) Is there justification for applying remote sensing or any new method to the problem? In that economics often dictates need, this question may not be answerable at this stage.

(3) Is there *any* chance that remote sensing can provide information that will assist in solving the problem? Because the answer to this question is

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based on experience, it is difficult to generalize. The analyst's experience in the problem's discipline is at least as important as his or her remote sensing experience. If confronted with a forestry problem, for example, a remote sensing analyst with a forestry background should respond better than an engineering photo interpreter or a computer data analyst. In contrast, the forester may respond poorly to a soil or geologic problem.

Completing the Remote Sensing Task

If it is decided that information that might be derivable through remote sensing could be useful, the analyst should determine the most expeditious and cost-effective approach for completing the remote sensing task. This will require problem definition and responses to the following questions:

- What are the targets (i.e., objects, keys, indicators)?
- What level of interpretation is needed?
- How can the targets be sensed?
- What are the available resources and required data?

Although these questions and their responses are highly interdependent, they will be reviewed in the order listed.

Question 1. What are the targets?

Determining exactly what must be sensed in order to complete the remote sensing task is critical and often the most difficult step. For example, assessing water quality usually involves sensing water color; assessing stressed vegetation may involve sensing spectral or spatial (morphologic) anomalies; assessing an area's mineral or ground water potential may involve sensing for geologic linears; and assessing the depth of soil over bedrock involves an analysis of landforms as well as gullies and other targets or keys.

Question 2. What level of interpretation is needed?

This relates to the level of abstraction of the remote sensing task. It refers to the number or "length" of linkages between that which is observed directly and that which is interpreted—in essence, image identification versus image interpretation. To illustrate, there are fewer linkages in identifying a target as a building than in interpreting the building's use (land cover versus land use). Similarly, identifying a specific drainage pattern (e.g., dendritic) involves substantially fewer interpretive linkages than recognizing a landform (e.g., granite), where drainage pattern, topography, and several other keys must be identified and synthesized.

Question 3. How can the targets be sensed?

In order to match the targets with remotely sensed data, the task and targets should be defined in terms of their remote sensing constraints—their spatial, spectral, and temporal characteristics.

What spatial resolution is required for sensing the targets? This usually can be determined from the task. For example, how large are the fields to be analyzed? What is the smallest part of the building that must be identified before the building's use can be interpreted?

What spectral resolution and spectral sensitivity are required? These will often require field sampling or judgment. Human visual response will indicate how "blue" lakes can be distinguished spectrally from "green" lakes, or how "green" lakes can be ranked spectrally; but the selection of spectral bands for separating different agricultural crops might not be so easily done. Spectral reflectance data from the literature may be inadequate, and atmospheric effects might negate the information they do provide.

What diurnal, seasonal, or annual changes might influence target recognition? Certain of these will be expected and taken into account (e.g., collecting thermal data at night to reduce solar effects); other temporal characteristics might not be known in detail (e.g., changes in a crop's spectral reflectance during its growth cycle). Notably, target recognition may be affected negatively or positively by solar altitude, snow cover, or other temporal factors. Further, the remote sensing task may actually require or rely on the detection of change (e.g., monitoring land use, flooding, or shorelines; differentiating crops by their growth patterns).

Question 4. What are the available resources and required data?

The final element to be examined before adopting an approach relates primarily to the cost of completing the remote sensing task as compared with the value of the information derived. The available resources—equipment, facilities, personnel, expertise, and funds—will depend on the organization, user, or client. As is obvious, the lack of computer facilities, coupled with the lack of funds for purchasing or contracting for computer capabilities, will restrict the approach to one or more manual methods. Conversely, easy access to computer facilities or specialized image analysis equipment will likely favor their use.

The available remotely sensed data will normally include satellite imagery and at least one date and scale of aircraft photographic coverage. Auxiliary data, such as soil or geologic reports and topographic maps, will be variable in terms of existence, accessibility, and reliability.

The analyst must eventually decide whether the remotely sensed and auxiliary data will suffice or whether new data are required. Because data needs vary with the task and circumstances, the analyst might characterize the informational value of any known or possible existing data as essential (e.g., change analysis problems), of interest and irreplaceable by new data, of interest but replaceable by new data, or of little or no value. Under certain circumstances, the acquisition of new data might actually cost less than the inventory and acquisition of existing data.

Adopting the Best Approach

Everything must now be brought together and decisions made. Although emphasis is placed on completing the remote sensing task, synthesis of the questions and responses must provide positive reinforcement to the earliest, tentative decision that useful information can be derived through remote sensing.

The "best" approach to completing the remote sensing task will be judged in the context of the task, the available resources, and the available or acquirable data. Based only on the costs for labor, for example, it is probable that the best approach to a particular task would frequently differ from a lesser developed country to a more developed country, or from a university to a remote sensing company.

Although the best approach cannot be defined without first defining all parameters, several fundamental points concerning the adoption of a remote sensing approach are listed, as follows:

Point 1. In general, the need for a human interpreter increases as the required level of interpretation—the number or length of linkages—increases.

Although computer interactive (man-machine) analyses can extend the interpretive capacity beyond that of a human interpreter, purely automatic recognition is usually limited to one level of abstraction, most commonly, spectral recognition.

Point 2. Spectral analyses and related computer approaches are quite valuable when seeking surface information, but they are often of little or no real value when seeking subsurface information.

This is a major dichotomy in remote sensing: surface versus subsurface information. Spectral analyses are most valuable for remote sensing tasks that involve the low levels of abstraction associated with recognizing directly observed surface targets, such as vegetation or water. In contrast, sensing for subsurface information usually requires synthesis of several surface indicators and can thus be accomplished best by a human interpreter. For these cases, spectral analyses are normally of secondary value. The primary exceptions to this rule are sensing of geologic linears, exposed rock, or exposed soil. But because these activities are in fact limited to recognizing directly observed targets, they are categorized better with surface than with subsurface information.

Point 3. As the required spatial resolution and spectral sensitivity approach the limits of the sensor, the need for utilizing the original remotely sensed data increases.

When dealing with data collected by "digital scanners," such as those on the Landsat satellites, substantially higher spatial resolution and spectral sensitivity will be afforded by the digital data (computer-compatible tapes) than by the derived images. Similarly, when dealing with photographic products from aerial cameras, the original negative or reversal photograph will offer the highest spatial resolution and the best product from which to assess or enhance spectral differences.

Working with density slicers or data derived from digitizing the original image or photograph are potentially effective techniques for enhancing spectral differences, though spatial resolution will normally be reduced. If the original image or photograph is not available for slicing or digitizing, the more closely derived the analyzed product is from the original the better.

Point 4. In general, a remote sensing approach cannot produce results of some specified reliability and geometric accuracy unless *all* input data are at least of that reliability and accuracy.

Pixel accuracy in the remotely sensed data does not ensure pixel-level accuracy in the results. Too commonly, the accuracy preserved or produced by the method of data analysis receives its due attention, while the reliability and geometric accuracy of the auxiliary data are overlooked.

To illustrate, questions concerning the reliability of the results might arise when data from different sources are combined. Images, soil maps, geologic maps, and other data are normally of different reliabilities as well as different scales. Their derived "composite," however useful, should not be rated as reliable as the best of the input data.

Similarly, questions concerning geometric accuracy might arise when a solution ends with relative rather than absolute orientation. Merging multi-date images to within one or two pixels demonstrates that two data sets can be distorted or resampled to fit one another—an important first step. In order to make statements regarding ground distances, however, these data sets must be referenced to ground control.

Point 5. The costs of data and data analysis should be justified and kept to a minimum.

The analyst should collect enough data to ensure that the immediate and foreseeable tasks can be completed. Additional data might also be collected for "unforeseen" or unrelated problems, but only if the costs are not excessive. This might relate to collecting aerial photography over targets of opportunity, or collecting data in all channels of a multispectral scanner instead of just one—given that the other channels need not be processed.

It follows from Points 3 and 4 that the analyst should adopt the least expensive method of data analysis that is compatible with the reliability and accuracy of the data, while still being capable of producing the desired results. The range of questions that might be considered includes:

- If processing of digital data is deemed necessary because of resolution, spectral sensitivity, desired enhancements, or simply because of the large amount of data, is interactive processing required or can bulk processing achieve acceptable results at a lower total cost?
- If the required spatial resolution and spectral sensitivity are achievable with imagery derived from digital scanners, is there justification for processing the digital data?
- If aerial photographs can be applied successfully in place of more costly sensor data (e.g., scanners or radars), can the collection and analysis of these other data types be justified?
- If black-and-white or small format photography can be applied successfully in place of color or larger format photography, can the latter be justified?

As a final step before implementing the "best" remote sensing approach, the analyst should decide if even this approach is unacceptable (e.g., too costly). Should the remote sensing task be restated, perhaps at a different level of abstraction, or should a non-remote sensing approach be considered?

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ERRATA

The following changes should be made to the September, 1984 issue of PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING:

The Photogrammetric Pioneers article about J. Victor Dallin appearing on page 1285 was written by Harry Tubis.

To the list of Officers and Board members, 1934-1983 beginning on page 1361, add the name Robert D. Baker, who served as Director from 1975-1977, and the name Joseph E. Steakley should read Joe E. Steakley.

To the list of Annual and Semi-Annual Meeting Directors appearing on page 1369, add the following: the 1968 Semi-Annual Meeting was directed by Edward D. Speakmen and the 1979 Semi-Annual Meeting was directed by Fredericka A. Simon, not Robert G. Reeves as the list says.