

Image Interpretation Concerns for the 1990s and Lessons from the Past

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ABSTRACT: This paper reviews some classical concepts of image interpretation introduced in the 1960s and early 1970s and relates them to the Landsat MSS era. This period was characterized by attempts to do automated image interpretation using a variety of image classification tools. The difficulties found in such approaches are identified and compared to those associated with methods that are still evolving for use with the higher resolution outputs of the newer sensors such as the SPOT HRV or airborne MEIS solid state scanner. The paper concludes with an assessment of the future direction of image interpretation.

INTRODUCTION

AIR PHOTO INTERPRETATION or image interpretation, for resource data collection became an area for academic study after World War II. The earliest paper known to this author was dated 1927 (Neblette). One might use that date to mark the beginning of the field. Others might cite the publishing of the comprehensive *Manual of Photographic Interpretation* (Colwell, 1960). Some might date the beginning with papers by Vink (1964), Chevallier (1966), or Clos-Arceud (1966). In any case, the historical development of image interpretation has seen researchers moving toward obtaining more information, more accurately, from more sophisticated sensors, for a broader range of problems.

The basic premise of this paper is that recently there has been too little attention paid to rigorous, visually-based image interpretation. This in turn should lead us to be concerned about our ability to properly use the imagery available to us from TM (USGS and NOAA, 1984), SPOT (Chevrel *et al.*, 1981), and the more sophisticated airborne scanners such as MEIS-II (Till, 1987) as well as the imagery that will flow from the systems envisioned for the 1990s such as RADARSAT (Ryerson, 1987). Many of the difficulties envisioned by Philipson (1980; 1986) can be found in work that, for example, results in land-use maps derived from digital image classification with Landsat data (see summary in Ryerson *et al.*, 1982) with accuracies lower than the standards set for such maps (Clawson, 1965).

This paper provides a review of some of the early ideas on image interpretation, discusses some negative influences of the very successful (and useful) Landsat MSS, and outlines the relationship among the new sensor outputs, classical image interpretation, and the analysis tools. The paper closes with a look to the future.

CLASSICAL IMAGE INTERPRETATION

Colwell (1960) defined photo interpretation (hereafter, the term "image interpretation" will be used) as "the act of examining photographic images for the purpose of identifying objects and judging their significance." He also defined the term "photo-reading," which was taken to be a more elementary form of image interpretation. While these definitions are useful for those beginning to interpret images, it is too simplistic and is not closely enough related to the nature of images to be useful as a conceptual basis for an image-interpretation paradigm.

A more useful definition of image interpretation was proposed by Chevallier (1966; I-7) as "the science of forms and structures, their functions, and their genesis in a two-dimensional space." (Translated by the present author.) With such a

framework, one can begin to approach an image in a more rigorous and scientific fashion. This concept has been widely used by those with a more "mathematical orientation" (we would now refer to them as users of digital image analysis). However, viewing images in such a rigorous fashion appears to have had little impact on those doing visual interpretation, but for several notable exceptions (e.g., Sequin and Ryerson, 1987; Colwell and Poulton, 1985; Gregory and Moore, 1986; Philipson, 1980; Philipson, 1986.)

Vink (1964) did offer a useful analysis of the process involved in the interpretation of images. He identified six kinds of interpretation: detection, recognition and identification, analysis, deduction, classification, and idealization. Six factors which influence the kind of interpretation were given as follows:

- the person executing the interpretation,
- the purpose for which he makes the interpretation,
- the kind of photographs available,
- the kind of instruments available,
- the scale and other requirements of the map, and
- external knowledge available and any other sensory surveys which have been or will be made within the same project.

For Vink, detection related to the visibility of an object. Recognition implied not only detecting an object, but also identifying its nature. Recognition and identification were equated to photo-reading. Analysis involved delineating like groups of objects, while deduction was a more complex process based on converging evidence leading to conclusions about features not themselves evident on an image. (For example, in the case of geology, deriving information about subsurface features based on converging evidence visible at the surface.) Classification includes descriptions resulting from analysis and categorization of surfaces into meaningful groups. Idealization is drawing a line to represent what is seen in the image. The image is the first abstraction from the real world, while the line is the second abstraction, albeit one filtered through the interpreter.

The descriptions and definitions given, while useful in understanding image interpretation, do not provide an explanation of the process. Obviously, for simple interpretation such as Vink's (1964) detection, this is not a concern. However, as one moves to more complex forms of interpretation, attempting to elicit more information from an image, the process becomes greatly complicated. One of the major problems is the level of knowledge required of the interpreter to render an adequate interpretation. A second difficulty is the procedural framework, or lack of it, usually found in the interpretation process. This results in a lack of consistency in the results of interpretations. The lack of consistency is not surprising given the standard criteria used to guide an interpretation. The factors usually used

include tone or brightness, color, texture, pattern, shape, size, shadow, and context. Except for color and tone or brightness, none of these is particularly well suited to the type of quantitative analysis with which one associates repeatability in interpretation.

An earlier study (Ryerson, 1975) presented a refined concept of a photo-interpretation key in an attempt to lead to more consistency in visual interpretation. The suggested approach called for a thorough analysis of how the resource system about which information was to be derived was spatially manifested. This was done in order to develop a systematic framework designed to establish the identity of certain objects to the exclusion of others using information specific to how objects appear on a given image. The resulting key is simply a series of questions asked "of the image" by the interpreter. The answers to these questions logically lead down a path at whose end there is an unequivocal answer as to the nature of the object in the image in terms related to the system under study and the information required about it. While others have developed useful keys (e.g., Philipson and Liang, 1982), there have been few studies of the process of building keys. The proper application of such an interpretation key developed by an expert allows a less experienced interpreter to do an interpretation using the knowledge base of the individual who created the key. This is also consistent with, but goes beyond, the first report of Commission VII of the International Society of Photogrammetry (1952).

One often overlooked part of the analysis of the resource system to build keys is the clear definition of the type and accuracy of information actually required about that system. For example, Ryerson *et al.* (1982) cited many studies dealing with mapping or detecting change in land use from satellite remote sensing using digital methods. All of these presented results with accuracies far below the 95 percent commonly held to be the standard for such maps in the benchmark publication by Clawson (1965). Indeed, but for a few studies (Gregory and Moore 1986; Aronoff, 1982a, 1982b, 1985), many involved in the remote sensing field seem either to be not interested in the accuracy of their interpretations, or to have developed sophisticated methods for overcoming inaccuracies to produce meaningful statistics, if not maps (Hanuschak *et al.*, 1980).

A thorough understanding of whatever system is under study, be it agriculture, forestry, or urban, is required to develop a key and to decide whether or not one may use image interpretation to derive either maps or statistics. The following section examines the use of Landsat MSS in the context of the approaches to, and the historical development of, image interpretation as outlined above.

LANDSAT MSS

Landsat MSS provided both an opportunity and a problem for the image-interpretation community. The fact that the data have very coarse spatial resolution compared to aerial photography caused several difficulties. First, this meant that only two of the eight criteria used in image interpretation, color and brightness, were truly meaningful for many of the types of interpretations that had become common with, for example, color and color-infrared aerial photography. With the coarse spatial resolution, there was an attendant increased reliance on spectral information, virtually to the exclusion of the other interpretative criteria noted above. This has had serious ramifications in terms of image interpretation. These ramifications are discussed below.

The first problem concerned the application of the concept of spectral "signature" with Landsat MSS data. Like-objects were assumed to have like spectral responses, or signatures. This concept may be useful in certain limited cases, such as for identifying specific features like certain land-cover or crop types in localized areas. However, this approach was not suited for gen-

eral application to MSS data. The problems associated with this concept were compounded by those who evaluated and often championed the method. All too frequently the tests were done using idealized environments such as the same uniform agricultural test fields or localized test sites (representing small geographic areas) that were used to generate the crop signatures used in classification (e.g., Mack *et al.*, 1975); and results which were not universal in their application were treated otherwise. A second problem, related to the first, saw the application of methods more appropriate for the identification of single features or a single class of feature, such as one particular land-cover class, to multiple features or classes of features within the same image. A common example of this is the application of the image classification to derive thematic maps of general land use. The problem with such maps is that the accuracies associated with different classes are often highly variable (e.g., Walker and Acevedo, 1987).

It should not be surprising that large volume use and general acceptance of MSS by the client community never materialized. Many of the proposed applications were as simplistic (and naive) as those from a generation ago who sought to operationally extract information from black-and-white air photographs using spot densitometers.

Landsat MSS did help to prepare us for some of the challenges associated with higher resolution satellite data, because it gave us a new and broader perspective of our world. It has also given us experience in handling large volumes of digital imagery. However, it has also sidetracked many of us for a decade from the search for a workable image interpretation paradigm, and has left us with a number of practical problems as we approach the 1990s.

These problems relate to the digital image analysis systems developed, how those systems are being used, the conceptual basis of the analysis being attempted, the results of these, and how these results have been interpreted by the user community.

The digital image analysis systems first made commercially available, such as the Image 100 (Economy *et al.*, 1974), were based on simplistic parallelepiped spectral classification algorithms. Moreover, the systems were neither user-friendly nor particularly useful for processing large volumes of digital image data, given their fixed 512-by 512-pixel loading format. These limitations become even more severe with the availability of higher resolution data from TM, SPOT, and airborne sensors.

Despite their limitations, there was a proliferation of image analysis systems based on simplistic algorithms. The proliferation occurred, at least in part, because of the hope that technologically complex digital analysis would unlock useful information unavailable from the MSS image products. Digital data were used successfully by some. For example, Brown *et al.* (1983) used digital data to derive a linear contrast stretch image suitable for visual interpretation. However, few have consulted users concerning their accuracy requirements in the development of applications for digital image analyses.

The typical approach — the one that seems to have developed for applications work with MSS — involved obtaining an image, often without benefit of ground data, to try to elicit as much information using the classification algorithms available on the particular system being used. These algorithms have generally fallen into two classes — those which rely on the supervision of the operator and those which are unsupervised. The image statistics and the suitability of the particular algorithm were rarely questioned. In any case, both methods usually result in colorful maps based more often on convenient or possible separations than on useful ones. All too often, applications research in remote sensing has not been driven by the practical information

needs of a user, or by a basic investigation of the information content of an image. In spite of these limitations, some very useful and practical work has been done by groups using a variety of methods (e.g., Gregory and Moore, 1986; Dobbins *et al.*, 1983; Brown *et al.*, 1983). As well, as noted above, there have been some useful methodological statements and assessments (Philipson, 1980 and 1986).

In most work with MSS, keys have not been used, and likely could not be used, because of the limited spatial information in an image. As well, human interaction with the images in Vink's terms of classification and idealization was rarely considered, and even then was limited by the hardware and software available. It should be noted, however, that the role of Geographic Information Systems (GIS) as a source of information for analysis and a recipient for results of analyses has long been recognized and even functional to a limited degree (Gierman *et al.*, 1975).

The results were predictable. There has been little recent progress toward the development of an interpretation paradigm. There has been widespread disillusionment in the user community concerning the value of satellite data to collect resource information, partly as a result of the early oversell of ERTS data. Perhaps worse, we have not adequately prepared ourselves for the challenges brought by the new higher spatial and spectral resolution sensors, despite thorough analyses of simulations and early TM data (e.g., Ahern *et al.*, 1981; Crist, 1984). Similarly, calls to integrate GIS and artificial intelligence into remote sensing analysis have just begun to be heeded.

THE NEW GENERATION OF SENSORS AND ANALYSIS TOOLS

The new generation of sensors, including Landsat TM, SPOT, and various high-resolution airborne sensors like MEIS (Till, 1987), have more in common with color infrared aerial photographs for interpretation than with Landsat MSS. A detailed comparison of the characteristics of the various image types in terms related to how they are interpreted should support this contention.

Data acquired by the new sensors all have significant spatial variability, which leads to the usefulness of the more complex interpretation criteria used with aerial photographs and discussed above. Furthermore, spectral classification with higher spatial and spectral resolution image types is prone to error as within-class variance becomes significant relative to between-class variance (Crist, 1984).

With the new data sources there are also more complex (compared to MSS) concerns about proper image-production techniques and corrections for errors inherent in the sensor system. There is a much greater possibility of creating lower quality images because of the number and characteristics of the new bands available, their radiometric sensitivity, and the use of new and not generally well understood specialized enhancements with specific but limited applications (Murphy *et al.*, 1984; Ahern and Sirois, 1989). In addition, geometric corrections may now be made more precisely because of the spatial resolution and the attention paid to the need for precise navigation information (Guertin *et al.*, 1985).

To handle these new data sources, there must be changes in the analysis systems. Systems must be able to take into account the requirements of visual interpretation, include artificial intelligence or expert systems, and integrate GIS. Some systems are available that can so treat photographic renditions of satellite data. For example, the PROCOM (Gregory and Moore, 1986) projects high quality images onto a map base for visual interpretation not unlike that used for aerial photography. However, there should also be an alternative that can use primary, or digital, data.

Recent advances in microcomputer based image analysis sys-

tems offer hope for those whose requirements may be better met through the use of digital data. The area which can be displayed and analyzed at one time remains small with such systems. The high resolution and consequent fine detail of the sensor outputs is such that it is becoming increasingly likely that the size of area a user will be able to study at any one time will also be small. As well, if GISs provide ancillary data and serve as the destination for an interpretation, it seems logical to assume that smaller areas can and will be acceptable as the basis of interpretation. It should be noted, however, that a fast refresh of the display will be necessary to provide a rapid overview of the region being studied. One will simply do an interpretation for an area, review it in the larger context, and, when done, send it to the data base—not unlike using a microcomputer word processing system to store a large document one page at a time.

The focus, then, must be on systems that are at the same time user friendly and GIS compatible. Such systems must be characterized by all of the ease associated with manipulation of hard copy images and maps, including overview, overlay, local area registration, and easy recognition and correction of minor geometric discrepancies. A user-friendly system will be able to change color/band assignments and do selective enhancements quickly and easily, allow lines to be drawn and corrected with a minimum of effort, and do simple spatial filtering and pattern recognition. It will also be able to extract information from a GIS, overlay it on an image, update the data, and return it to the GIS. It is assumed that most future analyses on these small systems will also use imagery corrected to the geometry of the user's data base. An alternative may be to temporarily warp the map information to the uncorrected image, extract or edit, and then return changes to the map base through a reverse transformation. While the systems will not likely be used to do computationally demanding transformations, such temporary warping of a map often involves data volumes low enough to be done "on the fly" at the time of display.

One problem of interest to the user and of vital concern to the manufacturer of these systems is the development costs. Such systems in the past, based on minicomputers, have been expensive, with fairly large margins, and only a few sales were required to recoup development costs. With micro systems the margins are smaller, problems of piracy greater, and the market is fragmented among a larger number of vendors. This leads to the question of whether the market place will be able to provide the incentive to produce what is needed in the future? This author's response is an unqualified "Yes." We are already well on the way, if we consider the problems of the future in terms familiar from the past.

A LOOK TO THE FUTURE

- The view to the future appears clear in some respects, while perhaps more murky in others.
- Expert system shells will be used to help develop visual image interpretation procedures analogous to the keys of the past.
- These procedures will include the integration of information held in GISs to assist in the image interpretation
- The image interpretation will rely on the interpretation criteria of tone or color, brightness, shape, texture, pattern, size, shadow, height, and context. It will remain difficult to quantify most of these criteria, and visual interpretation will become a central element in the information extraction process.
- Microcomputer-based GIS or image-analysis systems will be used for doing interpretations, as will systems based on photographic products.
- Interpretation results will likely be sent to a GIS as an update.
- The GIS used for interpretation may or may not be the same GIS that is updated.
- The users will include much smaller organizations than those who currently are involved in the field of remote sensing and GIS.

- A significant service industry will develop to meet the needs of users of clients whose requirements are not large enough to warrant the development of in-house capabilities.

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