Some Aspects of Remote Sensing Research*

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Introduction

Much of the discussion in yesterday's presentations was concerned with the operational activities using existing remote sensing techniques. My assignment is to focus on research and development which will lead to the capabilities for our future systems. However, first, some general orientation is in order.

What will an Earth Resources Observation System look like? The major components in the hardware portion of the system may be diagrammed as shown in Figure 1 (see Figure 1 of Reference 1). There must, of course, be a sensor system which views the earth, but it must be kept in mind that the surfaces of the earth itself are part of the system as is the intervening atmosphere.

There will necessarily be some additional processing activities that must take place on board the sensor platform. These may include data calibration, the merging of ephemeral information, analog to digital conversion and the like. Next in the system, data return is also required. This may be provided by a telemetry system in the case of an unmanned sensor platform.

On the ground, there is always a need for some preliminary pre-processing followed by the application of one or more data-reduction algorithms. Finally, here we include a block to indicate the consumption by the user of the information thus generated.

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There are a few additional parts of this diagram which are of interest. First, regarding this matter of data as compared to information, we emphasize that the two terms are not synonymous. However, the line of distinction between them is not always clearly defined. In the system of Figure 1 data "presumable" becomes "information" in the data reduction block; however, one man's information may be another man's data. For example, a photograph, i.e. an image, may make information immediately available to a human interpreter, however, the same image can only be data in a machine-oriented information system. This lack of conciseness is part of the problem that we now have in seeing what the uses for these kinds of systems will be. It is a matter of succinctly focusing on specific problems.

Another point is that the interface between data reduction and information consumption is particularly difficult. At this point in the system there is an interface between people of different backgrounds, different disciplines. Here, the information consumer is standing on one side of the interface saying, "I believe in your capabilities to generate information, Mr. Engineer, but what, specifically, can you give me that will do me any good?" On the other side of the interface we have the engineer saying, "I believe in your need for information, Mr. Consumer, but what, specifically, do you want?" They keep asking these questions, never getting answers. This is a factor in why so much collected data is not being used. Somehow they must be brought together and this stagnation circle broken down. Again, it would seem that the answer is to focus on specific problems.

The Dichotomy of System Types

We turn now to the examination of such systems from an entirely different viewpoint. In some cases, the dichotomy is rather subtle, in some cases rather obvious; nevertheless it is there.

There are two basic kinds of systems, those which are pictorially oriented and those which are numerically oriented. This dichotomy can often be seen in the manner in which sensors are chosen or designed. For example, a photographic camera basically is a sensor well suited for pictorially oriented systems. The images produced are rich in spatial resolution and detail. These are characteristics important to a pictorially oriented system.

The dichotomy will also often show up in the manner in which data is transmitted or preprocessed. In ERTS, for example, there are two sensor systems, a TV system and a scanner. In the telemetry of these two, the TV system uses analog telemetry signals, an approach which is better suited for providing high quality imagery back on the earth. For the multispectral scanner system on the other hand, a digital telemetry system was chosen so as to preserve the very large dynamic range in the data which such a sensor system can provide. This is important for a numerically oriented system.

Perhaps the most obvious indication of the dichotomy is in the type of analysis to be used on the data. The typical (though not the only) way in which data in a pictorially oriented system is analyzed is through photointerpretation. In the case of numerically oriented systems, it is customarily done by machine or manually aided machine operations.

Though a useful viewpoint, the dichotomy is not complete in that one can certainly have useful numerical information coming from a sensor system designed for pictorial purposes, and vice versa.

A few illustrations using actual data may serve to help at this point. Figure 2 (unpublished figure) shows an air photo of an agricultural scene.

It was taken as a part of a corn blight study done during the latter part of the last growing season in the Corn Belt. Several corn fields can be seen in this figure. One at the very bottom shows there is a moderate degree of infestation, another in which there is almost no blight at all, others in which the infestation is very severe.

Much more sophisticated photo-interpretative and photogrammetric techniques can be brought to bear, but it is apparent from this kind of analysis that a considerable amount of subjective information can be produced in addition to objective measures. For example, it would be possible to measure the area of various fields; however, it can also be immediately seen from the photo that there is a sand dune condition present and that it manifests itself in the crop.

Numerically oriented systems tend to have different capabilities. Figure 3 (unpublished figure) shows a computer printout of the analysis of data from the same general area in which resolution elements have been individually classified by machine as to the crop type and further, in the case of corn, the degree of infestation of blight. The large letters on the imagery indicate the crop type present as determined by ground checking; "c" for corn, "s" for soybeans, etc. The numbers on the corn fields indicate the degree of infestation on a scale of 1-6, 1 being no infestation and 6 being a case where the crop has been completely destroyed.

The small numbers printed by machine are the result of the machine decision as to the degree of infestation on the same scale of 1-6.

The point here is that a numerically oriented system can perhaps provide ready access to a different type of information than one can obtain readily from a pictorially oriented system.

Soil mapping has been done for some time on the ground and more recently aided by aerial photography. Figure 4 (unpublished figure) shows a machine-generated soil map indicating the percent of clay content in the soil. A conventionally drawn soil map is provided for comparison. In this case, the numerically oriented system provides a speeding of the overall generation of the soil map by merely objectively marking a specific boundary between soil types when the soil type may only be gradually changing from one to the other.

A final illustration will be given using photographic data gathered by Apollo 9. Figure 5 (see Reference 2) shows a color infrared frame of the Imperial Valley as seen from the Apollo 9 spacecraft. A computer printout of the data is shown on the right. The small square outlined in the printout is shown to full resolution in Figure 6 (see Reference 2). The portion of this figure inside the dotted lines was analyzed by machine and a printout obtained of the analysis results. This printout is shown in Figure 7 (see Reference 2). The classes used here are relatively simple as seen in the figure. Other analysis of this data has indicated a more detailed classification is possible by these means.

These examples are provided to show the range of applications for numerically oriented systems. Returning to the concept of the dichotomy of systems types and to investigate some of the characteristics of the two. Figure 8 summarized some of the major characterizing factors of these two types of systems at present. In the case of the pictorially oriented system, there is certainly a well developed technology in the U. S. today. This is not to say that further development is not in order and taking place, but these types of systems have been in both military and civilian use for some time on an operational basis.

This same degree of development may or may not exist in any given developing nation. It is further important to note that a pictorially oriented system is generally easily acceptable to the layman and the neophyte in that seeing the data in image form he can more readily understand that information is available in an accurate and useful fashion.

One of the advantages of this type of system is that it is well suited for producing subjective information. Also, relatively simple systems are possible and indeed very effective. On the other hand, large-scale surveys tend to be relatively difficult to carry out. This is because a large quantity of data (imagery) is needed and a large number of people capable of analyzing the imagery is required.

Now, in comparison, the technology for numerically oriented systems is much newer and not yet well developed. Further, since the techniques rely upon abstract principles, this approach tends to be less readily acceptable to laymen.

Numerically oriented systems are well suited for producing objective information from data and because of the possibility of machine processing or machine aided processing large-scale surveys will become feasible by these means. The systems necessary to carry them out, however, tend to be relatively complex.

We turn now to some specific comments on the essential characteristics of remote sensing research itself. These have a direct bearing on the international scene with regard to remote sensing. These characteristics are summarized in Figure 9.

First, remote sensing research is or should be both multi- and interdisciplinary. The distinction between these two terms is to be emphasized.

Progress toward useful systems never comes as fast if one has the users or applications scientists on one hand studying remote sensing and the remote technologists continuing their studies on the other without a close interrelationship. This is the same interface referred to earlier regarding the consumption of information. Thus, the term multi-disciplinary means that all disciplines must be represented and the term inter-disciplinary, that they must function together.

In the applications area, research is more efficiently done on a local basis. This is true, at least in part, because it is easier to focus on a specific problem when one is near it. Thus, it appears desirable to conduct applications research near its point of application and to conduct research toward advancing technology at technology centers. However, it is necessary for this close working relationship to develop at a single location.

Where does all of this lead us? Several points of conclusion are summarized in Figure 10. First, there must exist well-understood long term research objectives less the research done and the knowledge gained be inefficiently and uneconomically achieved.

Second, research and education are an inseparable pair. The intent, indeed the necessity, here is to use the new technology while it evolves. As a matter of fact, we sometimes stumble in attempting to use experimental data gathering and processing systems for operational purposes. We must fasten the educational activities closely to the research in order that this transfer can take place rapidly.

It is reasonable that the basic studies and development of technology can be best done in this country. Specific studies should be pursued in the developing nations for their applications as well as in this country for U. S. applications. This is desirable partly for reasons of education and partly for reasons of the need to do the research on a local basis.

In the development of technology particularly, we still have some distance to go in understanding the dichotomy of system types. There is still some tendency to judge one type of system within a context more appropriately suited for the other. There is also some tendency to consider the two types as being in competition.

At any rate it is most important that we break down the barrier which exists between the users and the technology developers (remote sensing engineers). This can best be done by focusing on specific problems.

In this respect it will be necessary to judge how useful the capability to remotely sense data will ultimately become. If it appears that it will be a broadly useful capability with wide applicability, then it behooves us not to attempt to solve all things at once.

Finally, with regard to the manner in which the remote sensing community of this country communicates with foreign countries, the message of Figure 11 seems to be a desirable approach. Since the complete technology of remote sensing does not yet exist, let alone the knowledge of how to apply it, it is a mistake to think that we know and can therefore show foreign nations how to achieve these advantages. Rather, cooperative programs in which we cooperatively learn and teach one another seems much more appropriate.

Not only will this lead to a maximum rate of development in the foreign nations, but it has a desirable second advantage that in helping the foreign nations in this area, a direct benefit in the form of a growth and development of our own capability can accrue to us a double return for the dollar spent.

References

1. Fu, K. S., Landgrebe, D. A. and Phillips, T. L., "Information Processing of Remotely Sensed Agricultural Data", Proceedings of the IEEE, Vol. 57, No. 4, April 1969, pp 639-653.
2. MacDonald, R. B., "Automatic Data Analysis Techniques for Earth Resources Information Systems", To be presented at the 1971 IEEE International Convention, Session 7G, New York, March 25, 1971.